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Factors affecting the use of a single switch with assistive technology devices

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Abstract—Identifying consumers' motor ability for consistent and reliable control can be a difficult yet essential part of a single switch assessment. Current literature does not identify the essential components of a single switch evaluation. Therefore, the following focus group study was conducted. Six occupational therapists with experience in assistive technology service delivery participated in a focus group meeting. The purpose of the meeting was to identify essential components of a single switch evaluation in the single switch assistive technology assessment. Eleven items were identified as essential to the single switch assessment. They are: reliability of motor movements, volitional nature of movement, safety, movements that are easily performed, endurance, activities and positions the client assumes throughout the day and evening, efficiency of movement, previous successful movements, ability to perform timed response, ability to activate the access device within a given time frame, and time between switch closures. The significance of this study is that essential components of a single switch evaluation were identified. Using this detailed information should lead to optimal switch placement and switch use.

Key words: *control interface, indirect selection, input methods, integrated controls, scanning*

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INTRODUCTION

There is a story that captures the essence of movements made efficiently and effortlessly. The author describes a man who uses a leg prosthesis and runs a busy diner in New York City (1). Customers are unaware of the owner's bobbing and weaving back and forth behind the lunch counter as he pours coffee, serves toasted bagels, and writes out bills. What the customers do notice, however, is that he is a part of every conversation as he completes the behind-the-counter tasks efficiently and effortlessly. For this restaurateur, efficiently and effortlessly means using his unique motor abilities to complete the tasks involved in running a diner while simultaneously engaging in conversation with his customers.

People with motor impairments use their unique motor abilities to operate assistive technology devices. Just as the owner of the busy diner uses his unique abilities to operate restaurant equipment, others operate assistive technology devices to facilitate their work, recreation, and daily living tasks. As stressed by Bain (2), assistive technology devices are most effective when consumers use their own unique motor abilities instead of trying to move in a manner that "looks" normal.

Assistive technology providers have for some time attempted to develop tools that would help them evaluate

various alternative access methods. Barker et al. (3) describe an assessment tool designed to help assistive technology providers analyze and compare a consumer's ability to use single switches, joysticks, and small keyboards. This tool, called the control evaluator training kit, could be configured to measure latency to activation, latency to release, scanning speed, and accuracy for single switches. Another early attempt to aid assistive technology providers in evaluating the control of their clients was the Single-Input Control Assessment (4). This assessment tool was developed to "assist the clinician in making an informed judgment." The tool was very useful in helping to break down the scanning task into its parts: response time, and ability to scan, hold, and release. All this information was helpful in identifying the components critical to scanning.

In the early 90's, assistive technology providers began to describe other attributes they had observed during assessments but that had not yet been discussed in the literature. Lee and Thomas (5) were among the first to discuss some of these characteristics. In selection techniques for switch control, they discussed accuracy, ease of control, and quality of movement as characteristics that were somewhat quantifiable. They suggested that persons involved in assistive technology assessments should be rating these parameters because they influence an end-user's performance. Cook and Hussey (6) describe factors effecting motor control, reaction time, apraxia, resolution, range, strength, endurance, and versatility.

All of these papers indicate the need to systematically measure the performance of persons who are candidates for alternative input methods, specifically, scanning. Selecting access methods for consumers with motor impairments is a complex process.

Models have been used to attempt to describe how assistive technology impacts the end-user. The Human Activity Assistive Technology (HAAT) model (6), widely used by assistive technology providers, emphasizes the importance of all access methods including single switch methods. Access methods described in the HAAT model assist in accomplishing tasks (**Figure 1**). In this model "human" refers to the person attempting to engage in an activity. The "activity," the fundamental element of the model, represents the daily living act that the human wishes to accomplish. The switch and the device are the essential elements allowing humans to complete the activity in an adaptive manner.

This "assistive technology" portion of the HAAT model encompasses four parts: the human/technology

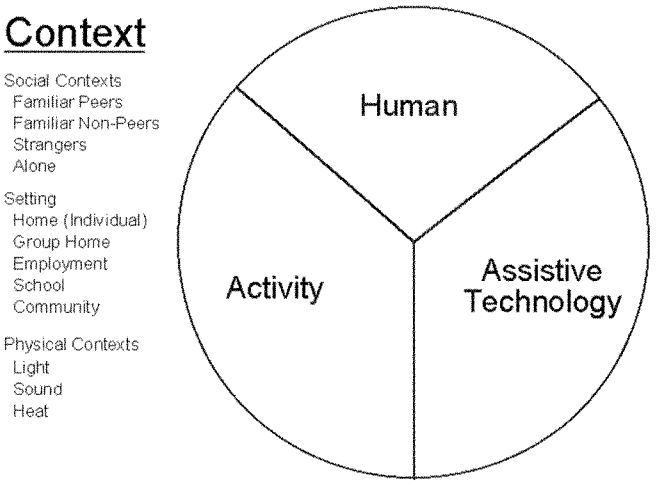

Figure 1.
Human Activity Assistive Technology Model. (Copied with permission, Mosby.)

interface, the processor, the activity output, and the environmental interface. The human/technology interface refers to the contact between the person and the technology device. The processor, in this case the switch, is the mechanical or electrical linkage that relays or interprets information from the interface so that the desired task can be accomplished. The activity output includes actions such as opening the door or turning on lights. The environmental interface is the link between the output of the device and the input from the environment (6). The final but essential factor presented in the HAAT model is that the activity enabled by the assistive technology takes place within a social, cultural, and physical context. For example, in urban settings in the United States outside doors are commonly locked and must be unlocked and opened for guests.

Each component of the HAAT model plays a role in assisting humans to engage in activity (6). All activities performed with assistive technology devices are initiated with the human/technology interface or access method. Success using an assistive device and completing activities is possible only when the access method matches the consumer's motor capabilities.

Clinicians and researchers have indicated that data in the area of switch assessments is critically important (6–9). Information on range of motion and resolution (target acquisition) skills has been discussed as essential in determining potential placement sites for input devices (6). The input device's height, proximity, and orientation

are described as fundamental in the placement and prescription process (8). Assistive technology providers performing switch assessments agree that providing proper switch assessments is important to the consumer's overall success in the use of assistive technology equipment. Yet, detailed descriptions or a framework for conducting comprehensive single switch assessments are lacking.

THE SKILL ACQUISITION MODEL

The Skill Acquisition Model, a system of movement classification (10), and the HAAT model have important implications for the single switch assessment. The Skill Acquisition Model, with roots in Bernstein's (11) systems model, describes skill as goal-directed behavior that is guided by the consequences of the movement it produces (10,12,13). Behavior is guided by action, movement, and neuromotor processes, not on a one-to-one basis, but on the basis of multiple interactions. The goal of skill acquisition is to attain economy of effort, consistently and efficiently, by maintaining or changing body orientation, object position, or both (10,12). This is the same goal therapists working in assistive technology strive for as they evaluate and match switch attributes to the movements consumers with motor impairments make. Thus, the Skill Acquisition Model (12,13) is relevant to the current discussion of efficient and effortless movement.

During the assessment phase, therapists attempt to find the ultimate match between a type of switch and body site. Once a match between the variables is identified, the switch activation act falls into what Gentile (12) refers to as a "closed and consistent motion task." That is, the relationship between the switch site and the consumer's movement remains consistent.

One premise emphasized in the Skill Acquisition Model is assumed in this paper. The therapist and the consumer agree on the goal of the action (10,12). Consumers clearly understand that accurate and consistent switch pressing can lead to engaging in desired activities. The switch represents the potential to control multiple functions such as word processing on a computer, dialing a telephone, and/or driving a wheelchair.

To complete a task successfully, the movement must match features in the environment (12). Because the consumer's movements are limited due to his or her impaired neuromotor system, the physical environment must adapt to the movement as much as possible. Examples of physical environment adaptations would be using an appropriate seating system and mounting the switch precisely within the consumer's reach. At the beginning of an assessment, the therapist manipulates the environment, matching it as best as possible to the consumer's motor control for maximum performance. Through active exploration, the consumer and therapist work together to identify matches between the environment and movement capabilities (10,13).

Two environmental categories identified by Gentile (12), stationary and moving, are important when using a single switch. These two elements, essential to scanning, are effectively described in the Skill Acquisition Model (12). Objects in the stationary environment stay in one location. Objects in the moving environment, such as an escalator, change position. Single switch scanning, a time-based control method, incorporates both stationary and moving components, although perhaps not in the conventional sense as described by Gentile (12). The challenge for the consumer is to press the switch at the exact moment the cursor highlights the desired item. Effective scanning is a learned skill. This discreet action requires training and time to learn.

According to Gentile (12,13) and Cook and Hussey (6), the therapists' responsibilities are to: 1) assess the consumers' capabilities by identifying the volitional (effortless and efficient) motor capabilities for the tasks; 2) understand the demands of the task; 3) select tasks that are potentially achievable; and 4) adapt task-related environmental constraints. During the assessment, therapists and consumers become active problem solvers as they identify purposeful, compensatory strategies and discard less useful or inefficient strategies (14). In order to meet these responsibilities, therapists must first understand the factors involved in switch pressing.

Current literature does not provide adequate information or guidelines regarding the contents of a single switch assessment. Although the previously cited papers mention the importance of conducting a proper evaluation and list a few items that should be included, there is no comprehensive list of the specific domains that should be covered in an evaluation. Therefore, the following study was conducted to ask clinicians experienced in assistive technology service delivery what areas they specifically cover during a single switch assessment.

METHODS

The participants, eight occupational therapists with experience in assistive technology (AT), were solicited to

participate in a focus group meeting. Two were unable to attend due to conflicts with other events; therefore, six occupational therapists participated. Six states were represented, from the eastern, midwestern, and western regions of the United States. The occupational therapists' work experience ranged from 3 to 24 years. The mean was 15.5 years and the median was 17.5 years. The therapists' exposure to assistive technology ranged from 2 to 16 years with a mean of 9 years and a median of 8.5 years.

Participants were selected by their national academic credentials; all had published two or more articles in peer-reviewed journals and had presented nationally three or more papers on assistive technology.

PROCEDURES

The focus group meeting coincided with a national occupational therapy conference. This helped to ensure a large geographic representation of participants and access to a number of occupational therapists with expertise in assistive technology. Participants were invited three weeks prior to the scheduled date of the focus group meeting. The prearranged meeting took place in the evening in a private dining room at a local restaurant.

The Nominal Group Technique (NGT) was used to conduct the focus group meetings (15). A script of the NGT directions for conducting the meeting was followed throughout. The meeting lasted approximately three hours. A brief description for the NGT follows:

- Step 1. Participants were asked to generate as many ideas as possible as a response to the question, "What are the most important motor characteristics to consider for the assistive technology single switch access assessment?" As part of the directions, participants were told to exclude seating and positioning from the factors considered important to efficient and effortless movement. The purpose of this focus group was to go beyond seating and position and describe the other factors essential to the single switch assessment. For the purpose of this study, participants were told to assume that seating and positioning would be taken care of and their job was to describe all other factors. Participants wrote down their ideas silently and independently.

- Step 2. Each participant provided one idea at a time in a "round robin" fashion until all ideas had been presented. All ideas were written on pages of newsprint and displayed on the walls around the room, allowing all of them to be displayed together as they were presented.

- Step 3. Each idea was discussed separately. Every participant was encouraged to provide comment or clarification to each particular idea.

- Step 4. Each participant was then asked to select from the newsprint list the ten ideas with the highest priority in assistive technology evaluation and write each idea on a separate card.

- Step 5. Each participant then ranked the ideas on the cards, 10 being the most important item and 1 being the least important item.

- Step 6. The ranking scores on the cards were then tallied. Topics with the highest number of points were presented to the group.

RESULTS

Thirty-six items were generated. The top 11 items were the factors deemed by the participants as those most influential in affecting single switch access. The top 11 items received the highest numbers of votes and they were voted on by a minimum of 3 participants. After the eleventh item, items received votes from only one or two participants; therefore, they were not included in the list of items impacting single switch access. The top 11 items are listed in **Table 1**. The number in parentheses refers to the total number of points the item received from the participants.

Table 1.
Top-ranking considerations for switch access.

1.	Reliability of motor movements (21 points)
2.	Movement should be volitional (14 points)
3.	Safety issues should be considered (12 points)
4.	Movements that are easily performed (10 points)
5.	Endurance (10 points)
6.	Activities and the positions the client assumes throughout the day and evening (9 points)
7.	Efficiency of movement (7 points)
8.	Previous successful movements (5 points)
9.	Ability to perform timed response (5 points)
10.	Ability to activate access device within a given time frame (5 points)

DISCUSSION

Each item helps the assistive technology provider understand the issues involved in the single switch assessment. Identifying the characteristics that impact on accurate and consistent switch presses will help clinicians identify where end-users are having difficulty. Identifying at what point in the switch-pressing process the end-user is experiencing difficulty will help both the clinician and the end-user find solutions.

1. Reliability of Motor Movements

The reliability of movement affects the consumer's voluntary ability to operate an assistive technology device (16,17). Reliability has been defined as the consistency with which a consumer completes a motor act to activate assistive technology devices (18). This definition implies that consumers make this movement in isolation from other movements. Movement reliability is often less than optimal. When this happens, therapists make recommendations for improvement by analyzing switch size, position, and orientation. Matching the consumer's capacity for movement to switch size ensures that the switch is large enough for the consumer to make contact easily. Evaluating position ensures that the switch has been placed in a location that the consumer can easily reach. Adjusting switch orientation or angle ensures that the switch is placed directly in the line of movement so that the consumer makes contact with the switch each time he or she attempts to activate it.

2. Volitional Nature of Movement

Movements used for switch pressing should be volitional and performed comfortably, without straining and in a manner that permits the rest of the body to remain calm. Horak (14) suggested that therapists manipulate the environment so consumers can move efficiently. For single switch use this includes manipulating switch size, orientation, placement, and control enhancers. According to the results, therapists should ask consumers undergoing a switch reassessment to demonstrate movements that have been reliable in the past. Observations of those movements can facilitate a smoother assessment by providing useful information and decreasing the time involved. Typically, movements that the consumer has used previously to operate devices may be more reliable than other movements. The consumer has already incorporated these skills into a reliable movement pattern and has practiced using them.

3. Safety Issues Should Be Considered

Safety is an important consideration. The access device itself should have rounded corners. It should be attached to a wheelchair or table in a manner that does not endanger the consumer or others. All wires should be secured to a stable surface to reduce entanglement or the possibility of dislodging the switch. All switches should be positioned so that body parts, clothing, or jewelry are not entangled. Freedom of movement is not encumbered.

Likewise, the end-user needs to practice controlling the device in terms of safety. If the end-user is driving a power wheelchair, then doing so safely is of utmost importance. End-users need to be instructed to drive carefully so as to avoid walls, people, and other objects. Power wheelchair users must drive particularly carefully around staircases, curbs, and streets where bodily injury could occur.

4. Movements that Are Easily Performed

Typically, movements that the end-user can perform easily should be used. This may seem obvious, however, it is important to remember that at times assistive technology providers may request individuals to perform movements that are unnatural. Therefore, movements that come naturally to the end-user should be used whenever possible.

5. Endurance

Endurance refers to the ability to sustain a force and to apply that force repeatedly over a period of time. Others have noted the importance of endurance when making single switch access recommendations (2,6,19). To achieve functional outcomes, consumers must move reliably not just once or twice, but for as long as the device is in use. This may last from a few minutes to several hours, depending on the needs of the consumer and the demands of the activity.

6. Activities and Positions the Client Assumes Throughout the Day and Evening

Consumers change their positions and environments throughout the day. Their motor skills and how they access assistive technology devices must accommodate these changes. Sam, for example, lives in an extended care facility. He spends six hours a day sitting in his wheelchair. During this time he is competent in using a wobble switch positioned at the right side of his head and mounted to his wheelchair. From there he operates an auditory scanning augmentative communication device.

However, when he lies in a reclined position in bed, his head rests on the pillow and he cannot operate the wobble switch reliably. When in bed, Sam uses a pillow switch pinned to the pillow next to the right side of his head. From this position, Sam turns his head to the right to activate the same augmentative communication device. Sam's access method accommodates the change in environment and still provides the switch access needed for communication. Using the HAAT model to explain this example, the change in the context (the bed) potentially could constrain communication. Through a change in the switch, communication continued seamlessly, regardless of Sam's environment. Using the Skill Acquisition Model to explain this example, the change in switches modified the environment to accommodate the change in motor performance.

Included within this item is context. According to the HAAT model (6), context includes the features of the physical environment within which a consumer executes a task. Assessment results may differ depending on changes in the environment. Therefore, whenever possible, switch assessments should be conducted within the actual environment in which they will be used. When this is not possible, the environment in which the assistive technology device will be used should be simulated. Using the environment or the simulated environment should give consumers the "feel" of what it will actually be like to use the switch connected to one or more assistive technology devices. Using the switch within context assists therapists and consumers in uncovering potential problems with equipment, software, and display placements before final selections and recommendations are made. Evaluating the device within context reduces the number of mismatches between the equipment and user, and ensures that all necessary equipment is ordered the first time, making follow-up sessions efficient.

7. Efficiency of Movement

For performance to be efficient, it is essential to assess environmental constraints thoroughly (12). In the case of switch usage, the environment consists of switch characteristics such as size, placement, orientation, and control enhancers. Control enhancers are low technology equipment, such as hand pointers, splints, and forearm supports (6), that extend the use of high technology devices. The challenge is adapting the environmental constraints to reduce the degrees of freedom controlled by the nervous system (14). The result is switch-pressing movement performed as accurately and efficiently as possible.

8. Previous Successful Movements

The client or advocate should be asked what movements have been used successfully in the past. Typically these movements are efficient, easy to use, and reliable. If they were used successfully in the past, they should be considered during a new assessment or a reassessment.

9. Ability to Perform Timed Response

Participants defined the ability to perform a timed response as waiting, or inhibiting the switch pressing movement until the cursor highlights the desired item. Lee and Thomas refer to this as "wait-activate" (5).

10. Ability to Activate the Access Device Within a Given Time Frame

Timing must be critically evaluated when examining single switch use (6,17–19). As consumers who use scanning know, a time lag in executing a movement can be detrimental to performance. Therefore, therapists teaching scanning to consumers must explain how to factor in execution time to determine when the cursor will highlight the item to be selected. This takes skill as well as practice. If a reliable switch activation site cannot be found, then the consumer using assistive technology devices may need to circumvent tasks requiring scanning and be limited to turning one device on and off.

11. Time Interval Between Switch Closures Is Appropriate for End-Users

This last item refers to the overall cursor speed. The cursor must be set at a speed that the consumer can easily use. The consumer watches the cursor move and then presses the switch at the appropriate time.

The last three items describe aspects of the timing that are critical to successful scanning. Clinicians must be aware that these items are separate. They need to be carefully scrutinized in order for the consumer to feel comfortable and to successfully use scanning.

There are some limitations to this study. Only occupational therapists at a national conference were invited to attend the focus group meeting. The results could have varied significantly with a different group of therapists. Holding several focus groups around the country could have avoided some of the inherent bias found in having only one focus group.

Some items that could be considered important overall might have been omitted, such as the scanning mode that the end-user can best operate: automatic, step, or inverse. Using the different modes can help an assist-

ive technology provider and the end-user evaluate which one the user feels more comfortable using and has the most control over. The participants of this particular focus group did not address these issues.

SIGNIFICANCE

The significance of this study is that key factors have been identified that can be used by therapists who conduct switch access assessments. This information can guide them as they evaluate movements to be used for switch activation. Optimal switch placement and switch use should be the end result of using this detailed information. Optimal switch configurations should provide consumers with the ability to engage in desired activities and actively participate in their chosen life roles. By using this information during the assessment phase, before procuring assistive technology devices and a switch, abandonment may be reduced. Further, it may be possible to apply these results to other types of access assessment such as when assessing keyboards, joysticks, and head-controlled movements assessments.

Switch access is only one piece of a complete assistive technology assessment, yet it is a critical piece that must be carefully examined to ensure that the assistive technology intervention succeeds. Findings from the present study yield important details for utilizing the Skill Acquisition Model (12) as well as for confirming ideas presented in the HAAT model (6).

These results direct research to future studies. Therapists can use this information to focus studies on particular aspects of objects that are to be manipulated within the environment. Looking at access methods, studies can be designed around the components that experts have agreed are important to consider. Studying the motor patterns that consumers prefer to use and the stability of those patterns within different motor limitations should be the focus of future work in this area.

CONCLUSION

Key movement components for efficient use of a single switch to activate assistive technology devices have been identified. Assistive technology providers are encouraged to consider each item when analyzing consumers' movement patterns. Each factor described can be manipulated systematically and the results observed. Therapists can then determine which changes improve function. Results can be used in the final set of recommendations for consumers with physical disabilities. Thus, consumers using single switch access can achieve optimal control.

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