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End-to-end system for autism severity estimation

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***Abstract*— This work presents an end-to-end DNN-based system for autism severity estimation of Hebrew-speaking children. The system includes a speaker diarization algorithm for identification of child speech segments and an algorithm for estimating the severity of core autism symptoms in individual children. Audio recordings of 132 children who completed an Autism Diagnostic Observation Schedule (ADOS) assessment were analyzed. The ADOS severity scores predicted by the system were significantly correlated with the true severity scores, yielding an average correlation of 0.581 and a Normalized Root Mean Square Error (NRMSE) of 0.254.**

***Clinical Relevance* — The presented system can identify child speech segments and estimate the child's ADOS severity score.**

I. INTRODUCTION

Autism Spectrum Disorder (ASD) is a neuro-developmental disorder that is diagnosed by the presence of social communication impairments, repetitive behaviors, and confined interests [1]. Recent research has shown that early treatment of ASD can improve clinical outcomes [2], motivating the development of new affordable and scalable techniques to identify autism symptoms at early ages. Recently, studies have shown that speech signals can be used to estimate autism severity [3].

II. METHODS

We analyzed audio recordings of 132 children (101 diagnosed with ASD and 31 without), ages 1.5-7.3 years (4.1±1.3), who completed an Autism Diagnostic Observation Schedule (ADOS) assessment. ADOS is a semi-structured assessment in which the clinician performs specific tasks, observes the child, and scores their behavior [1]. An ADOS assessment yields a score in the range of 0-30 with higher scores indicating more severe core ASD symptoms. The recordings were performed with a single distant microphone (CHM99, AKG, Vienna) located 1-2 m from the child.

The presented system, see Fig. 1, includes a diarization algorithm, where each recording is divided into segments containing different speakers (child, clinician, parent, simultaneous speech, silence and movement). This algorithm was based on a 512 x-vector feature extraction, a Fully Connected Deep Neural Network (FCDNN) which consists of 3 Fully Connected layers, and finally a Viterbi algorithm that was applied to the output of the FCDNN. Prosodic and acoustic features were then extracted from the child's speech segments (feature matrix), followed by estimation of ADOS severity scores using a CNN model. More detailed information about the extracted features and the CNN architecture can be found in our previous work [3].

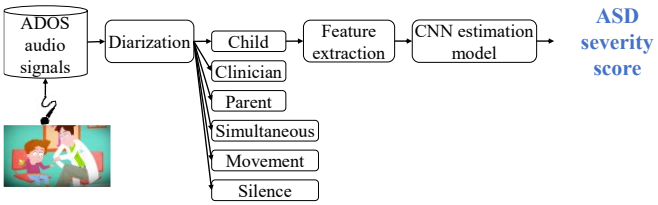

Figure 1. Flow chart of the proposed system

III. RESULTS

The proposed diarization system identified a total of 10:43 hours of children's speech. To test the performance of the system we divided the data into 50 different train-test groups while balancing the distribution of ADOS scores in each group. For each train-test data division the training and testing groups consisted of 80% and 20% of the data, respectively. The mean performance of the algorithm in estimating ADOS scores accross data divisions are presented in Table 1, where NRMSE referes to a Normalized RMSE by the difference between the maximum and minimum ADOS score of the test group.

TABLE I. ASD SEVERITY ESTIMATION PERFORMANCE RESULTS FOR 50 DIFFERENT TEST DATASETS*: MEAN ± STD.*

NRMSE	***Pearson R***
0.254 ± 0.032	0.581 ± 0.115

IV. DISCUSSION & CONCLUSION

The current study demonstrates the utility of an automated system for the estimation of ASD severity that integrates a speaker diarization algorithm and an ADOS estimation algorithm. Most importantly, the current system was able to estimate ADOS scores of children whose data was entirely omitted from the training set demonstrating generalization across recordings.

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