Multimodal Annotation Tool for Challenging Behaviors in People with Autism Spectrum Disorders

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ABSTRACT

Individuals diagnosed with Autism Spectrum Disorders (ASD) often have challenging behaviors (CB's), such as self-injury or emotional outbursts, which can negatively impact the quality of life of themselves and those around them. Recent advances in mobile and ubiquitous technologies provide an opportunity to efficiently and accurately capture important information preceding and associated with these CB's. The ability to obtain this type of data will help with both intervention and behavioral phenotyping efforts. Through collaboration with behavioral scientists and therapists, we identified relevant design requirements and created an easy-to-use mobile application for collecting, labeling, and sharing in-situ behavior data in individuals diagnosed with ASD. Furthermore, we have released the application to the community as an open-source project so it can be validated and extended by other researchers.

AUTHOR KEYWORDS mobile application, behavioral annotations, challenging behavior, autism spectrum disorders, autism, Android.

ACM Classification Keywords J.4. [Computer Applications] Social and Behavioral Sciences, K 4.2. [Computers and Society] Assistive Technologies for Persons with Disabilities

General Terms Design, Experimentation, Human Factors, Measurement, Reliability.

INTRODUCTION

Challenging behaviors in persons diagnosed with Autism Spectrum Disorders can seriously affect their quality of life as well as limit their ability to reside in more "normalizing" environments. These behaviors also have major impacts on family and social life. The term "challenging behavior" covers a wide gamut of problems in persons diagnosed with ASD. Aggression toward others, property destruction, self-injury, and stereotypies are some of the most common [8].

To address CB's, it is necessary to operationalize the behaviors and identify their antecedents and consequences. A common approach to doing this is through behavioral assessments. An essential element of behavioral assessment is collecting observable and quantifiable data. This data is used to understand and make decisions regarding behaviors targeted for change. A myriad of methods and instruments are available for behavioral assessment of CB's (for reviews see [3, 4]).

One of the most common approaches to data collection and annotation in school settings, therapy environments, and behavioral and psychological studies is the use of pen and paper, whereby an observer manually writes down the occurrence of each behavioral event of interest. While this methodology provides value, it can be slow, cumbersome, prone to human error, and limited in its ability to capture rich and complex behavioral and environmental data. In school and therapy settings the focus is on providing care to individuals and ensuring safety. For this reason, CB's are seldom documented by teachers or aids either as they occur, or near their occurrence. This delay in behavior recording can lead to an incomplete understanding of a child's behavior and the antecedents and consequences that may cause and/or maintain his or her CB's. While the economic cost of pen and paper annotations is low, there may be significant cost with respect to lost data and potential insight into an individual's CB's. In addition, pen and paper methods are not easily shared with other teachers and caregivers, and require a significant time burden to synchronize with other possible data sources such as video and physiological recordings.

Recent advances in mobile and ubiquitous technologies provide an opportunity to efficiently and accurately capture behavioral information over time and across locations. Such information could help researchers, parents, teachers, and therapists better document the occurrence and understand the antecedents of CB's, which could ultimately lead to improved care. In this work we present an easy-to-use mobile application for collecting, labeling, and sharing in-situ CB data in individuals with ASD.

The paper is organized as follows. First, we review relevant studies in the field of ubiquitous computing with respect to ASD and behavior capture. Second, we describe our system's design requirements and the final application. Third, we provide a qualitative evaluation of the system. Finally, we summarize relevant findings and discuss future work.

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RELATED WORK

Research by Hayes et al. [6] proposed CareLog, a system to efficiently annotate behavior to support Functional Behavior Assessments. The system requires the installation of cameras and microphones throughout a classroom, and the use of a custom-made remote actuator to trigger recordings. In a separate study, Kientz et al. [7] introduced another annotation technology: Baby Steps, which allows long-term monitoring of children to preserve memories and improve communication between parents and pediatricians. While these systems have been shown to provide value to users, they cannot be easily extended to new settings. Likewise, they limit other researchers from validating and/or extending their work, since it would require re-implementing their hardware and software systems.

In the time since the aforementioned studies were carried out, there has been a significant shift in technology resulting in the proliferation of inexpensive, small mobile computers such as smart phones and tablet computers. Most modern mobile computers are sensor and hardware rich, allowing for audio and video capture, location awareness, and movement information to be easily captured. When these mobile computers are connected to digital networks, they revolutionize the way we interact with digital information. For the first time, complex real-world behavior data can be collected in a variety of naturalistic settings and used to provide not only better scientific insights in special needs populations, but also better practical understanding and support of individual needs.

Applications such as EverNote [5] allow users to create multi-modal (text, video, and audio) annotations that can be shared over the Internet. Unfortunately, these types of applications are usually intended for personal organization, memos, or to-do lists. While useful, these applications do not accurately represent the domain of behavioral annotations, e.g., tracking the frequency of recurring behavioral events. Systems more similar to ours include SymTrend [9] and AutismTrack [1] that are mobile phone applications and web services that allow users to manually record behavioral events and track their evolution over time. However, these systems do not utilize the full functionality of modern mobile devices such as recording audio and video, and they are neither free nor open source.

Capturing and annotating CB's in children with ASD in a busy classroom requires new, specific tools to facilitate collection of this valuable data. A teacher faced with a CB has a lot to contend with, and will not have the time or attention to deal with a complicated interface. The system we design must allow customizable, multi-modal annotations while maximizing usability, minimizing cognitive load, and remaining inexpensive. Our proposed system leverages the growing capabilities of mobile devices to create a ubiquitous platform for collecting, sharing, and understanding CB's in children diagnosed with ASD. The following is an overview of our system.

SYSTEM DESCRIPTION

The design of the system was informed by a review of previous literature together with an iterative participatory design and deployment process with behavioral scientists and therapists at the Groden Center, a large non-profit school for people diagnosed with ASD in Rhode Island. Since the severity and appearance of CB's varies largely from individual to individual, the flexibility of the system to easily capture relevant events, and their context, is a key component.

After conducting interviews, we identified two primary data types to capture: events and challenging behaviors. Teachers at this school currently fill out a daily pencil and paper form for each student, as well as additional paperwork if needed, which contains information such as the beginning and end time of each class activity, the onset/offset of any clinically relevant behavior, and related event notes.

Taking the above description of teachers and therapists' needs into account, we developed a user-friendly device to meet those requirements. The main screen of the application is the annotation tool (see Figure 1). The top left corner of the screen clearly identifies which student the annotations belong to, while the remainder of the interface presents annotation markers and capture tools. The application allows for multiple events to be simultaneously recorded. Indicators on the left side of annotation buttons show three types: (1) short duration (only onset is annotated), (2) long duration (onset and offset are specified), and (3) repeated task (once the button is activated, the user is asked whether the event is happening at set intervals). Each type of annotation could be used for a different purpose. For example, short duration may be used if a teacher wants to mark an over-used word or a self-injurious behavior. Long duration is useful for timing of long-lasting activities and behaviors, i.e. tantrums or classroom programs. Repeated task is appropriate when there is a need to monitor the occurrence of certain behavior over a period of time. In order to enrich the annotation with dynamic, real world examples of complex behaviors, the application facilitates the capture of audio, image, and video data.

One of the most important features of this application is its customizability. The customization features allow users to define events of interest specific to a particular person. This both simplifies and enriches the application's abilities. Because CB's vary greatly between individuals, a data capture tool would either have to account for all possible behaviors, or ignore uncommon or individual-specific behaviors. The first case would result in an overly complex menu of selections, while the second case would result in important data being lost. Our approach bridges this problem by allowing the user to easily define what behavioral events to capture for any individual. Specifically, the application allows users to create, modify, and delete the types of events (Figure 1, center option of the bottom

menu), and to manage students who will be monitored (top left). Moreover, all of the annotations can be visualized and managed through a summary list (left option of the bottom menu).

Figure 1. Screen capture of the application while simultaneously recording an event and audio.

Application Benefits

Portable: The device can be used 24 hours/7 days a week to annotate and monitor data in real-life environments.
Scalable: This application can be installed on all Android devices (e.g., mobile-phones, tablets.)
Inexpensive: The application uses the capabilities of current mobile devices, and distribution of the software is free through Google's Android Market.
Customizable: The user interface and annotations can be easily changed and adapted to meet individual specifications.
Reliable: Teachers can quickly annotate events with one or two button clicks, and will not have to manually transcribe collected data.

Application Potentials

A significant potential benefit of this application is the possibility to share and synchronize annotations from different people at various times and locations. For example, it could be used in the home, school, or clinic to make annotations about the same individual and see their whole day. This captured data could then be centralized and controlled by caregivers for analysis and sharing with appropriate people. The ability to analyze and visualize multiple perspectives over time could result in insights such as "what events typically precede self-injury?" and enable better ways to eliminate possible contributing factors.

Analysis of long-term data can show the trend of CB's daily, weekly, and monthly, and show its relationship with context, potentially revealing unknown antecedents. Sharing objective information with related stakeholders concerned with an individual can also increase awareness and understanding of an individual's CB's, how it changes over time, and what potential function it serves.

USER STUDY

We evaluated the usability of our application using the System Usability Scale [2], a 7-point Likert usability questionnaire, and open-ended user response questions. In order to test and receive feedback, a sample of 8 Groden Center teachers (6 females, ages 23-37yrs and 2 males, 32 and 52yrs) were asked to annotate students' CB's using the mobile behavior annotation application. For this study, we installed the application on an Android tablet due to the large screen display enabling more events to be visualized at the same time. All teachers involved had previous experience conducting behavior assessments using handwritten annotation methods, and were familiar with the use of tablet computers.

Immediately preceding use of our annotation tool, teachers were given short instructions on how to use the system. This included in-person explanations and examples as well as a physical instruction manual for personal reference. Teachers were shown how to set up and change the activities and CB's as well as descriptions of all other controls: camera, audio and video, how to switch screens, perform multiple annotations, customize buttons, and make after-the-fact changes. Each teacher, with the guidance of the instructor, proceeded to customize the application based on the student he or she was working with that day (see Table 1 for examples of activities and relevant behaviors). Teachers used the annotation tool in their natural classroom setting for a half-day period after being directed to annotate students' activities and behaviors.

After the school day ended and the teachers had the opportunity to thoroughly use the device, they were then asked to fill out the System Usability Scale as well the Likert scales and questionnaires.

Activities		Behaviors	Type
Gym	Money	Self-injury	Short
Break	Sensory	Tantrum	Long
Vocational	Lunch	Non-Compliance	Repeated
Imagery	Bathroom	Inappropriate Vocals	Short

Table 1. Examples of activities and challenging behaviors

RESULTS

The system usability scale showed a mean of 80.3 (out of 100) with a standard deviation of 11.0. Scores from the System Usability Scale and the usability questionnaires are shown in Figure 2.

The usability questionnaires compared handwritten annotation methods to our mobile annotation system. Results with respect to traditional methods show that all teachers currently use paper and pen for in-class CB annotation and are dissatisfied with the method. Time requirements vary between teachers with respect to annotating. Teachers reported that forgetting to write events down, and inaccuracy, especially with respect to time of event, are problems with traditional methods.

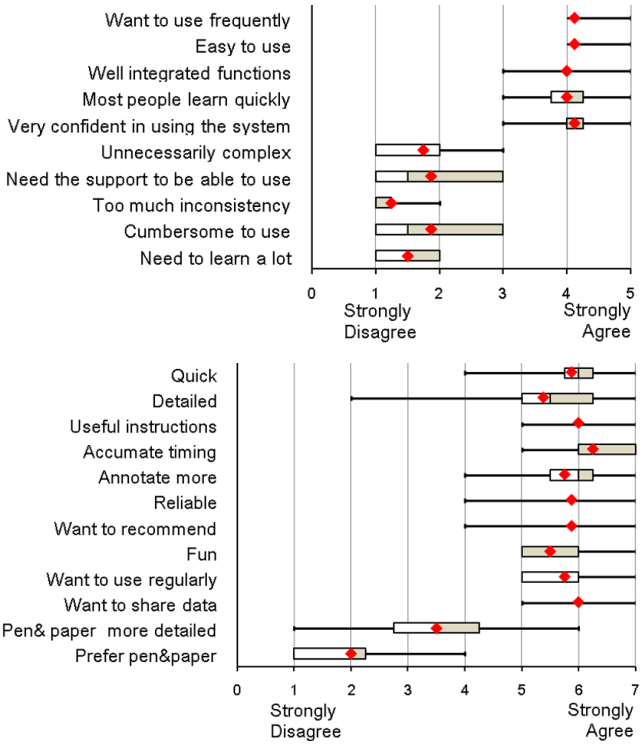

Figure 2. (Top) System Usability Scale results and (bottom) usability questionnaires.

Results from the usability scale show that teachers in this study preferred our annotation tool. In particular, the speed, the accuracy, and the ease of use were significant factors in their preference over traditional methods.

The application had no quantifiable impact on the children's behaviors or school performance, but there was one case where the child especially enjoyed using the tablet in conjunction with the teacher. The application seemed to help the child feel more in control of planning and time management.

Although the large screen display of tablets provides some benefits, feedback on the size of the device suggested that a smaller device could be a better option. As teachers stated, *"the size of the tablet makes it cumbersome to keep with you while working with a student,"* and *"change the size of the tablet to one possibly a little bigger than a smart phone so staff can put it in a pocket if need to respond to student with two hands free."*

FUTURE PERSPECTIVES

Although this study focused on annotation of CB's in people with ASD, our system could potentially annotate any type of event or behavior. As a next step, we will design a more systematic study to quantitatively investigate the differences between our method and traditional annotation methods. In addition, we will incorporate live monitoring of physiological signals that can be comfortably captured with wireless biosensors. Such recordings would allow us to investigate the relationship between observed CB's and unobserved physiological signals (e.g., a physiological setting event such as stress or pain). Future work will also be directed to create the infrastructure to share and visualize captured data by multiple people at different locations over extended periods of time.

CONCLUSIONS

In this work, we designed, developed, and evaluated a mobile tool to easily capture and annotate CB's. The application allows for easy customization that allows a user to capture any behavior and can associate annotations with dynamic media capture. Additionally, the software is made free and open source, with hope that the broader community might continue to validate and extend it (http://affect.media.mit.edu/projectpages/ama/).

This application has the potential benefits of 1) connecting stakeholders around objective behavior data, 2) providing data-driven characterization of person-dependent CB's in ASD, and 3) better informing personalized behavioral interventions, so that better experiences can result.

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