Considering Response Efficiency as a Strategy to Prevent Assistive Technology Abandonment

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Often, specialists in the field of Assistive Technology (AT) are presented with the challenge of teaching learners to utilize AT in order to increase, maintain, or improve their capabilities. Despite best efforts, rates of AT abandonment are alarmingly high. Understanding the factors that may influence an individual's choice to utilize AT may assist interventionists in designing and implementing effective interventions that prevent technology abandonment. This paper discusses some variables that may influence an individual's choice to utilize AT. Furthermore, the potential applicability of manipulating these variables to decrease the probability of AT abandonment are discussed.

Assistive Technology (AT) has enormous potential to enhance the lives of individuals. For example, environmental control units can allow users with severe physical impairments to operate televisions, lights, and other electronic objects; talking watches can increase the independence of users with visual impairments; and vibrating alarm clocks may allow users with hearing impairments to be awakened independently in the mornings. Unfortunately, this potential is often not realized. Individuals with disabilities are frequently dissatisfied with their assistive technology and, as a result, discontinue its use (Philips & Zhao, 1993). Studies suggest that assistive technology abandonment rates range from 8% to 75% (Tewey, Barnicle, & Perr, 1994). One of the reasons given for discontinuance of AT is that the AT did not meet an important functional need (Beigel, 2000; Reimer-Reiss & Wacker, 2000). As a result, the individuals chose not use the AT.

Understanding the factors that influence an individual's choice regarding the use of AT may assist interventionists in designing and implementing effective interventions. When working with individuals who utilize AT, interventionists may be able to manipulate a number of parameters of reinforcement in order to influence a learner's choice between available responses (Johnston, Reichle, Evans, 2004). Some of the parameters of reinforcement that can be adjusted in order to influence a learner's choice behavior are identified in the concept of matching theory (Mace & Roberts, 1993). Matching theory is the basis for the hypothesis that when an individual has the opportunity to choose between two or more possible responses, the response that the learner perceives as most efficient will be chosen. This paper will discuss variables that may influence an individual's choice regarding their use of AT.

Matching Theory to Prevent AT Abandonment

Herrnstein (1961) conducted a study in which he demonstrated that the distribution of behavior among concurrently available functionally equivalent alternatives was dependent upon the history of reinforcement for each of the available behaviors. This led to the hypothesis that when individuals have the opportunity to choose between two or more responses, they will select the response that is perceived as most efficient (Mace & Roberts, 1993). An individual's concept of efficiency is effected by at least four components: (a) rate of reinforcement (Martens and Houk, 1989; Martens, Lochner, & Kelly; 1992; Mace, Neef, Shade & Mauro; 1994; Neef, Mace, & Shade, 1993; Conger & Killeen, 1974; Horner & Day, 1991), (b) quality of reinforcement (Hollard & Davison, 1971; Miller, 1976; Mace, Neef, Shade, & Mauro; 1996; Neef & Lutz, 2001; Neef et al., 1993), (c) response effort (Bauman, Shull, & Brownstein, 1975; Beautrais & Davison, 1977; Horner & Day, 1991; Mace et al., 1996; Skinner, Belfoire, Mace, Williams-Wilson, & Johns, 1997), and (d) immediacy of reinforcement (Logue, 1988; and Rachlin, 1989; Neef et al, 1993; Horner & Day; 1991).

It seems plausible that one or more of the components of response efficiency may influence a learner's use of AT. Consider a four-year-old child with cerebral palsy who chooses to sit and observe activities from afar rather than use his walker to move from one place to another in his preschool classroom. This lack of use may be a result of the physical effort required to use the walker (e.g, if the motor demands associated with operating the walker are too great, the child may choose not to use it). Alternatively, the child may refrain from using the walker because the quality of reinforcement is not substantial enough to warrant its use (e.g., people in the

environment do not realize that the child is moving in their direction and therefore do not remain in one place long enough to make the use of the walker worthwhile).

As a second example, consider a learner with motor difficulties who chooses to refrain from eating independently using an adapted plate and utensils. This learner's lack of independence may be a result of the physical effort required to use the AT (e.g., if the motor demands associated with using the utensils are too great, the learner may choose not to use them). Alternatively, the learner may refrain from using the AT because the quality of reinforcement provided is not substantial enough to warrant its use (e.g., the learner may typically receive food regardless of whether or not she feeds herself independently). Finally, the learner may choose not to spontaneously use the AT because too much time lapses between the use of the AT and the delivery of the reinforcement (e.g., it takes too long to grasp and use the utensil to bring food to her mouth to make the use of the AT worthwhile).

A third example of a situation in which response efficiency may effect a learner's choice to use AT relates to the use of one mode of communication over another available mode. For example, consider a learner who is able to reject nonpreferred items via a gesture (e.g., shaking head from side to side) or a voice output communication device (e.g., accessing a symbol in order to emit the phrase "no thanks"). Using a gesture, this learner is able to reject without searching for and accessing the appropriate symbol. Thus, the learner could perceive this as a saving of response effort. However, the tradeoff to this choice is that a listener will only understand the gesture if he/she is looking at the learner. If the listener does not see the learner's gesture, there may be a decrease in the immediacy of the reinforcement. Subsequently, this may effect the learners' choice of mode of communication.

The following sections will further illustrate the potential role of the four components of response efficiency (i.e., rate of reinforcement, quality of reinforcement, response effort, and immediacy of reinforcement) in a learner's choice to use AT. For each component of response efficiency, the results of empirical investigations will be summarized in order to illustrate the potential influence of rate of reinforcement, quality of reinforcement, response effort, and immediacy of reinforcement. In most cases, the authors of these investigations did not design their studies in order to demonstrate directly the operation of the component being discussed. As a result, these summaries provide inferred, rather than direct, evidence of the components of response efficiency.

Role of Response Efficiency on Learner's Choice to Use AT

Response effort. The physical effort required to produce a behavior can significantly effect whether or not a learner will choose to emit that response (Bauman, Shull, & Brownstein, 1975; Beautrais & Davison, 1977). The potential effect of response effort can be applied to a variety of situations. Horner, Sprague, O'Brien, & Heathfield (1990) conducted a study in which the physical effort required for a 14-year-old learner with moderate mental retardation to use a voice output communication aid to request assistance as a communicative alternative to challenging behavior was altered. In the first situation, the learner was required to type the phrase "Help Please" on a voice output communication aid (defined as a high effort / low efficiency response). In an alternative situation, the learner was required to press a single key on the communication aid in order to emit the phrase, "Help please" (defined as a low-effort/high efficiency response). This investigation revealed that the high effort response did not result in a sustained decrease in challenging behavior. However, the low effort response did result in a significant and sustained decrease in challenging behavior. In summary, results of this investigation revealed when the response effort was too great, the learner chose to emit an alternative response (challenging behavior).

Typically, issues related to response effort are associated with the physical effort required to emit a response. However, it may also be important to consider the cognitive effort involved in emitting a response. For example, to prevent hip dislocation following a total hip replacement, many patients are required to use adaptive equipment, such as a sock aid and long-handled shoehorn when dressing. However, some patients find it difficult to learn how to use the equipment properly and efficiently. When the patient has the choice of using the sock aid and long-handled shoehorns, or bending down to place the shoes and socks over his/her feet, the physical and cognitive effort required for the patient to set-up and manipulate the equipment may be greater than the physical and cognitive effort required for the patient to reach for his/her feet. As a result, use of the adaptive dressing equipment may be less likely to be the chosen behavior.

A pilot study conducted by Gitlin, Levine and Geiger (1993) examined the reasons for nonuse of adaptive devices that assists users with activities of daily living, such as eating, dressing and bathing. Two of the common reasons for nonuse were that the users were able to rely on others to complete the tasks and a belief that the equipment was too cumbersome. This suggests that the effort required to use adaptive devices contributes to the user's choice behavior. Specifically, if using assistive devices requires greater physical or cognitive effort than relying on others to complete the tasks, the likelihood that the user will choose to use the AT is diminished.

Rate of reinforcement. Herrnstein (1961) discussed that when an organism is presented with two or more choices; his choice will be directly dependent on the rate of reinforcement delivered for each alternative. For example, if a learner is

reinforced twice as often for raising his hand as he is for speaking out of turn, matching theory would predict that this learner will choose to raise his hand more often than he will choose to speak out. This component of matching theory has particular significance for the implementation of AT interventions. Consider a learner who is being taught to use an adapted plate, fork, and cup to increase his ability to feed himself rather than be fed by an assistant. If all other variables are held constant, matching theory would suggest that he must be reinforced (e.g., have the food or drink successfully reach his mouth) more often for feeding himself than when being fed by someone else. If this learner receives the same rate of reinforcement regardless of whether he feeds himself or is fed by someone, there may be little incentive to use the adapted feeding equipment because the rate of reinforcement is not significantly greater than relying on an assistant.

An investigation by Cook and Cavalier (1999) demonstrated how the rate of reinforcement may influence a learner's choice behavior. This investigation was conducted in an effort to increase the exploratory behaviors of a young child with a significant physical impairment. The child had difficulty using her hands and arms. As a result, she rarely chose to manipulate objects in her environment. Based on this, she was taught to use a single-switch to activate a robotic arm that allowed her to explore objects (i.e., dump items from a container) or to bring objects closer to her. During intervention and maintenance, the child indicated interest, via vocalizations and pointing, in manipulating the robotic arm. Furthermore, she was reported to request additional opportunities to use the robotic arm. In terms of matching theory, these outcomes could be explained by concluding that a higher rate of reinforcement was provided by the use of the switch and robotic arm than by her attempts to physically reach for and manipulate objects.

Quality of reinforcement. Mace and Roberts (1993) discussed that when one event is preferred over another, the preferred event has a higher quality of reinforcement. Furthermore, they discuss that quality of reinforcement can effect a learner's choice behavior. When this phenomena is applied to interventions utilizing AT, it would imply that the reinforcement delivered contingent on a learner's use of AT must be preferred over the reinforcement delivered for not using it. For example, consider a learner who is being taught to use an adapted mouse to access computer games. If the learner does not enjoy the computer games, it is unlikely that the quality of reinforcer received for using the adapted mouse will provide adequate incentive for the AT to be used. The learner may instead make the choice to refrain from engaging in the activity.

The influence of quality of reinforcement can be inferred from an investigation by Zhang (2000). In this investigation, the experimenter observed the impact of a computer writing tool (ROBO-Writer) on the written output of 5 fifth-grade students with learning disabilities with written language deficits. The ROBO-Writer software provided assistance with content, word choice, sentence fluency, and convention. The results of this investigation revealed a pattern of improvement (in terms of quality and quantity) on the participants' written products. Furthermore, the experimenter noted that the professional-looking output of the written products motivated the students to share their finished products with peers, teachers, and family members. If the results of this investigation are applied to matching theory, it would seem to indicate that the quality of reinforcement (e.g., ease with which written products were produced, the professional-looking product) influenced the participants' choice to engage in writing activities.

Immediacy of reinforcement. The latency between the use of AT and the delivery of a reinforcer may also influence a learner's choice to use the AT. The influence of immediacy of reinforcement can be inferred from a qualitative study examining the use of assistive devices in school settings (Todis, 1996). In this study, Todis reported on an interview conducted with a teacher in a preschool setting for young children with and without disabilities. This teacher commented that the students with disabilities who used augmentative and alternative communication (AAC) in her class were more likely to opt out of a communicative opportunity rather than choose to tolerate the delay in reinforcement incurred as a result of having to go to another part of the classroom to retrieve their AAC device. If this information is applied to matching theory, it would suggest that the immediacy of reinforcement influences the students' choice to use AAC.

Interaction of rate, quality, response effort, and immediacy of reinforcement. Thus far, the four components of response efficiency have been discussed in isolation. However, rate of reinforcement, quality of reinforcement, response effort, and immediacy of reinforcement may interact to effect the probability that an individual will choose one behavior over another (McDowell, 1988). Thus, an AT user's role may be to analyze the interaction between a particular situation and the efficiency variables to determine the most efficient response.

For example, Johnston et al. (2004) discussed that if an individual is faced with the decision of whether to use a natural gesture (e.g., point to request) or compose a message using a voice output communication aid (VOCA) in a noisy environment, the individual may choose to use the VOCA even though its use requires more response effort than the natural gesture. This choice may seem inconsistent with selecting a behavior that requires the least physical effort. However, given the noise level of this environment, it may be difficult to obtain the attention of the communication partner

via a natural gesture. This, in turn, will jeopardize the rate, quality, and immediacy of reinforcement provided for the natural gesture. In contrast, the VOCA will enable the user to simultaneously obtain the attention of the communication partner as well as emit the communicative request. This may decrease the time between the learner's communicative utterance and the listener's response. As a result, even though the response effort associated with the use of the VOCA is greater than that of the natural gesture, the combined advantage of the use of the VOCA across the parameters of rate, quality, and immediacy may outweigh the disadvantage associated with effort.

Role of Response Efficiency in Meeting the Needs of Significant Others

In addition to considering response efficiency from the AT user's perspective it may also be important to consider response efficiency from the perspective of significant others. Numerous investigators have stated that programs will only be effective if the issues of significant others (e.g., family members) have been considered (Brotherson & Cook, 1996; Brinker, Seifer, & Sameroff, 1994; Gallimore, Weisner, Bernheimer, Guthrie, & Nihira; 1993).

In a study by Brotherson, Oakland, Secrist-Mertz, Lithchfield, & Larson (1995), parents who made the decision to use a gastrostomy tube for their child reported that they were faced with a difficult situation. Although the feeding tube meant adequate nutrition, reduced illnesses, and increased opportunities for interactions for their child; it also meant fewer extended family members who would assist with feeding, increased family isolation, and increased financial stress. Thus, in this situation, family members experienced an increase in their response effort in order to achieve an increase in quality of reinforcement for their child.

Examining the role of efficiency from the perspective of both the AT user and significant others will increase the likelihood of creating a contextual fit (Johnston et al., 2004). Contextual fit refers the congruence between an intervention, the individual that the intervention was designed for, and the individual's physical and social environment (Albin, Lucyshyn, Horner, & Flannery, 1996). Contextual fit is particularly important for AT interventions because many uses of AT occur in the context of social interactions. Thus, in order to be successful, the AT user's interactions must be deemed efficient from the perspective of the AT user *as well as* from the perspective of the individuals who interact with the AT user.

Designing Interventions with Response Efficiency in Mind

The components of matching theory can be used when developing interventions involving AT. The interventions can be designed by examining the role of response efficiency for the AT user and/or the significant others. For example, consider the following scenario in which the components of matching theory are manipulated to influence the choice behavior of an AT user. In this situation, interventionists are teaching a preschool learner, Josh, to independently access desired objects in his environment during free choice activities. Currently, Josh will move himself to different classroom areas, but requests the assistance of teachers (via eye gaze and vocalization) to help him interact with desired objects. As discussed by Mace and Roberts (1993), the first step involved in incorporating the components of matching theory into an intervention involves collecting information on the efficiency of Josh's current behavior. Figure 1 summarizes information about the four factors effecting efficiency that was collected via direct observation of Josh in his preschool setting.

Figure 1.
Rate of reinforcement, quality of reinforcement, immediacy of reinforcement and response effort for current method of communication and for the intervention condition.

Factor Influencing Efficiency	Current System	Intervention Condition
Rate of R+	Josh's teachers don't always see/hear his request for assistance to activate desired object. As a result, he is currently reinforced for only 60% of his attempts to interact with toys.	Ensure that the equipment and switches are properly set up so that Josh is reinforced for 90-100% of his attempts to interact.
Quality of R+	If Josh's teachers see/hear him, he receives assistance 100% of the time. Therefore, the quality of reinforcement provided for Josh's current behavior is high.	Provide an equal quality of reinforcement for the new behavior as the old behavior by having the switches consistently activate the desired objects.
Response Effort	The extent of Josh's physical disabilities makes it difficult for him to vocalize with sufficient volume to be heard. As a result, the response effort for Josh to request assistance to activate toys is high.	Have the switches and electronic devices placed in a location to ensure low response effort for the new behavior.
Immediacy of R+	Sometimes the teachers are involved in other activities when Josh wants to activate toys. The teacher's responses aren't always immediate (average latency of teacher's responses is 60 seconds).	Ensure that the equipment is properly set up to allow for consistent and immediate activation of the toy so the latency of response is less than that of the current behavior.

After obtaining information regarding the efficiency of current behaviors, the second step in the process is to formulate an intervention procedure (in this situation, the interventionists are considering teaching Josh to depress a switch in order to activate toys such as a tape player, an electric train, and a battery operated robot) that competes with the current behavior across the four components of matching theory. Figure 1 illustrates how the interventionists adjusted the rate of reinforcement, quality of reinforcement, immediacy of reinforcement, and response effort for the treatment condition. This figure reveals that the adjustments made by the interventionist result in the treatment condition receiving a (a) higher rate of reinforcement, (b) more immediate reinforcement, (c) lower response effort, and (d) an equal quality of reinforcement. This will increase the probability that Josh will choose to emit the target behavior over his current strategy of requesting assistance to access desired objects.

In conclusion, it may be feasible to manipulate various parameters (e.g., rate of reinforcement, immediacy of reinforcement, response effort, quality of reinforcement) in order to alter an AT user's and/or a significant other's choice behavior. This, in turn, has the potential to increase the overall efficiency and effectiveness of AT interventions. However, to date, interventionists are forced to rely primarily on extrapolation in order to speculate on the applicability of matching theory to choice behaviors regarding the use of AT. This extrapolation may or may not be accurate. Therefore, empirical investigations are necessary in order to validate the applicability of matching theory to AT. Research in this area should examine the influence of: (a) rate of reinforcement, (b) quality of reinforcement, (c) immediacy of reinforcement, (d) response effort, and (e) the interaction among each of these components on an AT user's and significant other's choice to use AT. Additionally, research should investigate the most efficient way to incorporate the four components of matching theory into interventions in order to increase their ultimate effectiveness.

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