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

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ABSTRACT
People diagnosed with Autism Spectrum Disorders (ASD) often have challenging behaviors (CBs), such as self-injury or property destruction, which negatively impacts their quality of life as well as that of those around them. Recent advances in mobile and ubiquitous technologies provide an opportunity to efficiently and accurately capture such behavioral information. The ability to obtain this type of data will help with both intervention and behavioral phenotyping efforts. With the collaboration of behavioral scientists and therapists, we identified the main design requirements and created an easy-to-use mobile application for collecting, labeling, and sharing in-situ CB 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, Android, autism spectrum disorders, autism.

ACM Classification Keywords H5.2. [Information Interfaces and Presentation] User Interfaces, J.4. [Computer Applications] Social and Behavioral Sciences, K 4.2. [Computers and Society] Assistive Technologies for Persons with Disabilities


INTRODUCTION
Challenging behaviors in persons diagnosed with Autism Spectrum Disorders seriously affect their ability to reside in more “normalizing” environments and have a major impact 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 stereotypes are some of the most common, and troublesome [6].

To address CB it is necessary to understand the underlying behaviors and antecedents. A common approach to this is through behavioral assessments. An essential element of behavioral assessment is collecting observable and quantifiable data. This data is then used to understand and make decisions regarding behaviors targeted for change. A myriad of methods and instruments are available for behavioral assessment of CBs (for reviews see [2, 3]).

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 a teacher or aid manually writes down the occurrence of each behavioral event of interest. While this methodology provides value, it is slow, cumbersome, prone to human error, and limited in its ability to capture rich and complex behavioral data. In school and therapy settings the focus is on providing care to individuals and ensuring safety. For this reason, CBs are seldom documented either as they occur, or near their occurrence. This delay in behavior recording leads to an incomplete understanding of the child's behavior and the antecedents and consequences that may cause and/or maintain their CBs. 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 CBs. 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 CBs, 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; data that will help both with intervention and behavioral phenotyping efforts.

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 the main design requirements and the final application. Third, we provide a qualitative evaluation of the system. Finally, we summarize relevant findings and discuss future work.

* Both authors contributed equally to this work
Growing capabilities of mobile devices to create a remaining inexpensive. Our proposed system leverages the while maximizing usability, minimizing cognitive load, and design must allow customizable, multi-modal annotations cycles to deal with a complicated interface. The system we collection of this valuable data. A teacher faced with a complicating in a busy classroom requires new, specific tools to facilitate mobile devices such as recording several modalities. SymTrend does not utilize the full functionality of modern events and track their evolution over time. However, applications such as EverNote [1] allow users to create multi-modal (text, video, and audio) annotations that can be web service that allows users to manually record behavioral shared over the Internet. Unfortunately, these types of annotations 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. A more similar example to our proposed system is SymTrend [7], a mobile phone application and a web service that allows users to manually record behavioral events and track their evolution over time. However, SymTrend does not utilize the full functionality of modern mobile devices such as recording several modalities.

Capturing and annotating CBs in children with ASD while in a busy classroom requires new, specific tools to facilitate the collection of this valuable data. A teacher faced with a CB has a lot to contend with, and will not have the spare cycles 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 CBs 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 CBs 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: classes and challenging behaviors. Teachers at this school currently fill out a daily form for each student, as well as additional paperwork if needed, which contains information such as the beginning and end time of each class, the onset/offset of any clinically relevant activity and behavior, and related event notes.

Taking the above description of teachers and therapists’ needs into account, we have developed a user-friendly device to fit 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 kinds of annotation: (1) short frequency (only onset is annotated), (2) long duration (onset and offset are specified), and (3) repeated task (the user is asked whether the event is happening at set intervals). Each type of annotation could be used for a different purpose. Short frequency for example, may be used if a teacher is keeping records of a frequent short-duration behavior, such as an over-used word, or OCD (obessive compulsive disorder) behavior. Long duration is useful for timing of long-lasting activities and behaviors, i.e. tantrums or classroom programs. Repeated task is a practical button when looking at a behavior that may be done in conjunction with another activity, such as a stereotypical behavior. 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. Figure 1 shows a screen capture of the main screen¹.

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 varies greatly between individuals, a data

¹ The annotation tool can be downloaded from http://affect.media.mit.edu/projectpages/ama/
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 and their icons (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).

**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-phone devices, and distribution of the software is free through Google's Android Market.

**Customizable:** The user interface and annotations are 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.

**Application Potentials**

A significant potential benefit of this application is the possibility to share and synchronize the annotations of 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. 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 provide significant insight into CB.

Analysis of long-term data can show the trend of CB for each day, week, and month, and show its relationship with context, revealing unknown antecedents. Sharing objective information with related stakeholders concerned with an individual can increase awareness and understanding of the specific traits and CB of the individual.

**USER STUDY**

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

Immediately preceding use of the annotation tool, teachers were given short instructions on how to use the system. This included in person explanation 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 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 schedule and relevant behaviors). Teachers used the annotation tool in their natural classroom setting for a half-day period after being directed to annotate the student’s behaviors and activities.

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.

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Behaviors</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gym</td>
<td>Money</td>
<td>Self-injury</td>
</tr>
<tr>
<td>Break</td>
<td>Sensory</td>
<td>Tantrum</td>
</tr>
<tr>
<td>Vocational</td>
<td>Lunch</td>
<td>Non-Compliance</td>
</tr>
<tr>
<td>Imagery</td>
<td>Bathroom</td>
<td>Inappropriate Vocals</td>
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**RESULTS**

The system usability scale showed a mean of 80.3 with a standard deviation of 11.0. Scores from the system usability scale and the usability questionnaires are shown in Figure 2.
teachers currently use paper and pen for in class CB annotations 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) results from System Usability Scale and (bottom) usability questionnaires.

Results from the usability scale show that the annotation tool was preferred by teachers in this study. In particular, the speed, accuracy, and 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 enjoyed using the tablet in conjunction with the teacher. The application seemed to help the child to feel more in control of planning and time management.

Although the large screen display of tablets provide 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 packet if need to respond to student with 2 hands free.”

FUTURE PERSPECTIVES

Although this study has focused on the annotation of CBs in people with ASD, the proposed tool could potentially annotate any type of events. As a next step, we will make 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 which can be comfortably captured with wireless biosensors. Such recordings would allow us to investigate the relationship between observed CBs and unobserved physiological signals. 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 tool to easily capture and annotate challenging behavior leveraging the benefits of mobile computing. The application allows for easy customization that allows a user to capture any behavior and can associate annotations with dynamic media capture. Furthermore, we provide the application to the broader community as an open source tool to allow the research community to validate and extend it.

This application has the potential benefits of 1) connecting stakeholders around objective behavior data, 2) provide data-driven characterization of individual traits of each person with ASD, and 3) better inform personalized behavioral interventions.

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REFERENCES
