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Automated Tracking and Quantification of Autistic Behavioral Symptoms Using Microsoft Kinect

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Abstract. The prevalence of autism spectrum disorder (ASD) has risen significantly in the last ten years, and today, roughly 1 in 68 children has been diagnosed. One hallmark set of symptoms in this disorder are stereotypical motor movements. These repetitive movements may include spinning, body-rocking, or hand-flapping, amongst others. Despite the growing number of individuals affected by autism, an effective, accurate method of automatically quantifying such movements remains unavailable. This has negative implications for assessing the outcome of ASD intervention and drug studies. Here we present a novel approach to detecting autistic symptoms using the Microsoft Kinect v.2 to objectively and automatically quantify autistic body movements. The Kinect camera was used to film 12 actors performing three separate stereotypical motor movements each. Visual Gesture Builder (VGB) was implemented to analyze the skeletal structures in these recordings using a machine learning approach. In addition, movement detection was hard-coded in Matlab. Manual grading was used to confirm the validity and reliability of VGB and Matlab analysis. We found that both methods were able to detect autistic body movements with high probability. The machine learning approach yielded highest detection rates, supporting its use in automatically quantifying complex autistic behaviors with multi-dimensional input.

Keywords. Kinect, autism, behavior, body tracking, machine learning

1. Introduction

Autism Spectrum Disorder (ASD) is a developmental disability that considerably impairs social, interactive, and behavioral faculties. Possible influences include those of an environmental, genetic, or behavioral nature. The number of those affected by ASD is rapidly climbing, and, according to the Center for Disease Control (CDC), the prevalence within the United States is estimated at 1 in every 68 births [1]. Often those affected by ASD exhibit major behavioral symptoms, which may manifest in the form of certain repetitive movements. These behaviors, labeled as stereotypical motor movements, are commonly believed to possess a self-stimulatory function. Such movements may be alienating towards others attempting to form relationships with those affected by ASD. Detecting and quantifying these symptoms is key for evaluating the efficacy of intervention and drug studies. However, to date there is still a lack of methods available that allows quantification of symptoms across large studies that do not rely on highly trained specialists.

The most common repetitive behavior includes hand flapping, spinning, and body rocking [2]. The autistic individual may flap their hands by either moving their wrists or their elbows up and down. Spinning varies from patient to patient, exhibiting a wide range of styles and behaviors. However, caretakers are normally unable to consistently monitor the dependents at all times for signs of behavioral improvement. They may also be affected by bias while observing them, since they may not retain the necessary degree of impartiality. Therefore, an objective method for quantifying autistic behaviors for extended periods of time in the home environment is needed.

In our study we utilized the Microsoft Kinect 2 hardware, whose sensor has been used to recognize patterns such as hand gestures and gait analysis in clinical research [3]. Kinect is ideally suited to accurately monitor a child's movement without tedious human observation [4]. Thus, the Kinect was used to perform contactless detection and quantification of ASD motor symptoms with machine learning and deterministic algorithms and evaluated their performance against manual scoring.

2. Methods

Twelve healthy participants were recruited for the experiment (6 male 6 female). Each actor performed three stereotypical motor movements, including body rocking, hand flapping and spinning. The stereotypical movements were completed every three seconds with three seconds of non-autistic motor behavior of similar movement intensity as control conditions. This created a total of nine instances of the autistic target behaviors and eight instances of non-autistic behaviors. To assess and compare the validity of the two computer-based detection methods (Visual Gesture Builder (VGB) and MatLab), performances were compared to these human scoring of autistic motor behavior symptoms. Kinect V2 recordings were obtained while twelve actors performed nine separate repetitions of hand flapping, body rocking and spinning.

Visual Gesture Builder (VGB) is an interactive tool for building models of body gestures using the Random Forest Regression (RFR) machine learning classifier. VGB utilizes two detection technologies: AdaBoostTrigger and RFRProgress. AdaBoostTrigger is used to detect discrete gestures, as different frames are indicated as true or false by Boolean values. RFRProgress detects analog or continuous gestures, and the progress of each motion is marked by Float values [5].

VGB was programmed to recognize the slightly different, personalized movements unique to each of the three actors and tag them as "correct." Each of the videos were analyzed with VGB and provided a graph that compares frame number with gesture completeness, where 0.0 indicates an incorrect gesture or no gesture at all and 1.0 indicates an accurate reading of the specific completed dynamic gesture. In order for this experiment to be reliable, the participants were asked to conduct the series of repetitive motions using live preview video streaming using the Kinect system.

In addition, a MatLab solution was created to train the videos, the output indicating the frequency and duration of the motor movements. Once the MatLab code was developed for each motor movement, test videos were run through the code and the outputs were obtained as text files. The MatLab code corresponding to body rocking evaluated the deviation of the spine vector, which connected the spine base joint (1) and the spine-shoulder joint (3), from the xz-plane. When the deviation angle reached a value of 10 degrees or higher, the code detected the specific rock as the target behavior. The MatLab code corresponding to hand flapping evaluated the deviation between the forearm joint (10) and wrist joint (11). The Matlab code corresponding to spinning detected movements of the hip vector to the ball and socket joints of the legs (13 & 17).

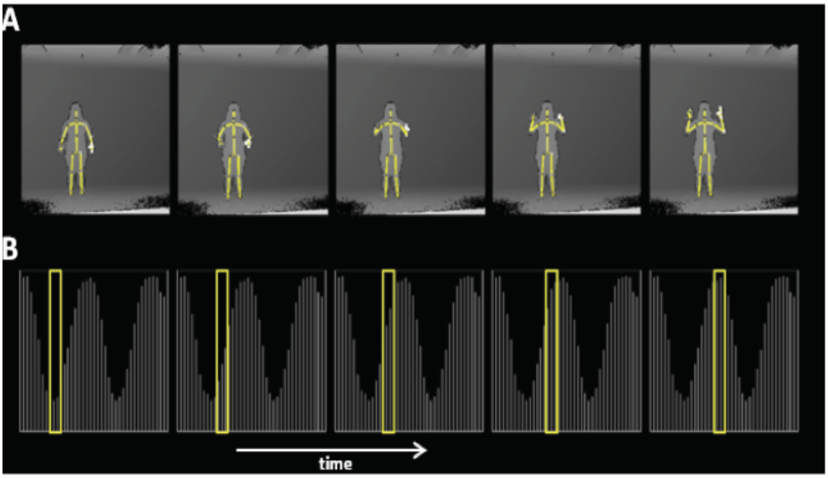

Figure 1. Progression of VGB scoring during hand flapping behaviors. A. As indicated by the skeleton body index and B. the matching degree of gesture completion, when the actor stands with hands down, the action corresponds to the relative minimum of the curve (see yellow bar). Similarly, as the hand flapping motion progresses, the bars reache a relative maximum. An uninterrupted progression from 0-100% indicates a completed dynamic gesture.

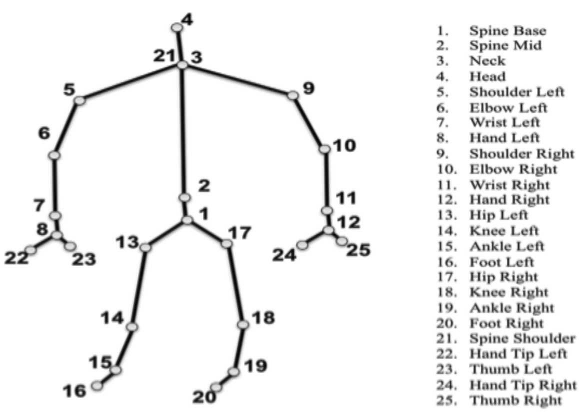

Figure 2. Human posture tracking using the Kinect v2 25 joint model that was used for both the VGB and Matlab solutions.

3. Results

Expert rating from manual grading was used as the 'gold standard' value for onset and offset of the ASD target behaviors in the experimental recordings. True positive detections using VGB analysis were 97.25% for hand flapping, 90.74% for spinning, and 95.37% for body rocking. False positive detections for VGB analysis for hand flapping were 2.75%, for spinning were 8.33% and were 3.73% for body rocking. True positive detections using MatLab were 88.07% for hand flapping, 87.96% for spinning, and 85.19% for body rocking. False positive detections for MatLab for hand flapping were 12.84%, for spinning were 35.19% and were 14.81% for body rocking. Overall the VGB approach outperformed the MatLab approach on each of the three stereotypical motor movements investigated.

4. Conclusion

This study shows that the Microsoft Kinect sensor is a valuable tool to provide non-contact detection and quantification of stereotypical behaviors in individuals with ASD. In combination with machine learning algorithms it may be used to facilitate the identification of relevant behavior patterns when assessing the effectiveness of specific treatments in clinical trial studies. Such automated quantification will take a step forward from manual grading, since Kinect v2 can be set up in a patient's home and allows for days of recordings without labor and cost-intensive manual scoring.

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