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AUTHOR Thorkildsen, Ron
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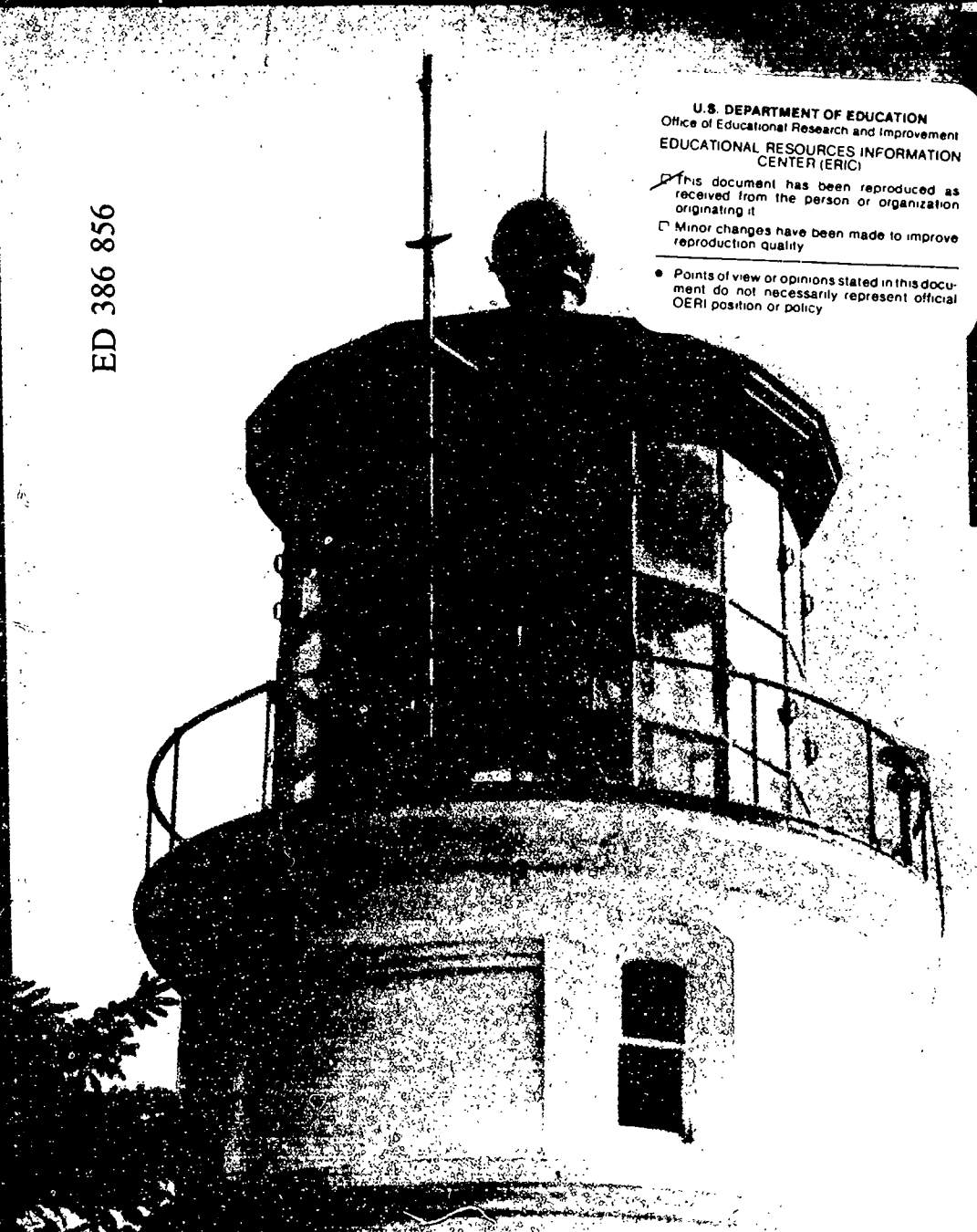
ABSTRACT

This executive summary of a research synthesis of information about assistive technology (AT) for school children with disabilities focuses on device characteristics as quality indicators of AT for manufacturers, clinicians, and consumers. It also provides an overview of AT use in the schools and how this use is determined or affected by the availability of funding and devices, the assessment process, and the need for and training about AT. Brief sections summarize the larger report's sections on: the educational uses of AT, popular AT devices, assessing the need for AT devices, training to use AT devices, and AT device characteristics and quality. A table summarizes the device characteristics rated as important such as effectiveness, affordability, operability, dependability, portability, durability, compatibility, flexibility, and ease of maintenance. In addition, a recommendation is made for greater application of principles of universal design, which involves the design of consumer products so that they can be used by a wide range of consumers. An appendix provides definitions for the identified design characteristics. (Contains 29 references.) (DB)



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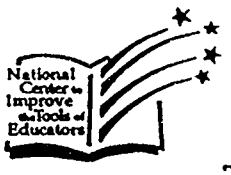

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Executive Summary of Research Synthesis on Quality and Availability of Assistive Technology Devices

by
Ron Thorkildsen, Ph.D., Associate Director
Center for Persons with Disabilities
Utah State University

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QUALITY AND AVAILABILITY OF ASSISTIVE TECHNOLOGY DEVICES

EXECUTIVE SUMMARY

PREFACE

This report provides a summary of a report titled Quality and Availability of Assistive Technology Devices. The larger report describes an extensive review of the literature concerning the availability and evaluation of assistive technology (AT). The larger report is organized as follows: (1) the Introduction provides a brief overview of AT; (2) the Educational Uses of AT section describes educational goals for using AT and barriers that inhibit the use of AT; (3) the Popular AT Devices section presents information about the most popular AT devices and how they can be located; (4) the Assessing the Need for AT section uses the area of augmentative communication as an example of assessing the need for AT; (5) the Characteristics of Effective AT Devices section provides a synthesis of information about effective characteristics of AT devices, and describes the limitations of the synthesis; and (6) the Recommendations section presents recommendations and guidelines to help consumers select quality AT and to help developers design quality AT for school-age children.

This summary report focuses on device characteristics as quality indicators of AT and provides a brief overview of AT use in the schools and how this use is determined or affected by the availability of funding and devices, the assessment process, and the need for and training about AT. Recommendations are made for developers, consumers, and clinicians that should help in the design and selection of effective AT.

ASSISTIVE TECHNOLOGY

IN EDUCATION

Assistive Technology (AT)[1] devices and services have been used for centuries, but the viability of their use has greatly increased with advances in technology. Potentially, technology can improve the lives of all people. For persons with disabilities, AT can make many life functions possible. For many school-age children with disabilities, AT makes education possible. With regard to school-age children, a generally accepted definition of AT is included in the Individuals with Disabilities Education Act (IDEA) of 1990.

A. The term assistive technology device means any item, piece of equipment, or product system, whether acquired commercially or off-the-shelf, modified, or customized that is used to increase, maintain, or improve the functional capabilities of individuals with disabilities.

B. The term assistive technology service means any service that directly assists an individual with a disability in the selection, acquisition, or use of an assistive technology device.

AT is redefining what is possible for school children with a wide range of cognitive and physical disabilities. For example, access to education becomes possible for many children through the use of augmentative communication and mobility devices. Without AT, children who cannot verbally communicate are denied many social and learning opportunities inherent in a formal education. With limited mobility, children may be unable to attend school. Other technologies, such as learning technologies are important, but for many children, AT is the key to receiving an education and may be viewed as the most important form of technology assistance for students with disabilities.

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[1]Assistive Technology (AT) refers to the devices and related services used to help persons with disabilities perform life functions.

Rapid advances in technology have increased the availability of Assistive Technology (AT) with a corresponding increase in demand for quality. The quality of AT, which varies widely (Enders & Hall, 1990), is related to the characteristics of AT devices and how devices match the needs of persons with disabilities. To help determine device characteristics, a synthesis of information about AT device characteristics was conducted and is contained in the report titled Quality and Availability of Assistive Technology Devices. Information for the synthesis was derived from research, clinical observation, and descriptive reports and articles. Information from the synthesis was used to identify design characteristics that contribute to the quality of AT devices. Information about these device characteristics was summarized in the full report. This executive summary provides a brief summary of the full report with a focus on recommendations and guidelines for manufacturers, clinicians, and consumers.

EDUCATIONAL USES OF AT

The ultimate goal for using AT is attaining independence. In the case of school-age children, a major goal is accessing education through augmentative communication, vision and hearing enhancement, and mobility assistance. The instructional goals for school-age children with disabilities are defined in the child's individual education program (IEP). Recent legislation, Individuals with Disabilities Education Act (IDEA), and subsequent interpretations (Shragg, 1990; cited in SMART Exchange, 1990) require AT to be included in the child's IEP. As the quality and availability of AT increases, the IEP requirement will become more viable.

The AT requirements of the IDEA will assist school-age children to meet their educational goals. At the same time, however, these requirements place financial and time burdens on the school system. As the demand for AT increases, the barriers to acquiring AT

become more visible. Acquiring AT is often hindered by one or more of the following barriers:

1. Lack of awareness of AT by consumers and professionals,
2. Lack of training in AT,
3. Insufficient funding or lack of knowledge about the access to funding for AT, and
4. The problem of school districts not allowing AT to leave the classroom.

These barriers are described in detail in the full report.

POPULAR AT DEVICES

Assistive Technology is often characterized as low-tech, medium-tech, or high-tech. Most AT is not high-tech; in fact, there are many simple solutions to accommodating disabilities. A variety of AT devices can be used to increase potentials and capabilities of students, as shown in the following examples:

> Low-tech. These devices are simple aids that are non-electrical. An example of a popular low-tech device is a white cane used by blind students to navigate. The advantage of low-tech devices is that they are relatively inexpensive.
>
> Medium-tech. These devices are aids that might use electricity, but are not computer driven. An example of a medium-tech device is an electric wheelchair. It allows the student with a disability to attend school and participate in a regular education classroom.
>
> High-tech. These devices require computerized systems that are operated through a particular software program. One of the most popular and versatile high-tech devices is the microcomputer. The primary advantage of the microcomputer is that most schools already have access to them. The microcomputer can be used by students with speech impairments to synthesize a voice, for students with learning disabilities to receive individualized instruction, or students with mobility impairments to use a network to access places that they might not be able to reach otherwise.

Currently, thousands of AT devices are available. Because there are so many devices, it is essential that teachers and specialists know how to locate and select appropriate devices for students. If the appropriate device is chosen, it can improve a student's academic and social experiences by reducing or eliminating the disability, compensating for the disability, and/or increasing the student's abilities. Locating an AT device can be facilitated by using an Information and Referral System (I&R). An I&R system provides consumer and clinicians with information and referral services about AT devices and services for persons of all ages with disabilities.

ASSESSING THE NEED FOR AT DEVICES

Determining the need for and selecting the appropriate AT device requires a functional assessment of the person with disabilities. The current trend in AT assessment is to use an interdisciplinary team for coordination. An interdisciplinary team assessment emphasizes the total needs of the person. When assessing a child, the family is included in the assessment process. With the interdisciplinary approach, a team of professionals in a school, hospital, or other setting work directly with the person with a disability, the family, and any other persons or agencies involved with the person to develop a comprehensive program. Many practitioners believe the interdisciplinary team approach is the most comprehensive and effective method of providing services to persons with a communication disability.

In addition to the interdisciplinary team approach, there are also the multidisciplinary and transdisciplinary approaches to evaluating a person with a communication disability. In the multidisciplinary approach, a range of professionals serve a given child, but generally work individually in providing evaluation and management. The transdisciplinary approach is often

favored by professionals working in residential settings. As with the multidisciplinary team approach, several professionals and family members may evaluate the person and contribute to planning the program. One professional usually is responsible for being the primary therapist rather than sharing the responsibility.

TRAINING TO USE AT DEVICES

After selecting a device, training is often required to effectively use the device. Typically, both the professional and the client require training to use the AT device effectively. Some devices are simple to use and can be operated by following the instructions provided with the device. In other cases, effective training strategies are essential to the operation of a device. Often, effective training is overlooked in research and development of AT in special education. In addition, few educators who work with learners with disabilities have received training on the use of adaptations and devices. Thus the device is often abandoned when a malfunction occurs. The training process may indicate device inadequacies. Consequently, training increases the likelihood of receiving the appropriate device, thus reducing abandonment. When training occurs, it is often initiated by the professional such as speech pathologist and/or an occupational therapist.

AT DEVICE CHARACTERISTICS AND AT DEVICE QUALITY

This section describes an analysis conducted to identify important AT device characteristics that are considered quality indicators of AT. Consensus about device characteristics that are considered indicators of quality may assist manufacturers in the design and development of AT and may help consumers and service providers select AT. An additional

indicator of quality is the frequency in which devices are abandoned. Both the evaluation of device characteristics and research on device abandonment are considered in the following analysis. The reader is reminded, however, that the ultimate test of the effectiveness of a device is how well it fits the user.

Determining Important Device Characteristics

In order to determine consensus among experts about effective device characteristics, a review of the literature was conducted. Over 100 articles that dealt with AT devices were reviewed. Twenty-nine articles contained relevant information and were selected for further review. An article was selected if the authors described an evaluation used for selecting AT devices, and if they included recommendations about device characteristics as a result of their evaluation. Information from the 29 articles was summarized and presented in the full report.[2]

Of the 29 articles summarized, 8 were derived from research findings, 3 from clinical trials findings, 4 from engineering analysis findings, and 16 from expert opinion. Only one of the research studies used a controlled experiment to determine findings. Findings from the other seven research studies were based on consumer opinion gathered through questionnaires, telephone surveys, and group consensus technique. All articles dealt with the importance of device characteristics.

The list of device characteristics contained in Table 1 are from the Batavia and Hammer (1990) study. The Batavia and Hammer list was used in this report to establish a base line of device characteristics for three reasons: (1) it was empirically derived, (2) it was prioritized, and

[2]Appendix A contains a bibliographic listing of the 29 articles contained in the summary.

(3) it appears to be the most comprehensive list identified in the current review. (Brief descriptions of each characteristic are contained in Appendix B.) The Batavia and Hammer set of characteristics is ranked by importance according to their research. The rankings in column 3 (Total Ranking) of Table 1 is based on frequency of occurrence for each device characteristic in the other 28 articles (excluding Batavia and Hammer) that were summarized in the research synthesis.

In developing the following analysis, an assumption was made that frequency of occurrence of a device characteristic is an indicator of importance. Concurrent validity for this assumption was provided by determining the relationship between the Batavia and Hammer ranking and the a ranking derived from the frequencies of occurrence from the other 28 articles.

Table 1. Ranking for Device Characteristic Importance from Batavia and Hammer (1990), Frequency of Occurrence of Characteristics from 28 Articles, Ranking According to Frequency of Occurrence and Average Rankings.

(1) Characteristics	(2) Batavia & Hammer Article Rankings	(3) Total Frequency of Occurrence from Other 28 Articles	(4) Ranking of Total Frequency	(5) Average of Column (2) & Column (4) Rankings
Effectiveness	1	4	13.5	7.25
Affordability	2	10	6.5	4.25
Operability	3	19	1.0*	2.00
Dependability	4	13	2.0	3.00
Portability	5	9	9.0	7.00
Durability	6	11	4.0	5.00
Compatibility	7	6	12.0	9.50
Flexibility	8	11	4.0	6.00
Ease of Maintenance	9	11	4.0	6.50
Securability	10	1	16.0	13.00
Learnability	11	9	9.0	10.00
Personal	12	9	9.0	10.50
Physical Comfort	13	7	11.0	12.00
Supplier	14	4	13.5	13.75
Physical Security	15	10	6.5	10.75
Consumer	16	1	16.0	16.00
Ease of Assembly	17	1	16.0	16.50

*Note: The highest frequency received a rank of 1

Kendall's Coefficient of Concordance (W) was used to determine the strength of relationship between the two sets of rankings (Batavia and Hammer and Total) listed in Table 1. The value of W is a measure of association between k sets of rankings as ranked by different judges. W ranges from 0 to 1. A W of 1 shows perfect association; a W of 0 shows no association. The value of W for the set of 17 characteristics listed in Table 1 is .75 with an associated X^2 value of 24.2 ($p = .09$). A W value of .75 shows a relatively high degree of association, which in turn show strong concurrent validity for the Batavia and Hammer set of characteristics and rankings that are common to the characteristics mentioned in the other 28 articles.

Table 1 is also divided by rows into two groups of characteristics with the first nine characteristics in the first group and the second eight in the second group. Interestingly, the resulting set of characteristics within each group are the same for both rankings. These ordered groupings of like characteristics also attest to the very close similarity between the two sets of rankings shown in Table 1.

Because there is some disparity of ranking within each group, it is difficult to determine which characteristic may be more important than another within the same group. It appears, however, that ranking by group may be useful with the lowest group labeled Important, and the highest group labeled Most Important. The lowest group is considered important because merely being included in the synthesis means a characteristic has been selected as important by consumers and other experts. Using this rationale for determining importance by group, the final set of characteristics are contained in Table 2, ranked by group and alphabetized within group.

Missing from the priority listing in Table 1 are Training Availability and Device Availability. Neither Training nor Device Availability were mentioned in the Batavia and Hammer priority list but were listed in six other articles and are listed as key considerations by Guthrie (1984). Consequently, these characteristics are included in Table 2 as important characteristics.

Table 2. Device Characteristics Ranked by Group and Alphabetized Within Group

(1) CHARACTERISTICS RANKED AS MOST IMPORTANT	(2) CHARACTERISTICS RANKED AS IMPORTANT
Affordability	Consumer Repairability
Compatibility	Ease of Assembly
Dependability	Learnability
Durability	Personal Acceptability
Ease of Maintenance	Physical Comfort
Effectiveness	Physical Security
Flexibility	Securabilty
Operability	Supplier Repairability
Portability	
Important Characteristics Not Identified by Batavia & Hammer	
Device Availability	
Training Availability	

Device Abandonment

An additional way to look at device quality, is to consider which characteristics contributed to the abandonment of devices. Realistically, a device would be considered effective only if a consumer continued to use an AT device in the face of continued need for AT. Phillips and Zhao (1993) conducted a study to determine why AT devices are abandoned and noted,

> A better understanding of how and why technology users decide to accept or reject a specific device is critically needed to improve the effectiveness of assistive technology interventions and enhance consumers' satisfaction with devices. (p. 36)

Phillips and Zhao go on to define the effect of abandonment:

> Technology abandonment can have serious repercussions. For individuals, non-use of a device may lead to decreases in functional abilities, freedom, and independence, and increases in monetary expenses. On a service delivery level, device abandonment represents ineffective use of limited funds by federal, state, and local government agencies, insurers, and other provider organizations. (p. 36)

Phillips and Zhao conducted a survey of 227 adults with various disabilities. The survey showed that 29.3% of all devices were completely abandoned and that the following four factors were significantly related to abandonment: (1) lack of consideration of user opinion and selection, (2) easy device procurement, (3) poor device performance, and (4) change in users needs or priorities. With regard to device procurement and poor device performance, they found that device performance was the most important determinant of abandonment. Convenience of use, energy required for use, and required assistance from others were determined to be less important. The characteristics categorized under performance were performed better (operability), reliability, comfort, ease of use, safety, and wear well (durability). These characteristics correspond closely to the characteristics contained in Table 2. Phillips and Zhao also found that a lack of training contributed significantly to technology abandonment. They

contended that both rehabilitation professionals and consumers need more technology training.

RECOMMENDATIONS

This section focuses on recommendations that will help designers and manufacturers improve the quality of AT. As noted before, the effectiveness of AT is dependent on the evaluation process used to select the AT device and on the quality of the device. However, the recommendations made in this report are confined to improving the quality of AT devices.

This section begins with recommendations based on the results of the synthesis contained in this report compared to recommendations made by other authors, followed by recommendations for universal design of all devices and appliances that may be used by persons with disabilities.

Recommendations for Designing AT Devices

The priority listing in Table 1 shows relative importance and is based on a consensus of research findings and expert opinion. As noted earlier, the degree of relationship (W = .75) between the contributors to this consensus is relatively strong.[3] Indeed, considering the diversity from which the frequencies and related rankings were derived, a W = .75 is surprisingly high. This research synthesis, to a great degree, corroborates the findings of Batavia and Hammer (1990).

All of the AT device characteristics listed in Table 2 are important and should be considered by manufacturers, consumers and service providers as indicators of quality. The six

[3]Borg and Gall (1983) contend that correlation coefficients ranging between .68 and .85 make possible group predictions that are accurate enough for most purposes.

characteristics listed in column 1 of Table 2 should, however, be considered the most important characteristics. They were ranked the top nine in each set of rankings contained in Table 1 and are listed as key characteristics by Guthrie (1984) in his book Evaluating AT for Disabled Persons.

The characteristic Effectiveness encompasses many of the other characteristics. Effectiveness is generally defined as the extent to which the device meets the user's need and the extent to which the device performs as claimed by the manufacturer. Based on this definition, effectiveness cannot be determined prior to use by the consumer. However, a manufacturer should attempt to predict effectiveness by concentrating on the set of characteristics that may contribute to effectiveness. This set, excluding Affordability and Ease of Maintenance, is essentially those characteristics listed as most important in Table 2. Affordability, would however, be important in the determination of cost effectiveness.

Any of the characteristics, if neglected by a manufacturer, could become a most important characteristic. For example, a device that was physically uncomfortable, very difficult to learn to use, or had an unacceptable appearance may be abandoned by the consumer and in turn become totally ineffective. Consequently, all of the devices listed in Table 2 should be considered important in the manufacture and evaluation of an AT device.

In considering the need for continuous quality improvement in the development of assistive technology, Russell (1993) notes the following:

> Assistive Technology is first and foremost a service business, and the priority of any service industry must be to listen and respond to what customers are saying. This may be even more critical in assistive technology programs given the unique and individualized needs of the consumer (p. 14).

Correspondingly Cohen and Frumkin (1987) suggest that the following questions need to be asked by the consumer and responded to by the developer:

(1) Is the documentation for the system complete, written in clear and concise language, and are all questions regarding the system included in the documentation?

(2) Is the manufacturer or developer easily available to the consumer to ask and answer questions that may arise concerning system operation or will additional consultation from other resources be necessary for the customer to fully understand the system design?

(3) Has the systems effectiveness and reliability been substantiated by research with the intended population?

(4) Are the systems designed using standard components, which allows for integration with other systems?

(5) Is the manufacturer's warranty, service policy, return policy, and cost notification sufficiently adequate to protect and direct the consumer?

(6) If the manufacturer or vendor helps evaluate the AT, are they knowledgeable about the nuances of communication disorders, physical disabilities, and disease processes?

Also with regard to service, the National Institute on Disability and Rehabilitation Research (1992) recommend that manufacturers of assistive technology should:

(1) disseminate product information to individuals with disabilities and service providers;

(2) evaluate product effectiveness with consumer input from persons with significant communication disabilities;

(3) provide warranties and timely product maintenance and servicing;

(4) ensure compatibility with other technologies;

(5) provide systems for trial use;

(6) work with researchers to facilitate technology transfer to the marketplace; and

(7) exhibit products and participate in seminars and conferences.

To ensure continued service and quality control, Russell (1993) recommends that manufacturers continually measure performance and suggests conducting consumer surveys. Russell includes specific criteria for designing a consumer survey (p. 15). He suggests that "Outstanding organizations have as one of their characteristics of dedication to measure a new performance in order to qualify the results and to improve their delivery of service". (p. 15)

The results of the synthesis contained in this report suggest that there is a set of characteristics that should be seriously considered when designing and manufacturing assistive technology. This set of characteristics is contained in Table 2. The synthesis also shows that selecting AT must be a team effort that includes the consumer in the decision making. Other authors who have made recommendations to manufacturers about designing and developing quality AT make similar recommendations.

The synthesis of information described in this report combined with recommendations from other authors provides sufficient evidence to warrant serious consideration to the priorities assigned to the groups of characteristics listed in Table 2. When a manufacturer cannot give full attention to all characteristics because of limited resources, the priority list could be considered a guide for allocation of resources. At least one characteristic, safety, should always be considered even though it appeared relatively low on the priority list. Additionally, if abandonment can be anticipated, training, even though low on the priority list should always be considered.

Universal Design of Devices

The focus of this report has been on AT devices designed specifically for use by persons with disabilities. There are, however, design considerations that can help make all devices or

products (not necessarily AT devices) accessible to persons with disabilities. Designing any product for a wide range of consumers is referred to as universal design. Attaining universal design requires attention to both the characteristics of the product (device) and the characteristics of the user. Matching these characteristics involves a concept called ergonomics.

Ergonomics is the process of determining how well a product's characteristics suit the user's characteristics; and from the consumers point of view, result in the following questions: Does it fit my hand comfortably? Is it easy for me to use? Can I use it safely? The essence of the questions is the emphasis on "I". In other words, does the product fit the needs of individual consumers and not the average consumer. Designing products that address these ergonomic considerations lead to universal design.

It is good business for designers and manufacturers to consider universal design, especially as it relates to persons with disabilities. This sector of the population is a rapidly growing market. The number of Americans with severe physical disabilities increased by more than 49% between 1970 and 1981. This increase is attributable to medical advances and to an increased older population. Universal design is a win-win design approach. Persons with disabilities get a greater product variety and developers have a larger market.

Summary and Limitations

The selection and maintenance of AT devices is an ongoing assessment and training process involving an interdisciplinary team, the consumer or consumer representative, and manufacturer. The membership of the interdisciplinary team is dependent on the consumer's disability. The consumer and manufacturer should always be involved.

The manufacturer, in addition to designing and manufacturing the device, should be responsible for service, training and ongoing performance evaluation. A set of prioritized device characteristics is available to assist manufacturers design, manufacture and maintain quality AT devices. Serious consideration of these characteristics and other recommendations regarding service and training will help ensure quality AT devices for consumers and an expanding market for manufacturers.

The recommendations contained in this report are limited by the scarcity of research about the quality and effectiveness of AT devices. There is sufficient information, however, from expert opinion and clinical trials to provide guidance to manufacturers in their design and development of AT devices. This information should continually improve. Additional research is being conducted, and standards for quality AT are being developed by numerous organizations such as the United States Veterans Administration. Additionally, organizations such as the Rehabilitation Engineering Center at the National Rehabilitation Hospital have been established to evaluate AT devices.

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APPENDIX A

Definitions of Device Characteristics

Appendix A. Definitions of Device Characteristics from the Research of Batavia and Hammer (1990)

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Effectiveness •Overall performance	The extent to which the functioning of the device improves the consumer's living situation, as perceived by the consumer, including whether it enhances functional capability and/or independence. •What does the manufacturer of the device claim the device will do? Does the device do what is claimed? •Does the device meet the specific needs of the consumer? If so, what specific needs are met and in what way? In meeting these needs, are other important needs compromised?
Affordability •Fundability •Reasonable cost	The extent to which the purchase, maintenance, and/or repair of the device causes financial difficulty or hardship to the consumer. •What is the price of the device? •Are there any hidden costs (e.g., installation costs)? •What are the likely costs of maintenance and repair? •Are the total costs of the device, including price, maintenance, repair, and any other costs within the consumer's means? Are they covered by public or private insurance (or other financing programs)? What share of the costs does the consumer have to pay out-of-pocket? •Are there any warranties on the device, and how do they affect the costs to the consumer?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Operability •Convenience •Easy to understand •Ergonomics •Requires assistance •Simplicity of use •Speed of response	The extent to which the device is easy to operate and responds adequately to the consumer's operative commands, including whether controls and displays are accessible and whether start-up time for each use is excessive. •Are the controls and displays easily accessible and usable? •How responsive are the visual displays in terms of viewing angles, colors, and shapes? How responsive are audible tones/alarms in terms of harshness, loudness, length, frequency, and understandability (e.g., speech or synthesized speech)? •What cyclical routines must be followed each day as the unit is used in the prescribed fashion? Does it need constant adjustment and/or excessive care in everyday use? Are there indications that the equipment is ready to use (e.g., meter readings, lights on or off, signals)? •Are there any tests or re-adjustments that need to be made as the equipment is used during the initial warm-up/use phase? •What portion of the turn-on/start-up routines must be followed each time the device is used? Is the start-up time excessive?
Dependability •Accuracy	The extent to which the device operates with repeatable/predictable levels of accuracy under all conditions of reasonable use. •Is the device dependable? What has been the prior breakdown history of these types of devices? Where was such information obtained? •Is any special room environment required (e.g., heating, cooling, dust-free)? Will low or high humidity cause problems? If so, what percentage of relative humidity is acceptable? Is the unit affected adversely by electromagnetic interference or power line "noise?" If so, by what levels? •What problems can arise if the equipment is not turned on and operated according to prescribed operating instructions? Can any permanent damage occur due to an improper action? If so, what actions will result in what kinds of damage? •Will the device remain dependable under repeated use?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Portability •Transportability	The extent to which the device can readily be transported to and operated in different locations, including whether the length of battery charge and the size and weight of the device permit physical relocation. •Can the device be transported easily to different physical and geographical locations without undue difficulty? Can it be carried comfortably or (in the case of long distance travel) transported in a car, train, or airplane? •If the device is powered by a battery, what is the length of the battery charge? •If the device depends upon an external power supply or other hook-up, will such hook-up be available in other locations? Can it be adapted to hook up in different locations?
Durability •Reliability	The extent to which the device will continue to be operable for an extended period of time. •What is the expected life of the device (i.e., how long will the device last before it can be expected to have significant dependability problems requiring frequent and expensive repairs)? •What level of care and maintenance is necessary for the device to last throughout (and beyond) its expected life?
Compatibility	The extent to which the device will interface with other devices currently and in the future. •Does the device operate independently or does it need to interface with other devices? •If it needs to interface with other devices, what are those devices? Is it currently compatible with such devices in the market? •Is the device likely to become obsolete in the near future due to compatibility problems with devices now being developed or contemplated?
Flexibility •Expandability	The extent to which the device is provided with available options from which the consumer may choose. •What options are available with the device? •Are these options important to the consumer? What is the cost of these options?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Ease of Maintenance •Maintenance requirements •Warranty	The extent to which the consumer (or his or her personal assistant) can easily maintain the device to keep it operable and safe, including whether it is easy to conduct all required maintenance, cleaning, and infection control procedures. •Is maintenance easily handled by the consumer (or personal assistant)? •How often are maintenance routines necessary? Are maintenance record forms provided? Are they adequate? •Are operation and maintenance manuals included with the unit? Does the instruction book spell out all maintenance routines to be followed? Are they effective? If not, in what ways are they deficient? •Are there adequate precautions for sterilization of the device (e.g., gas or steam) to prevent infection? What are the appropriate methods/chemicals for disinfection? Are specific cleaning procedures required?
Securability	The extent to which the device can easily be kept within the physical control of the consumer to reduce the likelihood of theft or vandalism. •Is the device easily secured so that it is difficult to steal? •Does it have any special features to enhance security?
Learnability	The extent to which the consumer, upon initially receiving the device, can easily learn to use it and can start using it within a reasonable period of time once assembled, including whether specialized training is required. •How long will it take for the consumer to learn to use the device effectively? •Are the operational instructions clear in terms of turning on the equipment, making any preliminary adjustments that are required, and allowing the equipment to warm up? •Is specialized training required? If so, how much training, and is it included in the price of the product? •How long should it take to run through all start-up and diagnostic routines that need to be done the first time? Can the consumer do these or must he or she have assistance?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Personal Acceptability •Appearance	The extent to which the consumer is psychologically comfortable when using the device in public (or in private), including whether the device is aesthetically attractive. •Would the consumer be embarrassed by any aspect of the device (e.g., physical appearance or unusual sounds)? •Is the design of the device compatible with the consumer's personality and lifestyle?
Physical Comfort •Ergonomics	The extent to whieh the device causes physical pain or discomfort to the consumer. •Does the device cause pain or discomfort? Does it make noises that are irritating to the ear or physical sensations that are irritating to the skin? •Does the consumer have to strain physically in using the device? Is it physically compatible with the consumer's body? •Does the device have special features to enhance comfort (e.g., a special seating system or shock absorbers in the case of a wheelchair)?
Supplier Repairability	The extent to which a local supplier or repair shop can repair the device within a reasonable period of time, including whether replacement parts are readily available and whether the manufacturer must conduct repairs. •If the device cannot be easily repaired by the consumer (or personal assistant), must it be returned to the manufacturer or distributor? What are the likely turn-around times of the most prevalent problems? •If the device typically can be repaired locally by a supplier or repair shop, what is the likely turn-around time? Are replacement parts readily available? Does it have any "built-in" diagnostic routines for fault determination? •Is a "hot-line" available to allow easy access to the manufacturer/distributor? If it is available, is the manufacturer/distributor responsive to calls?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Physical Security •Safety - electrical, mechanical, operational	The extent to which the device is likely to cause physical harm, including bodily injury or infection, to the consumer. •Is the device safe to operate? What are its safety features (e.g., emergency brakes)? •Are there any aspects of the device that are likely to cause physical damage or severe irritation, such as pressure sores? Does it disrupt internal physiologic functions (e.g., normal flow of blood or urine)? •Is the device likely to cause infection or other adverse physiologic reaction?
Consumer Repairability	The extent to which the average consumer (or his or her personal assistant) can repair the device if broken, including whether special repair equipment is needed. •What types of repairs can the consumer (or assistant) reasonably be expected to do, and what types of repairs must be conducted by an expert? •What, if any, education/training is required for the consumer or assistant to repair the device? •What, if any, special equipment is required to make any such repairs? •Does the unit have special design features (e.g., plug-in modules) that can reduce the difficulty of repairs? Have any spares been provided for this purpose?

Device Characteristic from Batavia & Hammer (1990) and Synonymous Device Characteristic from Other Authors	Definition from Batavia & Hammer (1990)
Ease of Assembly	The extent to which the consumer (or his or her personal assistant) can easily assemble the device upon receiving it, including whether it is packaged conveniently. •Will the supplier assemble and/or install the device? •If not, what portion of the assembly or installation can the consumer (or personal assistant) reasonably be expected to do? Is a technician or engineer required for initial assembly or installation? •Are instructions for assembly and/or installation included in the manual? Are the instructions complete, concise, clear, and easy to follow (i.e., a logical step-by-step procedure)? •Are any special tools required for assembly, installation or start-up? Is any test equipment (e.g., computer, multimeter, oscilloscope) required for start-up or calibration? •Are other kinds of devices/furniture required to complete the system (e.g., special tables, wall mountings)? If so, will the supplier provide these?

APPENDIX B
Bibliographic Information for the Twenty-Nine Articles Summarized to Determine Important Device Characteristics

APPENDIX B

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