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# An Assistive-Technology Intervention for Verbose Speech After Traumatic Brain Injury

## A Single Case Study

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**Objective:** To assess an assistive-technology intervention for neurobehavioral change, coordinated with a Web-based data recording system. **Participant:** Male, mid-thirties, with a complex history, having verbose speech subsequent to traumatic brain injury. **Design:** BAB' single-case. **Intervention and Measures:** The intervention (B and B' trials) was a digital recording of the participant's voice, stating "be brief," delivered at fixed intervals by a personal digital assistant. Utterance start and stop times were monitored with a wireless, Web-enabled device and were recorded in a server-side database. **Results:** Utterance frequency did not change. However, the total utterance time was reduced during B trials, attributable to the reduced frequency of lengthier utterances. **Conclusions:** The target behavior was modified successfully. The participant adopted a specific cue-appropriate strategy. Since a variety of alternative response strategies may be required of a person, given a range of context-specific social practices and community settings, the importance of context-sensitive assistive technology cue repertoires is discussed. **Key words:** *assistive technology, cognition disorders, handheld computers, Internet, rehabilitation, traumatic brain injury*

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ASSISTIVE TECHNOLOGY FOR COGNITION (ATC) is a type of environmentally based intervention that is well suited for persons having persisting neurocognitive changes. ATC interventions transfer to an electronic device responsibility for support,

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guidance, or initiation of critical functional task components that a person is unable to perform independently.[1] However, applied more broadly, ATC interventions can also facilitate acquisition or extinction of targeted behaviors[2] that are symptomatic of underlying neurocognitive and personality changes.

The article first briefly reviews pertinent work using ATC interventions. (The reader is referred to other recent publications for more comprehensive reviews of work in this area.[3–6]) Then, a single case study is described that assessed the effectiveness of a simple ATC intervention for an individual, with a complex history, having relatively severe pragmatic communication changes after traumatic brain injury. As a critical component of the study, the article also describes the development of an associated behavior-change monitoring system, using a wireless, Web-enabled personal digital assistant (PDA), for recording the incidence and duration of a targeted behavior.

## A SELECTIVE REVIEW OF ATC

There are many approaches to ATC intervention design. A conceptual framework that can be used to classify ATC interventions is presented by Kirsch et al.[4] In general, ATC interventions typically emphasize 1 of 2 alternative approaches: (*a*) tools such as daily planners or software design modifications that, in effect, provide users with an *adapted "interface" for managing the cognitive environment*, even if performance and behavioral response standards are otherwise relatively unchanged, and (*b*) *modification of the cognitive environment*, representing an analog to accommodations that facilitate physical accessibility.

In the first approach, an individual with less severe impairments may benefit, for example, from simple calendar software,[7] either "off-the-shelf" or specialized PDAs,[8] or individually tailored and modifiable software applications[9–11] that simplify using and keeping track of personal information, without significant modifications to primary task demands. Additionally, for some individuals and behaviors, use of the ATC device can be acquired over time,[12,13] particularly when implicit learning techniques are used.[14,15]

In contrast, for many individuals, independently initiated use of an ATC device may not be possible,[16] even with training. For these persons, interventions are required that (*a*) systematically modify the characteristics of the task to be performed, (*b*) provide active cueing to initiate activity performance, or (*c*) guide the person through individual activity procedures.

For individuals with severe distractibility and memory impairments, comprehensive environmental modifications may be necessary such as those incorporated into a "smart home,"[17,18] including devices that monitor medical status.[19] Individuals with more moderate impairments, including difficulty with sequencing and planning, may benefit from interventions that provide cueing for performance of prospective tasks or activity guidance systems that simplify functional activities by providing detailed, step-by-step cues.

The most comprehensive research program using this approach has been reported by Wilson and colleagues,[20–23] including the only large group study[24] in this field. These studies have collectively demonstrated that an alphanumeric paging system does facilitate prospective task performance for persons with cognitive impairments across a broad range of clinically targeted goals. Similar studies using a variety of cueing systems have been reported. Some of these interventions have been restricted to presentation of reminders about performing prospective tasks.[25,26] Other interventions have been developed to enhance the performance of multistep activities.[27–32]

## CLINICAL ISSUES ASSOCIATED WITH ATC CHOICE AND USE

These studies have demonstrated that cueing systems can facilitate the performance of a targeted behavior. However, there are 3 additional issues that are of direct relevance to the design and implementation of ATC interventions, and specifically to the study reported below:

- How are decisions to be made about when to use an ATC intervention?
- What issues must be considered to assure that the "match" between the person and the technological device will be appropriate and productive?
- What specific technological characteristics of ATC devices can facilitate performance of a desired behavior in a functional context?

In regard to the first question, our team members' impression has been that environmentally oriented ATC interventions are often most effective when therapeutic evidence already indicates that successful task performance or behavior change can be achieved in response to cueing provided by a caregiver. Using this approach in a critical study, Hart et al[2] reported the use of a portable digital voice recorder as an ATC intervention for behaviors that had been earlier identified as responsive to direct therapist intervention. However, ATC intervention was still necessary because it was not practical for therapists to be present at all times and in all settings.

In regard to the second question, the "matching" process requires careful consideration of the technological features of the intervention, including hardware and software components that constitute the "user interface."[3,4,33] Additionally, the interaction[34,35] between the person and the device must be considered. This interaction may be influenced by the meaning or significance that the person ascribes to the device[36,37] and factors such as the user's perception of whether or not the intervention contributes to improved functional outcome. As will be discussed later, the matching process can also be facilitated by using an interactive, participatory, design process that incorporates direct feedback from the users about their level of satisfaction with the intervention.

In regard to the third question, there has been growing interest in the use of ATC interventions for tasks that can be used in the community and that are responsive to user input or changing contextual demands. There are 2 primary technological features that support this goal. First, devices like PDAs and pagers are transportable and relatively unobtrusive. Second, wireless technology permits interactive communication between portable devices and a centrally located system that can be used to present messages and monitor client performance from a remote location, relative to the portable device. In the remainder of the article, an illustrative intervention of this sort will be described for a single individual having persisting severe difficulty with verbose speech after TBI. The intervention incorporated both an assistive-technology intervention for a targeted behavior and a Web-enabled data recording system.

## SINGLE CASE DESIGN

### Participant

The study participant, VP, was male, in his mid-thirties, had a long history of severe alcohol abuse, and had been homeless for approximately 1 year as of the time of an assault during which he sustained a moderate to severe brain injury. He was found unconscious approximately 24 hours subsequent to injury. Acute evaluation revealed facial fractures, bilateral subarachnoid hemorrhage, right-sided subdural hematoma, and contusion and hematoma along the superior convexity of the right frontal lobe. Total length of coma was estimated at 2 weeks.

After stabilization, he was transferred to a transitional treatment facility. He subsequently returned to live with his family and was enrolled in a neurorehabilitation day program. At the time of initial transfer, he was experiencing episodes of intense verbal anger, but without physical aggression. Over several weeks, this difficulty resolved without medication. There were no notable motor changes. Evaluations conducted by neuropsychologists, occupational therapists, and speech and language pathologists each revealed persisting problems with complex attentional

**Table 1.** Selected neuropsychological test scores for the study participants*

| Test | Score | Percentile rank |
|---|---|---|
| WAIS-III VIQ | 102 | 55 |
| WAIS-III PIQ | 75 | 5 |
| WAIS-III FSIQ | 89 | 23 |
| WAIS-III Verbal Conceptual | 112 | 79 |
| WAIS-III Perceptual Organization | 78 | 7 |
| WAIS-III Working Memory | 78 | 7 |
| WAIS-III Processing Speed | 66 | 1 |
| WMS-R Verbal Memory | 83 | 13 |
| WMS-R Visual Memory | 86 | 18 |
| WMS-R General Memory | 82 | 12 |
| WMS-R Attention/Concentration | 54 | <1 |
| WMS-R Delayed Recall | 58 | <1 |
| CVLT-II Total words | 42 words | 21 |
| Trails A | 56” s | 1 |
| Trails B | 155” s | 2 |
| Booklet Category Test | 69 errors | 12 |
| Wisconsin Card Sort (128 cards) | 0 categories | |
| TPT Total | 14 blocks in 30 min | <1 |
| TPT Memory | 5 blocks | 3 |
| TPT Location | 3 blocks | 18 |
| Tapping (Right dominant) | 42.4 taps | 5 |
| Tapping (Left nondominant) | 41.4 taps | 16 |
| WRAT-R Reading | 103 | 58 |
| PPVT-R Vocabulary | 96 | 39 |

*For WAIS-III, WMS-R, CVLT-II, WRAT-R, and PPVT-R, percentile ranks were obtained or derived from tables available in the technical manuals for these measures. For all other tests, percentile ranks were derived from Heaton et al. Percentile ranks for the Booklet Category Test must be interpreted cautiously since the Heaton et al[40,41] *t* scores were not originally developed for this version of the measure. Although there is controversy about the use of regression-derived demographically adjusted norms,[42,43] a decision was made to use these conversions to convey the unequivocal impairment experienced by the participant.

skills and moderately severe difficulties with executive reasoning tasks. Impulsivity was noted, with decreased tolerance for frustration, poor judgment, and a marked verbose pragmatic communication style. These difficulties appeared to be associated with multiple interacting factors. In addition to the brain injury and severe sustained alcohol abuse, one of VP's parents indicated that he “may have had attention deficit disorder” during school years. Some of VP's behavioral characteristics were consistent with this possibility, but the team members were unable to obtain any supporting documentation. Neuropsychological data are presented in Table 1.

Throughout the study, there were no known incidents of substance abuse. A community-based work evaluation plan was developed. However, his verbose communication style threatened to interfere with all activities requiring interaction with others.

To address this difficulty, verbal cues were provided by team therapists during individual and group sessions. These cues included both gestures and direct statements reminding VP to decrease his verbose communication. VP consistently responded to these cues when they were offered, but no persisting behavioral changes were noted. A decision was therefore made to attempt an

ATC intervention to deal with this pragmatic difficulty.

### Development of ATC and data recording tools

Two technological components were developed, one for cueing and one for behavior monitoring. The cueing intervention used a Handspring Visor Neo PDA (costing approximately $200 as of the time of the study, but similar devices are now available for as little as $140), running a recent version of the Palm operating system. The Handspring device includes a port that permits use of plug-in modules. For this project, the ProRecord™ plug-in module, manufactured by AdMobis Technology, Inc, was used (costing approximately $90 as of the time of the study). ProRecord is a digital voice recorder with up to 8.5 hours of recording time. A recording can be attached to a calendar item and played automatically as an alarm when the time for that calendar item occurs. It should be noted that any PDA/module combination having similar features could have been used instead.

Using this feature, as a first step, VP recorded in his own voice a reminder to decrease his utterance length. It should be noted that VP expressed the strong conviction that he was more likely to respond consistently to his own voice. In contrast, in other studies conducted by our team members, subjects have indicated a preference for verbal cues recorded in a therapist's voice. Since consistent use and sustained motivation are factors critical to the success of ATC interventions, our team members involve the user or caregiver into the planning process during intervention development, whenever possible, and respect his or her decisions in regard to some methodological details. As will be noted later, we have also found that the user's feedback is critical to intervention refinement implemented through iterative modification. Clearly, this is not possible with all subjects but has proven to be a productive approach for us, decreasing the likelihood that the user will find the intervention irrelevant or aversive.

A series of appointments was then entered the Visor Neo calendar application with audible alarms that triggered playback of a moderately lengthy (9 words) recorded cue, administered every 10 minutes. Using the above-noted iterative, participatory process, the cue content/appointment duration combination was negotiated and modified 4 times, with VP eventually suggesting that the verbal cue be shortened to the phrase "be brief." He also indicated that the audible alarm was distracting and the intercue interval too short. After turning off the alarm and lengthening the intercue interval to 15 minutes, VP expressed no further concerns.

For group sessions, during which cueing was used, earphones were attached to the ProRecord so that only VP could hear his self-recorded cue. VP positioned the Visor Neo at his own discretion, but he was always accessible for tapping. The cue was designed to repeat every 5 minutes until VP tapped the screen, but this feature was not needed during data collection trials.

For the monitoring system, a wireless, Internet-enabled Compaq iPaq 3850 (costing approximately $500 as of the time of the study) equipped with a Cisco Aeronet 350 wireless card (costing approximately $150 as of the time of the study) was used. Once configured, the iPaq was able to interact with Web pages created for the study, using the "pocket" version of Internet Explorer included as a component of the iPaq's Microsoft Pocket PC operating system. Web pages were made available over a medical center-wide wireless Internet, using standard 802.11b protocol (commonly referred to as "WiFi"). It should be noted that the wireless components of the monitoring system were based on readily available devices, similar to what might be used to set up a wireless network in one's home. Additionally, as with the cueing device, other devices with similar features could have been used for the monitoring system. For example, the Dell Axim 5 (costing approximately $300 **[QA1]** as of the time this manuscript was finalized) has essentially identical features, but it was not available at the time of the study.

The monitoring system software developed for the study was based on a combination of Web development tools. By way of background, a common language used for development of Web pages is Hypertext Markup Language (HTML). When used in conjunction with scripting languages such as Javascript, Web pages can be designed having dynamic content (eg, a color change on one part of the screen when another part of the screen is clicked). Despite these features, described fully in reference publications,[44–46] HTML/Javascript Web pages are restricted in regard to storage of data generated by the Web page. To interact with a database, other programming languages such as Macromedia Coldfusion are needed. Essentially, Coldfusion provides support for what is known as "server-side" data management. Using Coldfusion features, it is possible to develop Web pages that once loaded on a *client machine* provide data storage (eg, user screen taps) that resides on and can be accessed remotely from the *server*.

Using the above-described tools, development of the behavior monitoring system was relatively straightforward. Essentially, 2 Web pages were created. The first Web page presented the word "Go" in large green letters on the iPaq screen. The second Web page presented the word "Stop" in large red letters. An observing therapist would tap the Go screen whenever VP began an utterance. The screen tap initiated 2 events. First, the "clock" time of the tap was recorded (to the second) in the server-side database. Second, the Stop page was displayed. Then, when VP's utterance ended, the observing therapist would tap the screen again. The clock time of the tap (also to the second) was recorded in another server-side database field, and the Go screen was once again displayed. The Go-Stop sequence could then be repeated as many times as necessary during an observation session to assure that the starting and ending clock times of all utterances were accurately recorded. The wireless PDA, essentially acting as a stopwatch, could be held unobtrusively below the table top by the observing therapist.

## Design and method

A single case BAB' design was used to assess the intervention's effectiveness. The intervention was introduced during B and B' trials. The intervention was withdrawn during A trials. There were several reasons for choosing a BAB' rather than an ABA' design. First, as noted in the description of VP's clinical status, his verbose pragmatic style had been well established clinically (although not formally measured) during the course of several weeks of treatment prior to study initiation. Although the decision to use a BAB' design represented a methodological risk since there would be only one study phase during which baseline behavior could be demonstrated, clinical observation of his extremely consistent behavior over several weeks prior to intervention suggested that the risk was acceptable. Second, VP's speech pathologist and occupational therapist had demonstrated that VP would immediately terminate a lengthy utterance in response to verbal cues. Consistent with our team members' orientation that ATC interventions are often best used after effectiveness of "human" intervention has already been established, it was decided to assess the ATC intervention as the first trial phase rather than to reestablish baseline performance in the group context.

As noted above, after negotiation, the intervention presented VP with a digital self-recorded verbal cue to "be brief" at 15-minute fixed intervals. The fixed interval intervention represented a change from what had originally been implemented by therapists (ie, immediate intervention whenever an excessively long utterance occurred). However, because of the very high frequency of the behavior targeted for the study and because of VP's concern that excessively frequent interventions were disruptive, a decision was made to limit the intervention to fixed intervals.

Prior to the start of each group session, VP met with the team's speech pathologist or occupational therapist who reviewed with

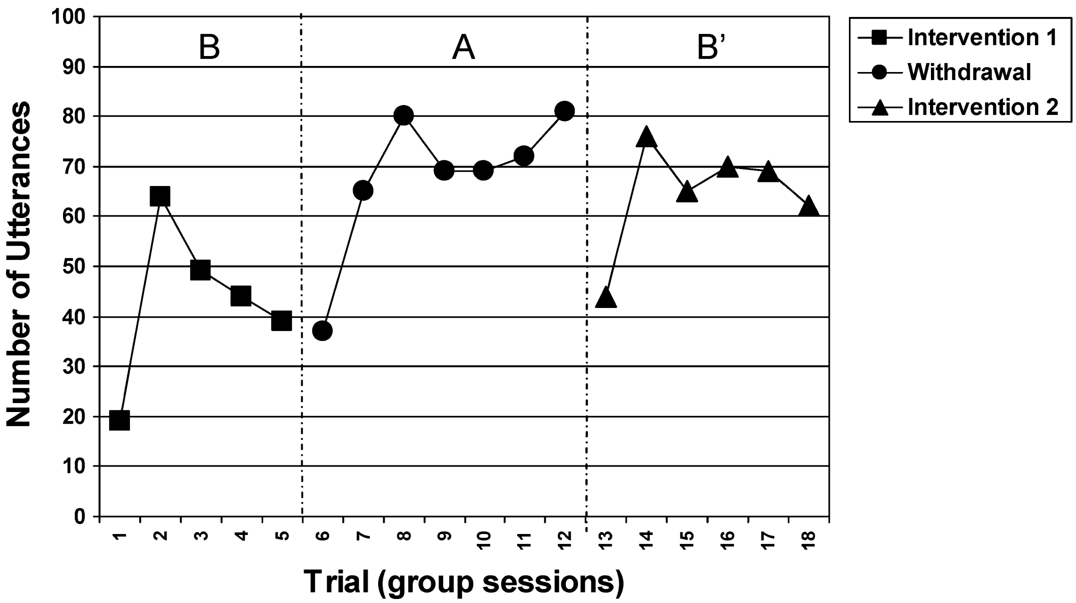


**Figure 1.** Utterance frequency during 60 minutes of a group session. B & B' indicates with intervention; A, without intervention.

him expectations for the upcoming group session in regard to his pragmatic discourse. Prior to each B and B' trial, the use of the PDA was reviewed. He was reminded that his utterances would be monitored, that he would be receiving a self-recorded cue every 15 minutes to "be brief," that he should tap the PDA screen upon receiving the cue, and that he should make every effort to comply with his own recorded behavioral directive. Prior to each A trial, VP was also reminded that his utterances were being timed and that he should make every effort to be brief. However, no reference was made to the PDA cueing system.

## RESULTS

Phase B of the study consisted of 5 trials, phase A of 7 trials, and phase B' of 6 trials. A total number of 1052 utterances were recorded during the 18 trials. All data were collected during regularly scheduled clinical group sessions, and so group size varied from trial to trial. The minimum group size was 2 (once during phase A), and the maximum group size was 9 (once during phase B'). There were 3 trials with group membership of 8, 1 in each of the 3 study phases. The mean group sizes were as follows: B = 5.83, A = 5.00, and B' = 6.17. A one-way analysis of variance, using study phase as an independent variable and group size as a dependent variable, was not significant ($F = 0.300$, $P =$ NS). A more conservative analysis could have been obtained by eliminating the data point from phase A for which group size was 2 (Trial 11). However, inspection of the figures presented below will confirm that this manipulation would not have changed the resulting between-phase differences in VP's verbal behavior. Utterance durations were calculated by subtracting the utterance-start "clock" time from the utterance-end "clock" time. Total utterance time per trial was then computed.

As displayed in Figure 1, no substantial difference was noted in the total number of utterances between the cued (B, B') and noncued (A) conditions. However, as displayed in Figure 2, the total utterance time during cued trials was substantially lower than during noncued trials. There was a marked trend during A trials for progressively increasing total

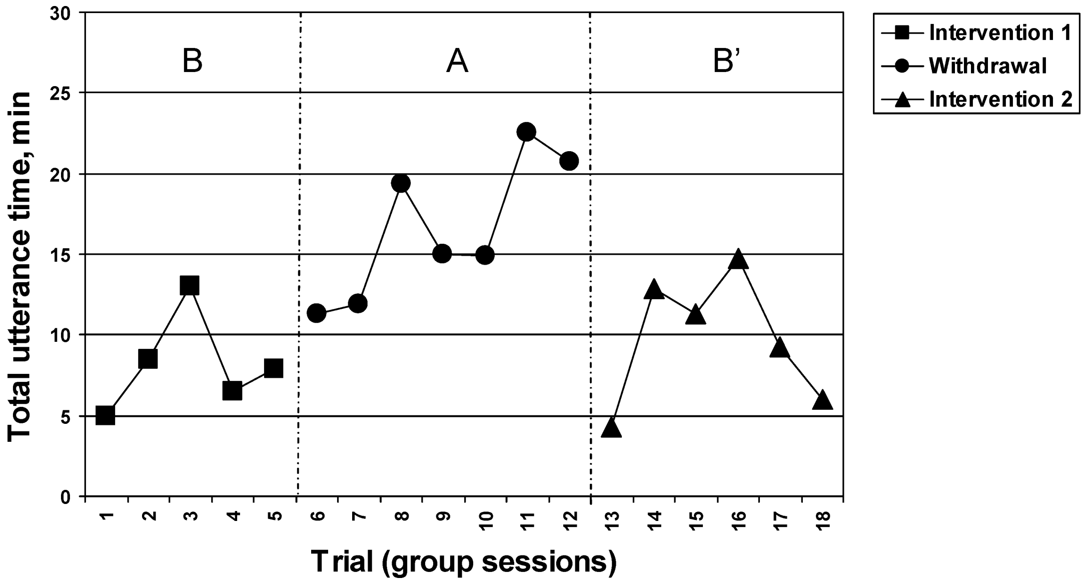


**Figure 2.** Total utterance time, in minutes, during 60 minutes of a group session. B & B' indicates with intervention; A, without intervention.

utterance mean time. For the last 2 A trials, the total utterance mean time was 21.63 minutes (36.05% of available group time). In contrast, the total utterance mean time for B and B' trials was 8.26 minutes (13.76% of available group time) and 9.71 minutes (16.18% of available group time), respectively.

Consistent with the cue to "be brief," Figures 1 and 2 indicate differences across study phases for total utterance time but not for total utterance frequency. In other words, in response to intervention, VP appeared to have reduced the number of pragmatically unsupportable utterances rather than the number of all utterances.

To further characterize this strategy, a set of additional calculations was completed. First, the first and third quartiles for utterance length were computed (4 and 14 seconds) for all the 1052 utterances. Then, utterance frequencies per trial were calculated for those utterances at or below the first quartile compared to those at or above the third quartile.

As displayed in Figure 3, during B trials, no consistent pattern was established for utterance frequency although a modest trend emerged during the last 2 trials, suggesting a tendency for VP to shift behavior toward utterances having a briefer duration. During A trials, there was a marked tendency for the frequency of lengthier utterances to be greater than for briefer utterances. In contrast, consistent with the trend noted during B trials, the pattern reversed during B' trials, with the frequency of briefer utterances being consistently greater than for lengthier utterances.

## DISCUSSION

This case study applied an assistive-technology intervention to a symptomatic pragmatic communication style that affected the quality of one individual's social interaction. The intervention reduced the study participant's total utterance time in groups to a level deemed more socially appropriate. The data indicate that VP achieved this change by emphasizing briefer and de-emphasizing lengthier utterances but without a reduction in the total number of utterances across trials.

The data also indicate that the intervention was transient as was characterized by the increasing verbosity over successive nonintervention trials. In other words, for VP, the

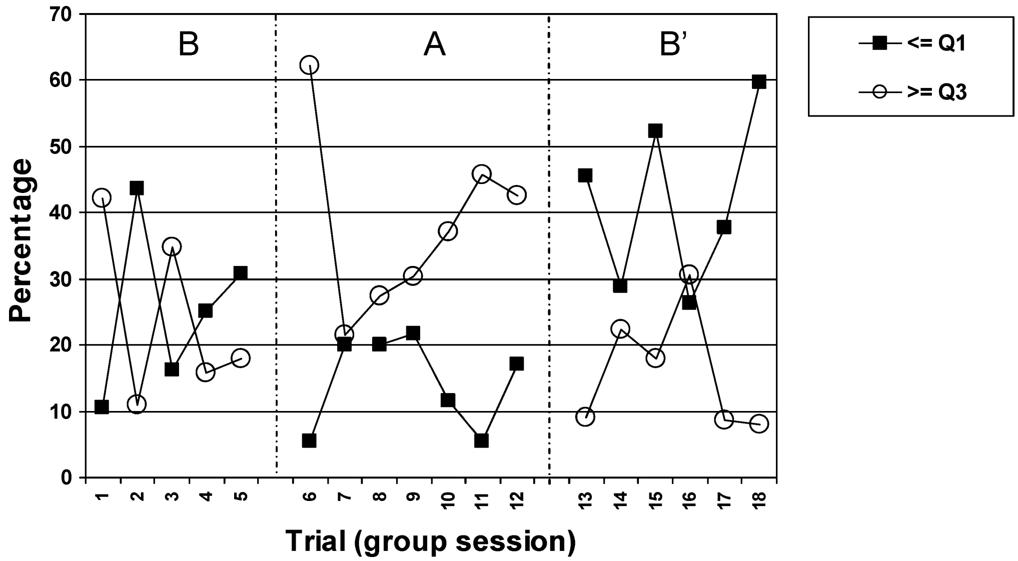


**Figure 3.** Percentages per trial of briefer (≤quartile 1) and lengthier (≥quartile 3) utterances during 60 minutes of a group session. B & B' indicates with intervention; A, without intervention; Q1, quartile 1; and Q2, quartile 2.

intervention appeared to be a necessary accommodation. However, alternative cueing regimens were not assessed. This is important since alternative cueing schedules might have supported robust maintenance of new behaviors despite intervention withdrawal, or facilitated generalization to community settings. Issues such as these can be pursued in further studies.

Additionally, as noted above, VP's behavioral strategy in response to fixed-interval cueing appeared to have been fairly specific. VP responded by decreasing the *number of lengthier* utterances rather than by decreasing the *total number* of utterances. Evidence such as this, suggesting a response style that is specific to the presented cue, raises the possibility that different cues can be developed for a single person, each eliciting an alternative and distinctive behavior. For example, decreased total utterance *time* may be a desirable strategy during group therapy but decreased *number of utterances* may be viewed more positively during work. For some ATC users, it may even be reasonable to develop an intervention repertoire (eg, "be brief," "speak less often," "don't speak at all," "only answer questions"), with each cue directed at the same underlying neurocognitive or neurobehavioral target but respectively eliciting the precise presentation required by the immediate context in which the ATC user must engage.

There are also a number of clear limitations to the case study. First, the data do not support the type of decision making associated with randomized clinical trials. Further work is needed, using both randomized clinical trials and single case studies, to evaluate issues such as (*a*) the specific clinical targets amenable to an ATC approach, (*b*) characteristics of cues to which different individuals are likely to respond, (*c*) variations in cue presentation based on behavioral context, and (*d*) factors that facilitate generalization and sustained use.

Second, in regard to generalization across behavioral settings, VP was not observed outside the clinical context. For this reason, the study does not address whether VP's response to intervention would have been sustained in other settings. Since the characteristics of behavioral contexts are so varied, the study also offers no guidance about whether generalization and sustained use are more or less likely in some community contexts rather than others. As greater experience is accumulated with a range of ATC interventions, it will be critical that ATC designers understand the specific characteristics of the community settings and social practices in which the ATC user must engage. Similarly, in regard to generalization across persons, the study may be limited to the degree that other persons with traumatic brain injury (who do not share some of the complex preinjury characteristics of the individual described in this study) may respond differently to assistive-technology intervention or require different intervention regimens. Both types of generalization will require further study.

In regard to the technology reported in this article, Kirsch et al[4] have noted that by using Web-based programming within a wireless Internet infrastructure, it is possible to develop ATC tools for contexts encountered on a daily basis by persons with traumatic brain injuries. For the present study, the intervention device was relatively straightforward, requiring no particular technical skill beyond information available in the device manuals. In contrast, the programming skills necessary to develop a monitoring system may, in many settings, require that rehabilitation engineers be consulted.

When both components are available, the combination of cueing and monitoring devices is particularly suitable for interventions that must be developed, tried, assessed, modified, and retried repeatedly, until the intervention proves successful or the need for an alternative becomes apparent. This approach is comparable to human-centered design processes[47] in which an iterative procedure helps determine the degree to which a product is "usable." In effect, for this project, the ATC intervention is analogous to a new product designed specifically for VP. Since the goal of ATC development is to facilitate independent performance of functional activities, the iterative design process is facilitated by engaging, whenever clinically possible, the user and/or the user's caretakers at critical stages of intervention development.[48–50]

On the basis of our team members' experience with the effectiveness of such interventions, our impression is that wireless, interactive, data-driven applications, based on Web technology, implemented in a person's home or in the community, but managed and monitored from a remote location, will acquire increasingly greater rehabilitation significance. These ATC cueing and monitoring systems are likely to constitute one form of remotely managed intervention for individuals, regardless of distance from the treatment center, whose activity performance must be both supported and assessed as they go about the routine business of their daily lives.[51]

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## Queries to the Author

QA1: Kindly check whether the edited sentence (For example, the Dell Axim 5 . . . at the time of the study) conveys the intended meaning.
QA2: Kindly update, if possible.
QA3: Kindly provide the name of the publisher and the date when the proceedings was held.
QA4: Kindly provide the name of the publisher, the place of publication, and the date when the proceedings was held.
QA5: References 38 and 39 are not cited in the text. Kindly cite them at appropriate places or delete them from the reference list.
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