REVIEW

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Frequency Measures of Behavior for Assistive Technology and Rehabilitation

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Documenting assistive technology outcomes has grown in importance, but outcome measurement remains problematic. A new approach uses natural science measures and a model (selectionism) from the field of Behavior Analysis. Selectionism defines behaviors by their effects (functional performance) and the environment (including technology) within which they occur, and explicitly treats variation in patterns of behavior over time for individuals (intervention effects). Its basic metric is frequency of behaviors (count per unit time) which is similar to robust engineering measures like centimeters, grams, and seconds. This approach eliminates many of the problems inherent to more traditional psychometrics. Selectionism based on frequencies also provides an empirical structure or taxonomy to organize efforts and outcomes, unified by the notion of fluency. Composite behaviors are combinations of smaller component behaviors that are required for performance of the composite. A frequency above which a component behavior is readily retained, generalized, and recruited into the more complex composite behavior is called fluency; thus individuals fluent on the critical components easily and efficiently demonstrate the composite. This model suggests that when assistive technology interventions raise component behavior frequencies to fluent levels, they will be integrated usefully into an individual's life. This selectionistic approach has been used successfully in the field of education. It has the added benefit of not only empirically defining measurable outcomes, but also of providing useful ongoing measurement of change during treatment. This paper briefly describes this "Precision Measurement" strategy and its data-driven feedback process and makes suggestions for further research and development efforts. The method provides a basis for better documentation, control, and outcomes of assistive technology and related interventions.

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A major goal of assistive technology (AT) is to improve the client's functional performance (Cook & Hussey, 1995). Documenting this improvement is important for at least three reasons. First, we need to assure that whatever techniques and devices we develop and apply are demonstrably effective in improving client performance. Second, since rehabilitation consumes scarce resources, we must be cost-effective. Finally, inherent to improving human performance, evaluative information should contain hard data on both process and outcome. To achieve these goals the measurement system should permit collection of data for purposes of accountability and as feedback for continuous improvement. This system should accurately, efficiently, precisely, and objectively measure elements of observable behavioral performance to document change and outcomes.

Ideally, this measurement approach would be descriptive and unambiguous, and understood by the client as well as all team members involved in the client's therapy. Such a measurement system would function as feedback to both client and therapist to keep the therapy on track and promote the most effective use of resources. Can such a measurement system be developed? A well-grounded theoretical platform exists which offers a way to move beyond the commercial outcome-measurement tools in current use (Johnston & Pennypacker, 1993b). This paper's purpose is to describe the theoretical possibility and establish the potential utility of such an empirical measurement system for assistive technology. The approach is based on

frequency measures of behavior, which are rooted in the cgs (centimeters, gram, seconds) frame of reference instead of the "expert judgment" scales of current instruments. Assistive technology, arising from engineering methods, should be well prepared to take advantage of a system relying less upon psychometric and more upon natural science concepts.

The functional assessment of performance within rehabilitation has made great strides since the early 1980s. Now many providers routinely collect such data for marketing and other purposes. Researchers have developed a variety of new, better, and statistically more sophisticated instruments and are constantly improving old ones. Still, a measure that "works" statistically for one purpose may not be well adapted for another (Merbitz, Morris, & Grip, 1989b). One measure for both clinical progress and outcomes marketing heretofore has seemed both technically difficult and expensive. Reviewing this situation, assistive technologists have called for bold new visions and strategies of measurement (Minkel, 1996; Vitaliti & Minkel, 1996). A new vision about the fundamental philosophy and underlying strategy of measurement offers the opportunity to leap beyond the assumptions and strategies embedded in current instruments. The present paper considers Precision Measurement, an approach that relies on observable performance as the outcome of interest. It builds upon a new philosophy of behavior and measurement and a new view of the structure of functional behavior.

When examined against a feedback model of rehabilitation-related interventions and the consideration that these interventions change behavior, these features also allow a more useful way to measure performance to provide better clinical control and detection of effective treatments. Thus, Precision Measurement applied in assistive technology can positively impact clinical resource allocations, activities, and outcomes. This universal approach provides a seamless measurement system which will yield more precise and effective outcome measures.

While other questions about measuring behavior are also important, this paper focuses on two fundamental issues that are addressed in this Precision Measurement approach. These are (1) how to define and recognize functional behavior, and (2) the strategy used to assign numbers to it.

BEHAVIOR AND MEASUREMENT

Observable Behaviors and Hypothetical Dimensions

Attention to functional assessment during the past decade has engendered many new tools. Even more important, it has focused on functional behavior as a key outcome variable. While subjective measures such a self-satisfaction are also important, functional behavior is undoubtedly the essential outcome demand. Kaplan (1990) has suggested that behaviors are centrally important outcomes in all health care efforts. He argued that at one extreme, death is the cessation of behavior, and at the other, medical conditions are considered worth treating only if they have some detectable behavioral effects. If a family, patient, or client changes in function, a change in behavior occurs.

The assistive technology intervention team, including the client, would agree that knowing the functional impact of an intervention is critical. We can disagree about the extent to which a person's actions really mean "independence." We can, however, easily observe and agree that on Tuesday she walked 600 meters in 12 minutes on level surfaces indoors with prosthesis A and 1,200 meters in 21 minutes with B, and that she had six complaints about A and four about B. Note that this behavior-oriented approach does not devalue subjective information. When a client says that he or she is "more comfortable now," an observable change has occurred, and the comment can be counted. While spoken words may not match other information, it can be argued that "ephemeral" words and actions are part of an accessible, concrete reality (Glenn & Madden, 1995; Layng, 1995). We can count expressions just as we can count buttons correctly buttoned and unbuttoned, walls bumped per meter traveled, keys pressed, illogical concepts expressed, and staff members greeted by name, etc.

What to Measure: Function as the Outcome

If indeed "functional outcomes are the only real measure of the success of assistive technology. . ." (Cook & Hussey, 1995) or even one of the key domains to measure, then functional measures are preferred over measures based on the form of behavior. This distinction reflects two aspects of behavior (Glenn & Madden, 1995) and two general approaches to measuring them. To measure form (sometimes called topography) of the behavior, one focuses on the action (e.g., does the arm swing have a smooth follow-through?). In the functional approach, one can examine the form, but the effect is measured as a variable of greater interest (e.g., how far away a specified target can be hit under what circumstances). The functional approach requires identifying the effects of an action, but also permits many paths to the same outcome. Thus, telegram, telephone, or e-mail messages may all be

equivalent actions in terms of sending a message that achieves some outcome.

To achieve an effect, we usually consider three broad components: (1) a stimulus environment (situation), (2) the action, and (3) the effect. Sometimes we assert that several distinctly different stimulus situations should be equivalent in terms of enabling the effect, even though the actions in each will be different. For example, using a wheelchair, scooter, bicycle, or ambulating may be equivalent for changing one's location for some purposes under a specified set of conditions. Thus, to be useful, the evaluation system must define the circumstances under which the effect is measured. This concept of defining behavior and measuring its effects is important. Effect is validated by outcome, in sharp contrast to some current systems, which simply look to validation using correlations with some other similar measure.

Selectionism as the Theoretical Basis of a Different Measurement Approach

Selectionism is an emerging philosophy of human behavior with great promise for improving the outcomes of rehabilitation. It offers a way to measure human performance so a change in individual performance can be directly related back to practice. Briefly, selectionism offers a view of a person as a dynamic collection of frequencies of observable actions that are detectable as effects and change as the person learns and grows (Chiesia, 1992; Glenn & Madden, 1995; Palmer & Donahoe, 1992; Skinner, 1953). A single organism is viewed as a population of observables or behaviors. These observables occur in time and exhibit some variability. The consequences of these behaviors cause some to reoccur more frequently and others less frequently. Over time, as we observe changes in actions, we speak of the person "learning" to say or to do things. Fundamental elements of selectionism are time (temporal progression), variability in behaviors that occur, and selection process(es) that operate to change the future probability of these events. One may see some cases of technology abandonment as a reflection of this process. When the desired effect, which once required an assistive technology device, can be obtained without the use of the device, the use of the device drops in frequency.

Frequency as a Metric for Selectionism

Life occurs in time, so in principle one could record every instance a person performed something observable that we agreed to claim as rehabilitation outcome. Thus, frequency or "count of a specified observable per unit of time" is a primary metric of selectionism (Glenn & Madden, 1995). Recognizing occurrence of observables in time permits definition of this portion of the helping mission as one of raising and lowering frequencies of observables or effects. As an assistive technology or rehabilitation outcome, the measurement system displays subjective goals, like ambulating 10 meters per minute, as observable quantities on a frequency spectrum.

Frequency of Observable Behavior

Frequency (counts or cycles per unit time) has a long history in science and does not require any statistical validation as a measure. Another feature is that if one counts observable outcomes or effects (e.g., hair neatly combed), then the variable of interest is the one measured and hidden variables are avoided (e.g., "John is becoming aware of grooming"). Finally, observable behaviors need not be limited to frequency, but as every observable takes place in some spatial and temporal context, every observable can be characterized by its frequency under defined conditions. Ambulation speed is a good example of a frequency-based measure; of course it need not be the only variable of interest in gait training (Roth et al., 1990).

At least two different frequencies are of clinical interest: daily frequency and repeated (called sprint or burst) frequency. A daily frequency is the number of observations of behavior a person performed in a day. Generally, a waking day is approximately 1,000 minutes. So, if a person typed 756 correct characters in a day, the correct character frequency would be 756/1,000 or .756 per minute for that day. One may also distinguish between "correct" and "incorrect" characters and record both frequencies. Alternatively, it may be of interest to consider only the characters typed in an uninterrupted burst or sprint. For example, the person may type 40 correct words per minute for 6 minutes. Repeated performance of an observable indicates the extent to which that behavior is a useful and accessible part of the person's repertoire. It also becomes a potential training exercise.

Fluency and Automaticity

Clinicians and researchers have long noticed that fast performers were also highly skilled, retained skills and information without practice, and generalized well. In frequency terms, such learners are said to be fluent (Binder, 1993, 1995, in press; Binder, Haughton, & Eyk, 1990; Haughton,

1981; Johnson & Layng, 1992, 1994). Recently, a view has emerged that this fluency is what should be meant by mastery of a skill. Excellent summaries of this position have become available recently (Johnson & Layng, 1994; Binder, in press; Lindsley, 1996). Stated another way, it seems that a fluency criterion can be empirically established by research on a group of skilled performers as the frequency of performance that predicts the following:

(1) Retention: fluent skills are remembered even after long periods of no practice.
(2) Endurance: fluent skills can be performed for appropriately long periods without fatigue.
(3) Application: fluent skills generalize; they are readily deployed in novel situations.
(4) Extension: fluent component skills readily combine or are recruited into more complex composite skills (see below).

An additional advantage of fluency is its reduction of complex terminology. For example, the term automaticity is used in the learning literature, but since "automatic" in this context just means "fast," it seems confusing to say that a person "has automaticity" as if it is a property of the person. Similarly, "overlearning" or learning beyond 100% correct is superfluous when considered in frequency terms; 100% correct is limited by the opportunities presented for the performance and a performance can be 100% correct and still not be retained, enduring, or generalizable.

Component and Composite Structure of Behavior

One can consider every human action as a "composite" of smaller actions ("components") down to the level of single neurons firing. Some researchers use the language of analyzing complex observables or skills ("composites") into simpler components (Johnson & Layng, 1992, 1994; Lindsley, 1995). As related to fluency, the issue is to determine empirically what frequency of component performance predicts with a high degree of probability that a given component will easily be recruited into a composite. An implication for rehabilitation is that preserved "islands" of skills are probable with some impairments and can become key resources to optimize function. This determination of a component predicting larger composite behaviors would be a validity concept in traditional test and measurement language.

Johnson and Layng (1992, 1994) suggest that required components of the target composite be taught to fluency. If one is fluent in the component skills, learning a new composite is easy. In their highly successful programs, students consistently spend greater time learning components (lower level skills) than composites (higher level skills) because when the components are taught to fluency, the composites are learned rapidly and easily. Sometimes students generate the composite as soon as the components are fluent; hence, the term "generative instruction" for this instructional process. Obviously this phenomena suggests some interesting outcome measurement implications. Outcomes might be predictable or measurable through the frequencies of relatively small sets of components.

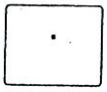
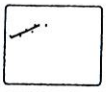
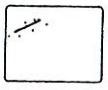
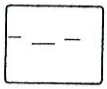
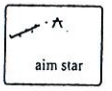
Combining the concepts of observable outcomes with frequency and fluency has substantial implications for assistive technology and rehabilitation. Haughton (1980) pioneered the use of alternative channels of stimulus contexts and performance effects in a systematic program of training. One might select specific sensory or motor functions as appropriate for the individual's goals and responses to training. Similarly, assistive technology can be used as an alternative to an impaired organ system to achieve fluent levels of performance. These levels of fluency form empirical goals for the rehabilitation of specific individuals and achievements. Furthermore, clinicians and patients can compare level of performance (frequency), change in performance per unit time (celeration), endurance (length of time maintaining a specified frequency), and variability (bounce) for different technologies or performance situations. These observations of frequency have an objective yet personal basis on which to plan an intervention; remediate weaker channels or advance stronger ones; or select technological options for functional effects (Lindsley, 1994, 1996).

Measuring and Displaying Frequency (Count/Unit Time) in Practice

Count per minute is convenient for frequencies of human behavior (Johnston & Pennypacker, 1993b; Lindsley, 1972, 1991, 1992, 1995, 1996; Pennypacker, Koenig, & Lindsley, 1972), while hertz (Hz, cycles per second) is commonly used in the natural sciences. Lindsley and coworkers (Lindsley, 1992, 1996; Pennypacker, et al., 1972; Potts, Eshleman, & Cooper, 1993; White and Haring, 1980) have designed a graph (the Change Chart,[1]

[1] Change Charts and training resources are available from Behavior Research Company, P.O. Box 3351, Kansas City, KS 66103.

TABLE 1. Some frequency terms, their graphical representations, and benefits of usage. A Daily Change Chart displays behavior frequencies from .001 per minute (1 per 1,000 minute day) to 1,000 per minute; the center of the y-axis is 1 per minute. The Chart shows frequencies across 140 calendar days

Term	Calculation	Graph	Description	Benefit
Frequency	count / minute		Performance or level of behavior	Shows a single day's performance that may be related to goals
Celeration	count / min / week		Trend in behavior	Shows where behavior started and predicts where it is going if current trends continue; relates to real time issues (such as days to discharge).
Bounce	ratio of highest to lowest frequency around a celeration course		Distribution of frequencies around a celeration	Shows extent to which behavior is consistent; reveals any unusually good or bad days for further investigation. Measure of daily variability.
Floor	1/minutes observed		Reciprocal of observation interval	Informs viewer how long the behaver was observed; the lower the floor, the longer the observation. Also implies endurance level for performing the behavior.
Aim and aim star	An aim is a frequency goal; often fluency research suggests the frequency for aims.		Goal frequency. An aim star is placed at the goal frequency and date.	Defines behavioral goals in concrete, measureable terms. An aim star also defines the date by which the goal is to be met and thus implies the minimum celeration needed to reach the goal.

formerly called the Standard Celeration Chart) that is optimized for the display and analysis of human frequencies in applied settings, and have developed many conventions and techniques for using human behavioral frequencies. While detailed presentation of these are beyond the scope of the present paper, a brief discussion follows.

The sprint or burst frequency is an easily accessible frequency for the clinic for many component performances. For others, observation all day by the client, staff, or electromechanical device (Merbitz, Grip, Halper, et al., 1989; Merbitz, King, et al., 1992; Merbitz, King, Bleiberg, & Grip, 1985) may be useful. Computerized systems for clinical measurement of frequencies have been described (Merbitz, Cherney, & Marqui, 1992; Merbitz, King, et al., 1992; Merbitz, Grip, Hulper, et al., 1989), but are not required (Carr & Williams, 1982; Cherney, Merbitz, & Grip, 1986). Data that are inspected daily allow changes in the treatment as appropriate to maintain progress. Finally, some clients may take frequencies at home and phone in their data. Thus, they can save trips and time while supporting clinical monitoring of progress and improvement. Recently, the advances in personal and hand-held computers may make this measurement and data handling task even less expensive (Merbitz, King, et al., 1992). Table 1 depicts some frequency terms and the benefits of their use.

Mathematically inclined readers may recognize the formulations of frequency, celeration, and bounce and consider their parallels in the field of mechanics. This approach to measuring human behavior resembles natural sciences and engineering rather than social sciences or education. Few technical issues bedevil frequency measures. Repeated measures are easily taken and the measurement can be used to give feedback relative to any previous performance or in absolute terms.

To optimize terms of accurate sampling, individuals can be timed during bursts of at least 12–15 (or more) repeated performances of the skill or component. With repeated frequency data plotted on Lindsley's Change Charts, it is trivial to separate the immediate performance effects of transient situations (such as sickness) from longer term issues, since any single day's frequency data are easily compared to any other day's data and to the celeration (overall learning) for that person. Also, since frequencies of performance are quite stable, if a question ever arises about accuracy of a performance, it is simple to just take additional samples and compare the frequencies until some performance is determined to be an unrepresentative outlier. Furthermore, since frequencies of

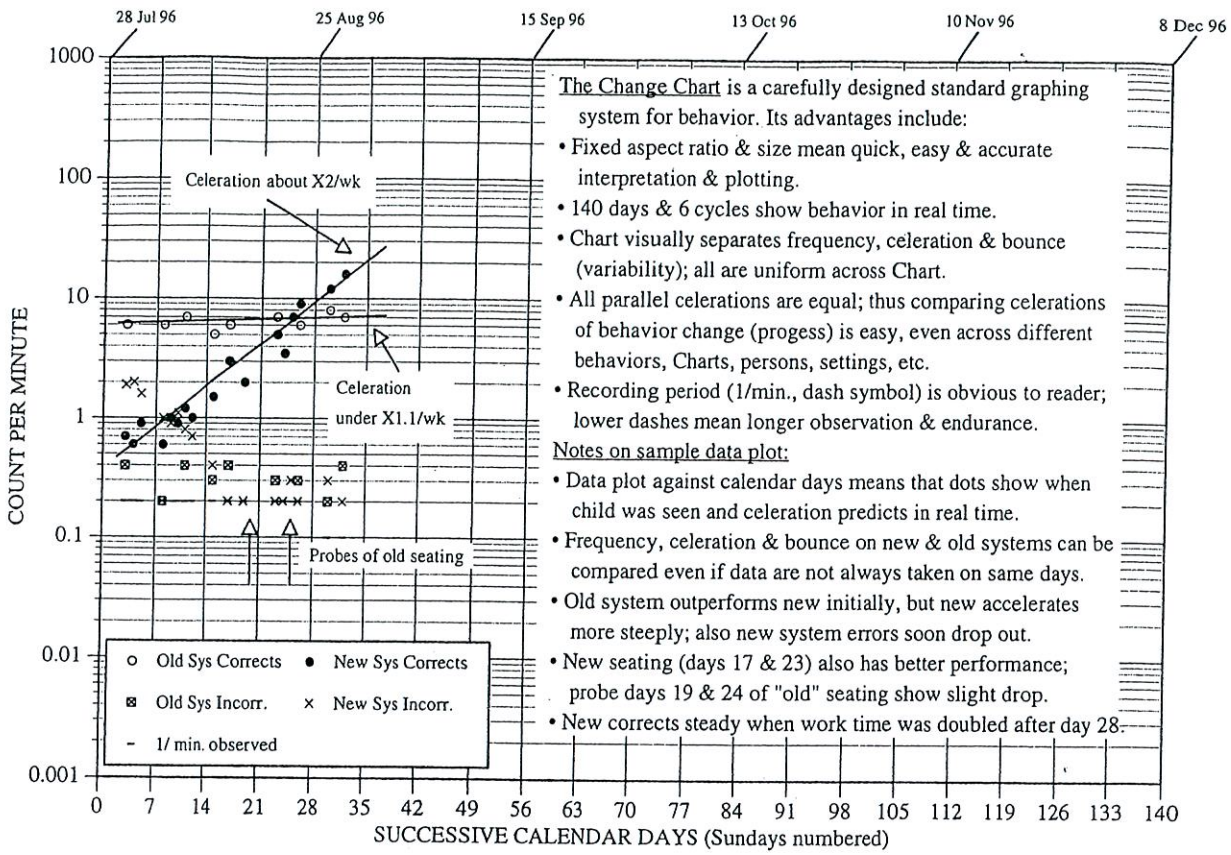


FIG. 1. Simplified full-sized graphic of a Change Chart showing hypothetical data on a child's words and errors per minute using old and new alternative communcation systems. Actual Change Charts are printed in blue to facilitate accurate plotting (Potts et. al., 1993) and provide space for demographic information: Data are plotted on the days child was in the clinic; the old system about two days a week and the new system more often. The dash symbol (−) shows 1/minute observed; change in its plot of from 0.2 to 0.1 after day 28 shows when the communication recording time was doubled to 10 minutes to begin building endurance.

human performance are measured precisely but also occupy a relatively narrow spectrum, it is easy to compare them across patients, techniques, institutions, and diagnostic classes. Since statistical processing is not needed to plot data, this feature prompts practitioners to check immediately on the accuracy of data points out of the expected range.

Communication performance provides a simple example of how Change Chart frequency data can reflect utilization of assistive technology. The hypothetical data in Figure 1 show a client's words correctly and incorrectly produced using two augmentive communication systems over about 5 weeks of more or less regular clinic visits. For this example, data are shown as collected for 5 minutes each day initially, and twice that for the last 2 days; session lengths may be varied if desired. To facilitate comparison, the data are simply overplotted on days when both systems are tried. As can be seen, while the old system begins with a substantial advantage, within eight clinic sessions a steep acceleration in corrects with the new system is evident. Generally, one would also control which system was tried first each day to detect fatigue effects. Errors quickly drop out with the new system and simply maintain with the old. The data show effects of a probe of a positioning modification on Day 19; as it successfully raised the correct frequency, subsequent probes of both positioning alternatives were used to confirm its superiority. Note that this positioning change produced a jump in communication frequency but no change in celeration as an illustration of the independence of frequency, celeration, and bounce. Finally, using authentic Change Charts, fluent staff can plot data at 12 points/minute or more, so both staff and clients can see progress immediately and data handling chores consume minimal resources.

APPLICATIONS OF FREQUENCY TO ASSISTIVE TECHNOLOGY

Frequency Measures Provide Mechanisms for Assistive Technology Decision-Making

Two general systems of medical management are the diagnostic/prescriptive and the empirical/feedback. The former involves the assignment of the patient to a class (diagnosis) and the subsequent prescription of a known remedy. This method uses a specific route of administration, applies a calculated strength of intervention, and targets a predicted outcome. This system is powerful and useful. It may be characterized as a "ballistic" system because ideally measurement is not required after the initial classification. Alternatively, and often used in practice, an empirical/feedback system (Bernard, 1957/1863) is also applied. This is the model in which repeated observations are taken as treatment progresses to insure that the treatment is working. Since many assistive technology and rehabilitation applications rely so heavily on learning and on human interactions, a feedback model is usual. However, good outcomes from feedback systems depend on the quality of the data that are collected and sequentially compared.

From a larger perspective, this process can be characterized as a nested set of temporal feedback loops, operated by practitioners and administrators. Clinicians help individuals improve their performance and comfort, reduce impairments, and prevent future impairment. It is a feedback system when an intervention team learns from a person with a disability and the situation what to do to improve that person's performance. In a larger loop, what is learned about one person can later be used to help another. As this information is communicated, effects can be beneficial well beyond the original participants. Interestingly, O'Leary (1996) reports that, on a larger scale, this sort of feedback and control loop for organizations is an important direction of the future as seen by the Joint Commission on Accreditation of Health Care Organizations. This feedback model may also be conceptualized as a single-subject design (Barlow & Hersen, 1984; Gonnella, 1989; Kazdin, 1982, 1984). A final advantage of this feedback process is that successful treatment changes the client. The feedback process provides continual measurement and adjustment of the treatment environment as it is required to match the "new" individual.

Consequences of Slow or Fuzzy Data

In a feedback system, the data about the person's progress are used to control the process; changes are made if the data point to deterioration or lack of appropriate progress. Unfortunately, data may be slow (delayed in getting back to the practitioner or team), fuzzy (they may indicate ranges rather than exact quantities like meters or kilograms), or grossly categorized (like a seven-point scale to cover the range of all human grooming activity). In the latter case, any change that is less than one scale step is invisible, so a patient should be kept in a treatment mode long enough for the expected effect to occur. Of course that time may turn out to have been wasted if the effect never materializes. Slow or fuzzy data are to be avoided because of the risk of keeping the patient in an ineffective treatment situation or even wrongly changing out of one that is effective because the data were not exact enough to see progress. These problems are relatively easy to avoid with frequencies if appropriate behaviors are measured.

Data Design Issues

Beyond the quality of the data, some basic features influence its utility. For example, as noted above, faster data acquisition, analysis, and deployment allow quicker decision-making and redeployment of efforts. Similarly, more precise data support more precise outcomes. Daily frequency data also allow use of trends and rate of change as predictors, so that correction may be applied without the process ever exceeding a boundary condition. They also avoid irrelevant data which may clog the decisional channels and be counterproductive. Finally, the data only reflect the power of the treatments to influence performance; weak treatments mean little change.

Fundamentally, the system depends on sufficient data to predict what will happen if treatments are unchanged. Useful data usually includes the following features: (1) collected and processed rapidly enough to be of immediate use, (2) precise enough to show small gains and losses, but also have sufficient range to accommodate the best and worst possible user, (3) apply to relevant performance issues, (4) form a seamless chain from daily events to more long-term outcomes, (5) be objective, absolute, and standard (like centimeters, grams, and seconds), and (6) be inexpensive to collect, store, display, and analyze. Frequency measures of behavior meet these criteria when structured into a taxonomy of component/composite fluencies.

Link Between Process and Outcome Measures

Ideally, intervention planning and control will use a faster (shorter cycle) and more precise feed-

back process than many current outcome instruments can provide. Given the detailed nature of frequency-based measurement, there may be a tendency to focus on process as opposed to outcome. Thus, it is important to research a taxonomy of fluency-based functional behaviors to define how components fit the composite outcomes. In this way relevant outcome measures can be defined and the full benefits of frequency-based measures felt. Using such a taxonomy also assures a seamless and well-measured chain between daily clinical actions and post discharge outcomes. These may also allow more efficient interventions as one linked measurement system is applied throughout the intervention process. Also, by enabling the viewing of resource decisions during the course of intervention and seeing their results as outcomes, such a measurement system contributes to improvements in clinical and administrative resource decision-making.

Role of Learning in Outcome Measurement

Assistive technology influences function in two distinct ways. Both need to be measured, but only one is obvious. The most overt category involves external/structural changes (new eyeglasses, splint, wheelchair, prosthesis, track shoes, hearing aids, pencil). The other involves behavior changes (the individual learns to use the new splint, increases strength, improves performance on computer-based communication aid, endurance). Learning is the pervasive behavioral construct we use to explain many of the changes we induce (Bleiberg & Merbitz, 1983). Frequency measures are conducive to observing the behavioral aspects of assistive technology that are based on learning to use a device or system. While assistive technology may be focused on devices, we often need to measure learning as a contributor to the outcome.

Frequency Measures and Current Outcome Measures

A frequency measure approach will not duplicate the traditional rehabilitation outcome measurement efforts. Frequency measures are quite different from tools such as the Functional Independence Measure (FIM) (Granger, Cotter, Hamilton, & Fiedler, 1993; Linacre, Heinemann, Wright, Granger, & Hamilton, 1994). Frequency measures of behavior provide direct measures of the observable behaviors as opposed to measuring abstract and subjective constructs such as "independence" or "quality of life." Also, frequencies are positioned on an absolute dimension of count per unit time with an interval or ratio level metric. Therefore, this scale is invariant from person to person, site to site, and time to time, and is not a score based on a probability dimension requiring the assumption of one central tendency. Frequencies provide immediate, not delayed, feedback to the intervention team. By using the notion of fluency to build a component into a composite, frequency measures form a seamless measure. With frequency measures, we can assess the range of outcomes from using a pointer-holding splint to the enhanced productivity of creative writing activities.

CONCLUSIONS

A frequency-based measurement system has great potential to improve our documentation of the outcome of assistive technology device use and services. Frequencies are a convenient and theoretically sound metric. The discovery of component fluency as the key to composite mastery forms a measurable chain that multiplies from the lowest component to the largest composites. One current need is for fluency research to determine fluency criteria at each level of the behavioral taxonomy of performance for people with disabilities. With this information, better frequency relationships can be delineated. Eventually, this would develop a suite of more useful and universal goals.

This measurement approach allows rehabilitation to be viewed as a value-added process. Individuals begin at knowable frequencies of some component observables; these are improved and new composites are taught. Ideally, clients learn components to fluency and move on, addressing larger and larger composites as they succeed. Assistive technology fits into this process, as it affects the frequency of outcomes achieved.

In contrast to common assessment scales, frequency-based measures give a WYSIWYG (what you see is what you get) quality that does not depend on statistical processing for units or intelligibility. In practice, this allows for rapid replication and application across clinics, institutions, disabilities, and countries. Just as measuring length in meters allows communication and replication in the physical sciences, measuring function in performance frequencies would provide a consistent language in assistive technology and rehabilitation outcome measurement.

This paper introduces a theoretical platform to allow movement beyond the present commercial outcome-measuring tools by constructing an empirically-based system, as the centimeter, gram,

and seconds frame of reference is used in engineering. The paper points to the possibility of a highly effective system of treatment resting on frequency measures of the composite performances that are the desired outcomes. The deployment of frequency measures, however, requires that both practitioners and administrators consider a significantly different method of evaluating outcomes. Consequently, these concepts may not be popular with persons used to traditional measurement approaches.

The successful implementation of these ideas, as with other new approaches, will require research, study, practice, and effort. As can be seen from the references, there is a documented rationale for this approach, but human behavioral frequency research as applied to assistive technology is in its infancy. Determining its success in application will be made through pilot studies and comparisons to other possible methods. However, there is no magic; as in other arenas, the magnitude of the changes in outcomes achieved will in general be proportional to the effort invested and the degree to which the system is implemented as a natural science technology.

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