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Feasibility of Automated Training for Facial Emotion Expression and Recognition in Autism

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Compliance with Ethical Standards

The authors report no potential conflicts of interest. The research involved human participants. Informed consent was obtained prior to data collection.

Abstract

Impairment in facial emotion recognition (FER) and facial emotion expression (FEE), often documented in Autism Spectrum Disorder (ASD), are believed to contribute to the observed core social-communication disability that characterizes this disorder. Moreover, impaired FER and FEE are frequently seen in other disorders and problem behaviors. We describe the development of a novel system to detect and give real-time feedback on these processes, termed FEET (Facial Emotion Expression Training), an automated, game-like system that is based on 3-dimensional sensing (Kinect) technology. A sample of 40 children (*n* = 20 ASD, *n* = 20 typically developing) interacted with our prototype system, which presented audiovisual stimuli and assessed responses of participants. Overall, consumer satisfaction ratings were high, and youth with ASD reported enjoying interacting with the system moreso than did the typical youth. Results suggest that new technology-based interventions are acceptable to consumers and viable for use in remediation of transdiagnostic processes, such as FER and FEE. Implications for future technology-based intervention to target transdiagnostic processes are discussed.

Keywords: autism; technology; facial emotion recognition; facial emotion expression; affective computing

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In recent years, there has been an upsurge in the development of novel technologies to remediate social communication deficits in children (Wieckowski & White, 2017). Facial emotion recognition (FER) and facial emotion expression (FEE), two of the four constructs subsumed by National Institute of Mental Health (NIMH)'s Research Domain Criteria (RDoC; Insel et al., 2010), are fundamental for effective interpersonal human relations (Nuske, Vivanti, & Dissanayake, 2013). Although FER and FEE impairments are seen in a range of diagnoses including eating disorders, externalizing disorders, and schizophrenia (e.g., Aspan, Vida, Gadoros, & Halasz, 2013; Dickson et al., 2014; Rhind, Mandy, Treasure, & Tchanturia, 2014), they have been most widely documented in youth with Autism Spectrum Disorder (ASD; e.g., Evers, Steyaert, Noens, & Wagemans, 2015; Loveland et al., 1994; Lozier, Vanmeter, & Marsh, 2014; Rosen & Lerner, 2016).

The majority of the technology-based treatment research in the area of nonverbal social communication impairment has targeted improving FER (e.g., Harms et al., 2010). Relative to FER-targeted neurotechnologies, there has been considerably less research on FEE interventions for youth with ASD. In a recent comprehensive review of the extant research on technologies for social communication deficits, Wieckowski and White (2017) found 18 studies targeting FER, in some capacity via technology, in youth with ASD. In contrast, only 10 studies focusing on FEE in youth with ASD, many of which were on program development. Several technologies were employed in these studies including virtual reality platforms (e.g., Abirached et al., 2011), robotics (Bekele et al., 2013), and mobile applications (e.g., Escobedo et al., 2012). None of the studies included evaluation of usability. Additionally, most of this technology either does not

allow freedom of movement (of the child) and/or provide real-time feedback on expression accuracy.

Children with ASD can spontaneously display basic emotions through facial expressions, but they often do so less precisely and less frequently than children without ASD. This atypical FEE is seen despite lack of consistent evidence for group differences at the physiological level of emotional experiences (Hobson, Chidambi, Lee, & Meyer, 2006; Kasari, Sigman, Mundy, & Yirmiya, 1990; Shalom et al., 2006), although some research has found atypical physiological emotional responding in ASD (e.g., Dichter, Benning, Holtzclaw, & Bodfish, 2010). Targeting both FER and FEE may prove maximally effective, as these processes are strongly correlated (Ricciardi et al., 2017) and may be partially codependent. As summarized by White and colleagues (2015), technology offers a promising modality for improved remediation of processes that underlie observed symptoms. As such, we developed a novel intervention technology, targeting both FEE and FER in children with ASD. The system, termed "FEET" (**F**acial **E**motion **E**xpression **T**raining), was designed to be noninvasive, low-cost, and unobtrusive to maximize transportability, if found effective in improving FEE/FER. The FEET system presents audiovisual stimuli to a child in order to elicit certain displays of emotion. FEET uses a small, monitor-mounted Kinect sensor to capture 3-dimensional (3D) representations of the child's face. The software automatically detects the emotion being dynamically expressed and provides real-time feedback to the child, in a game-like setting, based on the facial expression of the child. Automated FER, developed using machine-learning techniques, is a novel component of the FEET system.

FEET automatically recognizes four basic emotions: happiness, fear, anger, and the neutral expression. Although most research in this area has found that FER deficits are diffuse

rather than emotion-specific (Lozier, VanMeter, & Marsh, 2014), there is evidence that the deficit may be most pronounced for negative emotions (e.g., fear; Uljarevic & Hamilton, 2013). Given this, we opted to target negative emotions (fear, anger) as well as positive (happiness) and neutral in order to be able to compare functioning across discrete emotions. Additionally, during initial FEET development, these emotions were the most readily classified by the machine learning algorithm (Aly et al., 2015). The accuracy of the automated FEET expression recognition classifier was 72.5%, based on an offline evaluation for the 20 typically developing children (Aly, Abbott, Wieckowski, White, & Youssef, 2017). Although humans can be trained to reliably code discrete facial expressions, there is considerable variability in human-based recognition across emotions and stimuli type (e.g., Alvino et al., 2007; Bartlett, Littlewort, Frank, Lainscsek, Fasel, & Movellan, 2006; Bartlett, Littlewort, Frank, & Lee, 2014; Wang et al., 2008). For example, past research by Yitzhak and colleagues (2017) found variability in human coded emotions (i.e., values ranging from 65% agreement for disgust to 97% agreement for happiness).

Although the FEET system was designed for eventual use as an intervention, consistent with the guidance of clinical trial methodologists (e.g., Leon, Davis, & Kraemer, 2011), the primary goal of this pilot study was to evaluate the feasibility of this technology-based approach. As such, the present study did not seek to evaluate the clinical impact of the FEET system on FER/FEE deficits. Participants interacted with FEET for only a single session, rather than repeatedly over time as would be expected if it were implemented for treatment purposes. We hypothesized that FEET would be feasible to implement and that FEET would be acceptable to children with and without ASD. Specifically, we expected that participants in both groups would indicate either neutral or positive feelings about FEET, indicating acceptability of the system as a

potential intervention. We secondarily examined group differences in FEE and FER, as it was anticipated that the children with ASD would show more FER and FEE impairment. We also examined use of technology (e.g., computers, gaming), as it was thought that familiarity with technology might be associated with youth-rated enjoyability of FEET.

Method

Participants

Participants were between the ages of 9 and 12 years, non-treatment seeking, and free of any co-occurring intellectual disability. The ASD group consisted of 20 participants (18 boys) with prior clinical diagnoses of ASD. The ASD diagnoses were confirmed in this study by the Autism Diagnostic Observation Schedule-2 (ADOS-2; Lord et al., 2012), a play-based observational assessment used for diagnosis of ASD, from research-reliable clinicians. This gender composition (90% male) is consistent with epidemiological studies, which have generally indicated a male to female ratio of approximately 5:1 (e.g., Kim et al., 2011). The typically developing (TD) group comprised 20 participants (14 boys) with no clinical diagnoses, based on parent report. The groups were statistically equivalent in terms of gender ($\chi^2 = 2.50$, $p = .114$) and age ($t = 1.76$, $p = .087$) distributions. There was a significant group difference in cognitive ability, measured by an abbreviated cognitive ability test (Wechsler Abbreviated Scale of Intelligence: WASI-II; Wechsler, 2011), with the TD group scoring higher ($t(38) = 4.35$, $p = .000$) (see Table 1).

Measures

NEPSY-II Facial Affect Recognition Test (Korkman, Kirk, & Kemp, 2007). The Facial Affect Recognition (AR) test is one of 32 tests that comprise the Developmental Neuropsychological Assessment (NEPSY-II), a comprehensive neuropsychological assessment

battery. The AR test is designed to assess ability to discriminate among common facial expressions. Further, the NEPSY-II has been used to measure deficits in FER among youth with ASD (Williams, Gray, & Tonge, 2012). It yields age-based standard scores with a mean of 10 and standard deviation of 3, with low scores indicating poorer FER ability. Internal consistency, though somewhat variable across ages, is .88 at age 10 (Korkman et al., 2007). The NEPSY-II was administered once to each participant, after the FEET session. Within our sample, internal consistency was good (alpha= .703) across scaled score and errors for each emotion.

Feasibility Questionnaire. Children completed an acceptability questionnaire after completion of their session with FEET (Table 2). The questionnaire comprised six questions, the first four of which were answered on a Likert scale from 1 (very easy/very fun/absolutely) to 5 (very hard/ very not fun/ absolutely not). The last two questions were open-ended, asking about difficult or frustrating aspects of FEET and the fun or enjoyable aspects of the system, respectively.

Procedure

Every participant completed one session, lasting approximately 60 to 90 minutes. After providing consent and assent, participants completed several questionnaire measures. Participants were also administered the WASI-II and the ADOS-2 to establish eligibility. Afterward, the participants completed the FEET computerized task (described above), were administered the NEPSY-II AR test, and filled out the feasibility questionnaire.

When interacting with FEET, the child proceeds through four scaffolded levels. The levels were sequenced so as to provide less obvious guidance on the target emotion (Figure 1). Specifically, the levels proceed from simple animated cartoon faces showing discrete emotions (Level 1), to dynamic short recordings of a child actor showing emotions (Level 2), to scenes

without faces and just an audio track prompting the facial response of the target emotion (e.g., lightning at night shown, with child's voice saying, "*It's dark in the woods and I hear something growling behind me!*" to target fear; Level 3), to avatars showing the emotions (Level 4). Within each of these levels, the intensity of the depicted emotion increases (e.g., smile widens). For every stimulus presentation, the child is instructed, "*With your face, show what I am feeling*." With accurate FEE (as detected in real-time by FEET's machine classifier), the child progresses through to subsequent stimuli and levels. Subjects receive corrective feedback ("*That's not quite right. Try again.*") following incorrect responses (i.e., showing an emotion other than the target), and reinforcement for correct responses (e.g., image and audio congratulating the child).

Results

Descriptive data for the sample are provided in Table 2. There were group differences with respect to the enjoyability of FEET, $t(38) = 2.26$, $p = .03$ (Figure 2). The ASD group reported a higher mean enjoyability rating for FEET than did the TD group (Table 2). In terms of task difficulty (in interacting with FEET), responses were generally mid-range (2.60 for ASD, 2.35 for TD). ASD participants indicated that the difficult aspects of FEET included the following: "When it [FEET] did a face I did not know how to do" and "Getting the faces wrong." This latter comment refers to the FEET system informing the participant that his/her expression was not the expected one.

Regarding the enjoyable aspects of the FEET system, example responses from the ASD participants included: "It was fun doing the computer tasks"; "Got to do a video game"; and "Trying to do the emotion." In terms of feasibility, only one potential participant with ASD refused to participate after learning that he would be asked to show facial emotions, indicating it would make him feel too uncomfortable; this subject did not work with FEET. None of the TD

participants refused participation. After starting the computer task, none of the children, in either group, stopped participation prior to completing all FEET levels.

As expected, the ASD group demonstrated more impairment in FER based on the NEPSY-II Affect Recognition, even when controlling for IQ, $F(2, 37) = 4.27$, $p = .04$. The ASD group had a mean standard score on the AR test of 10.50 (2.54) and the TD group's mean standard score was 12.00 (1.97), both of which fall in the average range. When asked if their child's facial expression generally seemed appropriate to the situation, 100% of the parents in the TD sample responded affirmatively (Table 3). In contrast, only 50% of the ASD parents responded affirmatively. Likewise, whereas all of the parents in the TD group indicated their children showed a "normal range" of facial expressions, only 11 of the parents of children with ASD responded affirmatively.

Across both groups, parent-reported amount of time spent working or playing on a computer or tablet had no relationship to children's self-reported enjoyment of FEET ($p > .05$). However, for the ASD group, time spent watching television (parent-reported) has a moderate negative association with child-rated ease of using FEET ($r = -.462$, $p = .04$). This relationship was not found for the TD group ($r = .055$, $p = .817$).

Discussion

Technology designed to improve FER and FEE, based on these results, appears to be acceptable to children with and without ASD and feasible to implement. These findings are promising and suggest that investment in further research to develop and apply technology to transdiagnostic processes, such as FER and FEE (e.g., Insel, 2010), is warranted. There have been few therapies, technological or otherwise, developed to target FEE. An advantage of FEET is that children are given real-time feedback on the accuracy of their expressed emotions, with

accuracy determined based on match to the "target" emotion that is depicted in the stimuli. The system is completely non-invasive, and sessions in this pilot study were brief in duration.

In this sample, the youth with ASD reported more enjoyment in interacting with FEET than did the TD children. This is consistent with prior research indicating that affinity for technology may make it a viable modality for clinical intervention for ASD (White et al., 2016), and that youth with ASD may preferentially attend to technology over humans in intervention deployment (Bekele et al., 2013) and perform better during robot-administered intervention relative to human-administered intervention (Zheng et al., 2015). However, television exposure (but not gaming), as a proxy for technology affinity and familiarity, was inversely related to FEET enjoyment for the ASD group. Although further exploration of this relationship is needed, we did find that the children with ASD spent more time in gaming than the TD group.

As expected, the youth with ASD evinced more impairment in FER based on the NEPSY-II AR test, even when controlling for IQ. Although a group difference in the expected direction was found, both groups' scores fell in the average range. This is consistent with prior research in which the NEPSY-II AR scores of ASD samples have fallen in the average range, despite behavioral evidence of FER difficulties and group differences on the test, relative to children without ASD (e.g., Loukusa, Mäkinen, Kuusikko-Gauffin, Ebeling, & Moilanen, 2014; Williams et al., 2012). It should be noted that, in terms of FEE, only half of the caregivers of children with ASD indicated that their child's facial expression generally seemed appropriate to the situation, compared to 100% of the parents in the TD group. These findings underscore the importance of considering interventions to target FER and FEE in ASD.

As previously described, the intent of this study was to establish proof of principle and to evaluate feasibility. The FEET system was found to be feasible to implement and generally

acceptable to consumers. It is unlikely that such a system would produce clinically significant or sustained benefit as a stand-alone intervention. Rather, FEET is likely to be most impactful as an augment to behavioral therapies such as social skills training groups (e.g., Laugeson, Frankel, Gantman, Dillon, & Mogil, 2012; White, Koenig, & Scahill, 2007). Computerized systems that are low-cost and mobile, such as FEET, are well-suited for home-based use. Additionally, most previous computational FER systems have relied on 2-dimensional (2D) images (e.g., Deng, Jin, Zhen, & Huang, 2005; Kumbhar et al., 2012), which impose additional constraints related to consistent illumination and head positioning. The FEET system, because it uses 3D capture, is forgiving of child movement and requires less control of illumination.

In the context of this technology's unique strengths related to deployability and ease of use, findings must be considered in light of the study's limitations. Although the sample size is typical for pilot feasibility studies, it limits use of more sophisticated analytic approaches and rigorous protection of potentially inflated error rate for running multiple comparisons. Additionally, integration of wearables into the paradigm in order to assess reactivity and physiological response during FEET interaction would have possibly allowed a more fine-grained analysis of arousal during the tasks. This type of data (e.g., heart rate variability) may further inform our understanding of likely utility of FEET as an at-home intervention (Goodwin, 2016). Finally, the classification reliability of the system must be improved considerably (as it is currently at about 72.5%; Aly et al., 2017) for FEET to be used as a clinical application. Refinement of the machine-learning techniques and migration to next generation Kinect technology are underway to improve the system's reliability.

In conclusion, we found that children with ASD found a novel, non-invasive technology designed to improve FER and FEE in real-time acceptable and enjoyable. Our prior research

indicates that this system can accurately detect and categorize FEE at a level better than chance when classification is done offline (Aly et al., 2017), and we are now evaluating real-time classification accuracy of FEE, relative to human-coded FEE. Clinical impact, in terms of remediation of FER and FEE deficits, will be evaluated subsequent to this. The results presented here support continued development of technologies for remediation of transdiagnostic processes that affect social communication, such as FER and FEE. As proposed by White et al. (2015), neurotechnology applications for use in mental healthcare should be developed to ultimately be verifiable, useful, consistent, reproducible, mechanism-driven, complete, and deployable. This research represents an initial step in the development of a neurotechnology to address FER/FEE deficits in children with ASD; we demonstrated that the system is verifiable (i.e., user-friendly), mechanism-driven (i.e., focused on FER and FEE), and likely deployable (i.e., capable of large-scale distribution due to low cost and non-invasiveness). To determine the ultimate utility of such a system, further research – including evaluation of FEET as an intervention with larger samples, is needed.

References

Abirached, B., Yan, Z., Aggarwal, J. K., Tamersoy, B., Fernandes, T., Miranda, J. C., & Orvalho, V. (2011). *Improving communication skills of children with ASDs through interaction with virtual characters.* Paper presented at the IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH). doi: 10.1109/SeGAH.2011.6165464

Aly, S., Abbott, A. L., Wieckowski, A. T., White, S. W., & Youssef, A. E. (2017). *Fast 3D facial expression recognition*. Manuscript submitted for publication.

Aly, S., Trubanova, A., Abbott, L., White, S. W., & Youssef, A. (2015, May). VT-KFER: A Kinect-based RGBD+time dataset for spontaneous and non-spontaneous facial expression recognition. Poster presentation at the Annual International Conference on Biometrics. Phuket, Thailand.

Aspan, N., Vida, P., Gadoros, J., & Halasz, J. (2013). Conduct symptoms and emotion recognition in adolescent boys with externalization problems. *The Scientific World Journal, 2013*. http://doi.org/10.1155/2013/826108

Bartlett, M. S., Littlewort, G., Frank, M., Lainscsek, C., Fasel, I., & Movellan, J. (2005). Recognition facial expression: Machine learning and application to spontaneous behavior. *Proceedings of Computer Vision and Pattern Research*. San Diego, CA. doi: 10.1109/CVPR.2005.297

Bekele, E. T., Lahiri, U., Swanson, A. R., Crittendon, J. A., Warren, Z. E., & Sarkar, N. (2013). A step towards developing adaptive robot-mediated intervention architecture (ARIA) for children with autism. *IEEE Transactions on Neural Systems and Rehabilitation*

Engineering, *21*(2), 289-299. doi:10.1109/TNSRE.2012.2230188

Deng, H., Jin, L., Zhen, L., & Huang, J. (2005). A new facial expression recognition method based on local gabor filter bank and PCA plus LDA. *International Journal of Information Technology*, 11(11), 86-96.

Dichter, G. S., Benning, S. D., Holtzclaw, T. N., & Bodfish, J. W. (2010). Affective modulation of the startle eyeblink and postauricular reflexes in autism spectrum disorder. *Journal of Autism and Developmental Disorders, 40(7),* 858-869. doi: 10.1007/s10803-009-0925-y

Dickson, H., Calkins, M. E., Kohler, C. G., Hodgins, S., & Laurens, K. R. (2014). Misperceptions of facial emotions among youth aged 9-14 years who present multiple antecedents of schizophrenia. *Schizophrenia Bulletin*, *40*(2), 460–468. http://doi.org/10.1093/schbul/sbs193

Escobedo, L., Nguyen, D. H., Boyd, L., Hirano, S., Rangel, A., Garcia-Rosas, D., . . . Hayes, G. (2012). *MOSOCO: a mobile assistive tool to support children with autism practicing social skills in real-life situations.* Paper presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.

Evers, K., Steyaert, J., Noens, I., & Wagemans, J. (2015). Reduced recognition of dynamic facial emotional expressions and emotion-specific response bias in children with an autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *45*(6), 1774–1784. http://doi.org/10.1007/s10803-014-2337-x

Goodwin, M. S. (2016). Laboratory and home-based assessment of electrodermal activity in individuals with autism spectrum disorder. *Journal of the American Academy of Child & Adolescent Psychiatry, 55(10S),* S301-S302. /10.1016/j.jaac.2016.07.280

Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism

spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychology Reviews, 20*, 290-322. doi: 10.1007/s11065-010-9138-6

Hobson, P. R., Chidambi, G., Lee, A., & Meyer, J. (2006). Foundations for self-awareness: an exploration through autism. *Monographs of the Society for Research in Child Development.* 71(2), vii-166.

Insel, T., Cuthbert, B., Garvey, M., Heinseen, R., Pine, D.S., Quinn, K., . . . Wang, P.,2010. Research domain criteria (RDoC): toward a new classification frameworkfor research on mental disorders. *America Journal of Psychiatry, 167* (7), 748–751. doi: 10.1176/appi.ajp.2010.09091379

Kasari, C., Sigman, M., Mundy, P., Yirmiya, N. (1990). Affective sharing in the context of joint attention interactions of normal, autistic, and mentally retarded children. *Journal of Autism and Developmental Disorders*, 20(1), 87-100.

Kim, Y. S., Leventhal, B. L., Koh, Y., Fombonne, E., Laska, E., Lim, E., …Grinker, R. R. (2011). Prevalence of autism spectrum disorder in a total population sample. *The American Journal of Psychiatry, 168(9)*, 904-912. doi: 10.1176/appi.ajp.2011.10101532

Korkman, M., Kirk, U., & Kemp, S. (2007). *NEPSY-II: A developmental neuropsychological assessment.* San Antonio, TX: The Psychological Corporation.

Laugeson, E. A., Frankel, F., Gantman, A., Dillon, A. R., & Mogil, C. (2012). Evidence-based social skills training for adolescents with autism spectrum disorders: The UCLA PEERS program. *Journal of Autism and Developmental Disorders*, *42*(6), 1025-1036. doi: 10.1007/s10803-011-1339-1

Leon, A. C., Davis, L. L., & Kraemer, H. C. (2011). The role and interpretation of pilot studies in

clinical research. *Journal of Psychiatric Research*, *45*(5), 626-629. doi: 10.1016/j.jpsychires.2010.10.008

Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S. L. (2012). *Autism diagnostic observation schedule (ADOS-2)* (2nd ed.). Torrence, CA: Western Psychological Services.

Loukusa, S., Mäkinen, L., Kuusikko-Gauffin, S., Ebeling, H., & Moilanen, I. (2014). Theory of mind and emotion recognition skills in children with specific language impairment, autism spectrum disorder and typical development: Group differences and connection to knowledge of grammatical morphology, word-finding and verbal working memory. *International Journal of Language and Communication Disorders, 49(4),* 498-507. doi: 10.1111/1460-6984.12091

Loveland, K. A., Tunali-Kotoski, B., Pearson, D. A., Brelsford, K. A., Ortegon, J. & Chen, R. (1994). Imitation and expression of facial affect in autism. *Development & Psychopathology*, *6*(3), 433–444. http://doi.org/10.1017/S0954579400006039

Lozier, L. M., Vanmeter, J. W., & Marsh, A. A. (2014). Impairments in facial affect recognition associated with autism spectrum disorders: a meta-analysis. *Development and Psychopathology*, *26*(4), 933-945. doi:10.1017/S0954579414000479

Nuske, H. J., Vivanti, G., & Dissanayake, C. (2013). Are emotions impairments unique to, universal, or specific in autism spectrum disorder? A comprehensive review. *Cognition & Emotion*, *27*(6), 1042-1061. doi: 10.1080/02699931.2012.762900

Rhind, C., Mandy, W., Treasure, J., & Tchanturia, K. (2014). An exploratory study of evoked facial affect in adolescent females with anorexia nervosa. *Psychiatry Research*, *220*(1-2), 711–5. doi: 10.1016/j.psychres.2014.07.057

Ricciardi, L., Visco-Comandini, F., Erro, R., Morgante, F., Bologna, M., Fasano, A., ... & Kilner, J. (2017). Facial Emotion Recognition and Expression in Parkinson's Disease: An Emotional Mirror Mechanism?. *PloS One*, *12*(1), e0169110.

Rosen, T. E., & Lerner, M. D. (2016). Externalizing and internalizing dymptoms moderate longitudinal patterns of facial emotion recognition in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *46*(8), 2621-2634. doi: 10.1007/s10803-016-2800-y.

Shalom, D. B., Mostofsky, S. H., Hazlett, R. L., Goldberg, M. C., Landa, R. J., Faran, Y., McLeod, D. R., & Hoehn-Saric, R. (2006). Normal physiological emotions but differences in expression of conscious feelings in children with high-functioning autism. *Journal of Autism and Developmental Disorders*, 36(3), 395-400. doi: 10.1007/s10803-006-0077-2

Uljarevic, M. & Hamilton, A. (2013). Recognition of emotions in autism: A formal meta-analysis. *Journal of Autism and Developmental Disorders, 43,* 1517-1526. doi: 10.1007/s10803-012-1695-5

Wechsler D. (2011). *Wechsler Abbreviated Scale of Intelligence–Second Edition (WASI-II)*. San Antonio, TX: NCS Pearson.

White, S. W., Koenig, K., & Scahill, L. (2007). Social skills development in children with autism spectrum disorders: A review of the intervention research. *Journal of Autism and Developmental Disorders, 37,* 1858-1868. doi:10.1007/s10803-006-0320-x. doi: 10.1007/s10803-006-0320-x

White, S. W., Richey, J. A., Gracanin, D., Coffman, M., Elias, R., LaConte, S., & Ollendick, T.

H. (2016). Psychosocial and computer-assisted intervention for college students with autism spectrum disorder. *Education and Training in Autism and Developmental Disabilities*, *51(3),* 307-317.

White, S. W., Richey, J. A., Gracanin, D., Bell, M. A., LaConte, S., Coffman, M., ... & Kim, I. (2015). The promise of neurotechnology in clinical translational science. *Clinical Psychological Science*, *3*(5), 797-815. doi: 10.1177/2167702614549801

Wieckowski, A. T., & White, S. W. (2017). Application of technology to social communication impairment in childhood and adolescence. *Neuroscience & Biobehavioral Reviews, 74*, 98-114. doi: 10.1016/j.neubiorev.2016.12.030

Williams, B. T., Gray, K. M., & Tonge, B. J. (2012). Teaching emotion recognition skills to young children with autism: a randomised controlled trial of an emotion training programme. *Journal of Child Psychology and Psychiatry*, *53*(12), 1268-1276. doi:10.1111/j.1469-7610.2012.02593.x

Zheng, Z., Young, E. M., Swanson, A. R., Weitlauf, A. S., Warren, Z. E., & Sarkar, N. (2015). Robot-mediated imitation skill training for children with autism. *IEEE Transactions on Neural Systems and Rehabilitation Engineering.* doi:10.1109/TNSRE.2015.2475724

Table 1

Demographic data

	ASD	TD	X^2 / t
Gender (male)	18 (90%)	14	2.50
Race			5.03
White	16	17	
Black	2	0	
Latino	1	0	
Asian/Other	1	2	
NA	0	1	
Age (months)	122.50	129.75	1.76^
IQ	100.55 (13.96)	118.15 (11.53)	4.35**

^ $p < .10$; *$p < .05$; **$p < .01$

Table 2

FEET acceptability

	ASD *M* (*SD*) *N* = 20	TD *M* (*SD*) *N* = 20	*t*
How easy was it to understand the computerized emotion task?	2.10 (1.02)	2.35 (.93)	.81
How fun or enjoyable was the computerized emotion task?	2.25 (1.16)	3.15 (1.35)	2.26*
Would you want to do more of the computerized task?	3.00 (1.26)	3.25 (1.33)	.61
How hard was it to do the computerized emotion task?	2.35 (1.09)	2.60 (1.05)	.74

*$p < .05$

Note. Acceptability items rated on 5-point scale, such that 1 = 'very easy/very fun/absolutely', 3 = 'not sure/maybe', and 5 = 'very hard/very not fun/ absolutely not'

Table 3

Group comparisons

	ASD	TD	X^2
	n (%)	*n* (%)	
Does your child show a normal range of facial expressions? [a]	11 (55%)	20 (100%)	11.61**
Does your child's facial expression usually seem appropriate to particular situation? [a]	10 (50%)	20 (100%)	13.33**
Do you think child's facial expressions seem authentic or genuine? [a]	17 (85%)	20 (100%)	3.24^
	M (SD)	*M (SD)*	*t*
NEPSY-II Affect Recognition[b]	26.05 (3.47)	28.80 (2.51)	2.87**
Time spent watching television (hrs)	1.30 (.88)	.83 (.68)	1.88
Time spent on computer or tablet (hrs)	1.49 (1.18)	.92 (.57)	1.94^
Time spent gaming (hrs)	1.00 (.88)	.23 (.38)	3.58**

^ $p < .10$; *$p < .05$; **$p < .01$

[a] Statistics indicate the 'yes' endorsements to the question

[b] NEPSY-II Affect Recognition total score (standard scores provided in text)

Level 1 Level 2 Level 3 Level 4

Figure 1. A single frame from stimuli for first four levels depicting fear.

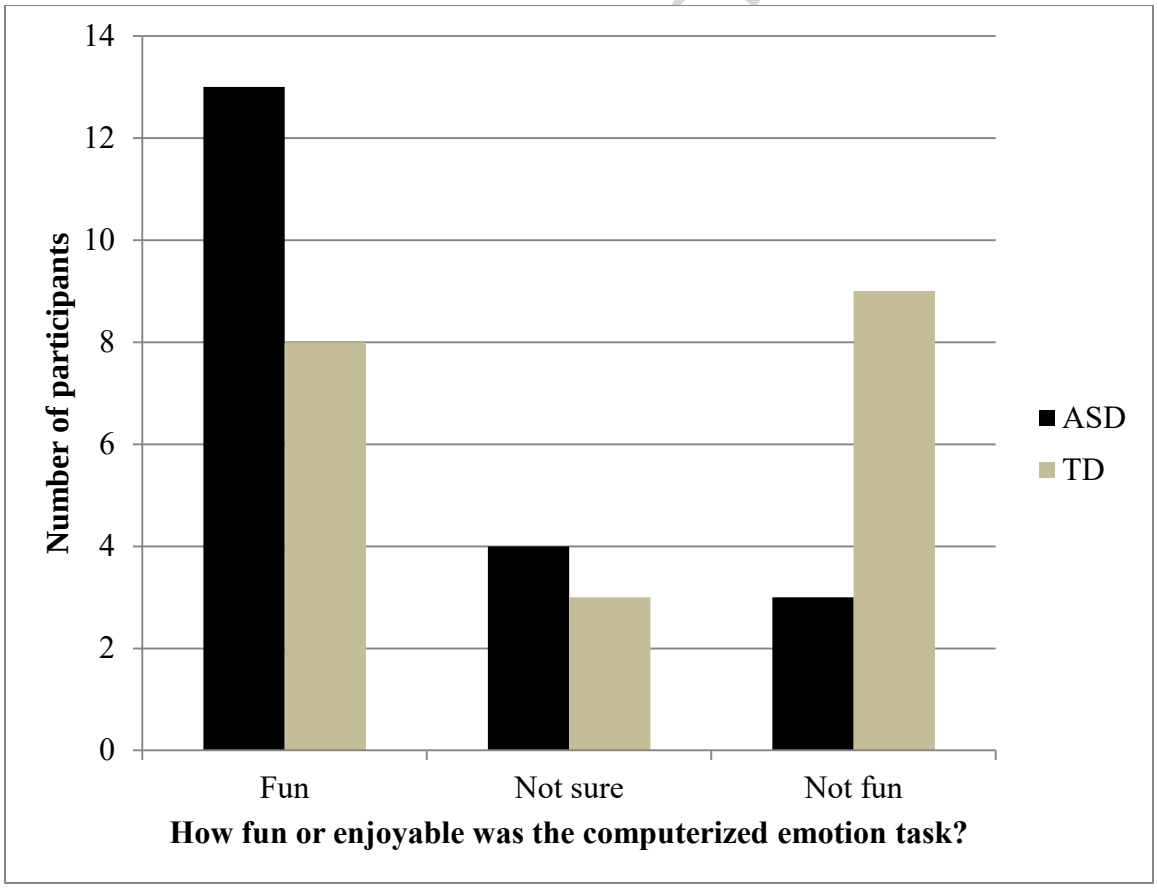

Figure 2. Youth-rated enjoyability of FEET.

Highlights

- Technology provides a noninvasive method through which to remediate emotion expression impairments
- A novel, automated emotion recognition system was acceptable to youth with autism
- Youth with autism may enjoy technology-based interventions moreso than youth without autism