Leveraging Virtual Reality and Machine Learning as Mediated Learning Tools for Social Skill Development in Learners with Autism Spectrum Condition

Thomas Hughes-Roberts[1], Vanessa Cui[3], Mufti Mahmud[2] and David J. Brown[2]

[1] University of Debry, Markeaton Street Campus, UK
[2] Nottingham Trent University, Clifton Campus, UK
[3] Birmingham City University, UK
t.hughesroberts@derby.ac.uk

Abstract. Learners with Autism Spectrum Condition (ASC) are often characterized as having deficits in core social competencies affecting ability to communicate and interact with other people across multiple contexts. However, such deficit views of ASC lead to narrow interventions that cannot be generalized to wider learning contexts nor the real world. Taking a non-deficit view can offer a means of broadening understanding of ASC by taking a more holistic view of an individual. Thoughtfully designed VR solutions that take a non-deficit view can provide learning tools allow learners to develop their self-determination awareness and skills such as decision-making, self-advocacy, reflective problem-solving. Furthermore, through the use of machine learning approaches such solutions have the potential to provide real-time monitoring of learners during interaction offering a holistic understanding of individuals with ASC. This position paper sets out the support case for utilizing VR through non-deficit models and examines the role machine learning can play in further understanding of learners with ASC. It is intended that this sets out a case for future research directions.

Keywords: Virtual Reality, Autism, Machine Learning

1 Introduction

This position paper is to review the current "state-of-play" of Virtual Reality (VR) and its use in providing a platform for adolescent learners with Autism Spectrum Condition (ASC) with particular focus on social skill development. From this, we intend to outline gaps in the field and propose avenues for further research that utilize modern approaches to understanding learners with ASC.

Learners with ASC are often characterized as having deficits in core social competencies affecting ability to communicate and interact with other people across multiple contexts (Bolte, 2014). As such, Virtual Environments (VEs) such as those presented in VR systems can provide a vehicle for teaching and learning social skills (Mitchell et al., 2007) by providing safe, realistic 3D scenarios that can represent everyday situated interactions (Parsons et al., 2006).

However, the view of modeling ASC in terms of deficits is open criticism as it overlooks the strengths or neutral differences that can also be associated with autism (Dinishak, 2016; Robertson, 2010). Consideration of ASC through this holistic lens provides new avenues of consideration for the design of VR solutions tailored towards social skill development. A need has been highlighted, for example, to shift the focus of research onto modeling real life challenges (Robertson, 2010) and this requires a holistic understanding of individual learners and their needs. This is true both in the design of suitable solutions but also in the real-time monitoring of the impact of these solutions.

This paper, therefore, aims to review current research through this lens of a "non-deficit" model of ASC and provide suggestions for VR solution designs. We explore how we can gain a more holistic understanding of target users and feed this into real-time monitoring aiming to provide effective feedback of the users' state. To this end, machine learning can potentially provide a powerful means of monitoring the user in real-time to assess their affective state. However, such approaches must be considered carefully to avoid also feeding into a deficit view of the ASC learner, that there is a desired state they should be in.

This paper therefore has the following research questions:

1. How is VR currently utilized and to what extent is it influenced by a deficit view of ASC?
2. What role can VR solutions play in providing opportunities for social skill development when taking a non-deficit view of ASC?
3. What role can machine learning play in offering a meaningful and holistic understanding of ASC learners?

The remainder of this paper is structured as follows: first, a review of the current use of VEs and VR in ASC research with a view to defining what problems are being tackled and how, secondly, a summary of the field that highlights the potential gaps in work when viewed through a non-deficit view of ASC, thirdly, a review of the role machine learning can play in informing a holistic understanding of the user, finally, conclusions and recommendations are made from the point of view of the position taken in this paper.

2 Research on the Use of VR with ASC Learners

This section aims to outline why VR can play an important role in social skill development in learners with ASC and examine how the technology is currently utilized in cutting-edge research. We focus on the design of VR systems and seek to unify the language used in this field study in order to clarify the terms used.

2.1 Why VR?

As noted, virtual environments provide opportunity to engage with safe scenarios for experiencing and practicing social interaction. VR builds on this and can provide additional benefits because it can offer authentic real-world situations modelled in controlled environments (Parsons and Cobb, 2010). The concepts of presence and embodiment promoted by authentic VR simulations make learning experiential and potentially more powerful (Slater, 2017; Wallace, Parsons and Bailey, 2017). When discussing VR, the field does suffer from a lack of formalization with regard to terms used. Studies may use the term VR but refer to "desktop" VR (Ke et al., 2020), the use of CAVE systems (Yuan and Ip, 2018) or the use of general VEs (Ghanouni et al., 2019). Although there may be some crossover in the design of such systems, VR where a Head Mounted Display (HMD) is used, will have its own unique challenges in relation to achieving that sense presence through immersion that makes is a powerful tool for experiential learning. As such, this paper refers to VR as that which requires an HMD to stereoscopically view the environment being experienced and recommends this as a formal definition in future work.

VR platforms utilize an array of tracking points that enable their functionality. Tracking points such as gaze direction, posture and postural stability, accelerometer data etc. where each of these provide some insight into the user and their state of interaction. Additional data points can also easily be added through non-invasive techniques; for example, measures of electro-dermal activity (EDA), heart rate or EEG data. When combined together in a multi-modal data fusion approach, there is the potential to gain a holistic view of a user's affective state using machine learning approaches. Affective computing has seen application within VR systems. For example, it is seen as an attractive prospect for those studying emotion due to VRs potential to provide controlled environments that have a high degree of presence (Marin-Morales et al., 2020).

As such, VR and affective computing solutions would seem ideally suited to tackling ASC by both aiding those with ASC and furthering understanding of the individual needs during learning. We therefore seek to examine what work has been done in this area and how is the issue of deficit dealt with in the design of VR and associated research studies?

2.2 Towards a non-deficit model

Latest developments in VR and ASC education calls for a user centered approach to the design and evaluation of applications in order to ensure the authenticity of VRs interventions in autism (Parsons, 2016) and the empowerment of ASC learners (Parsons et al, 2020; Robertson, 2010).

The non-deficit view of learning ability is underpinned by research on neurodiversity which challenges the myth of the ideal rational person. The concept of neurodiversity commonly refers to perceived variations seen in cognitive, affectual, and sensory functioning differing from the majority of the general population, usually known as the 'neurotypical' population (Rosqvist, Stenning and Chown 2020). While defining the scoping of neurodiversity is currently an ongoing empirical investigation among scholars in the field, this concept strongly challenges the view and practices that put learners with ASC as persons with defects/disorders. This deficit model of learning ability is underpinned by the idea of persons with disorders that impact on their social engagement and flourishment. Interventions which aim to fix their disorders thus use approaches that promote how to behave according to a social norm.

Rather than suggesting there is a 'normal' way to think and act in which learners with ASC need to meet, the non-deficit view considers persons with a wide range of cognitive, affective and sensory abilities and behaviors. Through this consideration, individuals should have choice and control over their own authentic lives. It acknowledges that there are areas that learners with ASC want to learn and develop in social engagement, but crucially it recognizes the strengths and neutral differences of ASC learners in social situations.

2.3 Current VR Research and ASC

VR then, can provide a means to explore interaction that is not based on deficits and can provide a holistic understanding of learners through the sandbox experiences that can be created. The creation of sandbox environments allow users to explore situations on their own terms and learn through a process of careful self-reflection. The following review aims to examine research through this lens and highlight areas for opportunity.

VR has been demonstrated to have positive outcomes when used to tackle developmental concerns in learners with ASC as shown in a systematic review of the field (Mesa-Gresa et al., 2018). From this review, social skill development was the most common topic of research being addressed as this is the "hallmark deficit" for learners with ASC. This concurs with a separate review that also demonstrates the effectiveness of VR for working within the field of ASC (Bozgeyilkli et al., 2017). This work further summarized the field in terms of a set of design guidelines for creating VR systems. These guidelines, while useful, focus on accessibility of VR systems rather than how they can be designed to further understanding of individuals from a non-deficit perspective.

Didehbani et al. (2016) note that that work within the field of ASC and VR research tend to focus on designs that are of scripted interactions where participants communicate passively with the scenarios presented. Halabi et al., (2017) for example, outline a study in which scripted scenarios are used to develop communicated skills in learners with ASC. A scenario may require a learner to correctly greet their tutor within the virtual setting after having observed this interaction taking place. The use of speech recognition determines when a response has occurred and if it has taken place at the correct turn in the conversation. While this utilizes the technology well it also exemplifies the deficit-oriented approach to ASC and VR research; that there is a correct way of going about interactions that must be trained. This no doubt serves an important purpose, however, there is scope for the field to also provide approaches that move beyond such definitive outcomes based on "correct" behavior. Such studies do not allow generalization of learning to untrained situations or to real life (Parsons and Cobb, 2011)

VR can be used to model very specific environments that offer a safe means of performing social interactions, such as a shop floor for practicing conversations for shopping (Stewart Rosenfeld et al., 2019). This study also utilized speech recognition to detect several “hot” words such that the conversation transitioned at the correct time. Findings suggest that such applications provide a means of practicing communication that is free from negative consequences and learners can improve their social skill through repeated use. While this is perhaps not as scripted as previously discussed it does assume that there is a specific conversation to be followed and certain words need to be said for progression through the scenario. This may, in part, be a result of technological limitations; having a free-flowing interaction with an AI driven avatar may not be feasible but what of alternate designs?

Some flexibility can be added into scenarios through the addition of third party-controlled characters. Such designs can include a confederate whose role it is to coach the learner through more open and dynamic interactions that can be altered based on the needs of the participants (e.g., Didehbani et al., 2016). A similar approach was taken by Ke et al. (2020), where researchers controlled virtual characters through voice morphing software. Rather than requiring a specific outcome, general social skills were measured (e.g., initiation, negotiation etc.) demonstrating the flexibility offered through less prescriptive approaches to scenarios. However, this study utilized “desktop VR” which, as mentioned, holds different design challenges to those that may use an HMD. Full VR using an HMD was utilized in a similar study by Herrero et al. (2020) where a researcher controlled the interactable avatars by selecting from a series of pre-defined responses ranging from positive to negative. Such approaches are well utilized in VR research outside of ASC interventions. A “wizard of oz” approach where a virtual agent can be driven by an external confederate is common in work rooted in social psychology (Pan et al., 2015; Pan et al., 2016). Such VR designs avoid a potential model where specific responses are required in scripted scenarios thus avoiding a deficit view where there is a “right” way of going about social interaction. Furthermore, such designs open up the possibility for furthering work in learning and education as the VR tool can provide a mediated learning experience with educators playing a key role in the interaction. This provides opportunity for the confederate (e.g., a teacher) who controls virtual characters to also benefit from the interaction. As they are involved in the mediated learning process, they in turn can potentially learn more about their students through the mediated VR environment. Such applications of VR where a more holistic approach to teaching and learning is possible, appear underexplored. Few studies, if any, have explored the implications of such a tool in terms of the dynamics this would create between educators and learners nor attempted to define formal pedagogies for future work.

There is a need, then, for VR pedagogical frameworks that has the experiential learning and immersion offered by VR at its core (Fowler, 2015) that enhance and improve learners’ social interaction through a more holistic understanding of individual learners. This understanding can be conveyed to the educator through participation in the interactions such that together these learner-teacher dyads develop. It is important to consider how the pedagogy and learning tools allow learners to develop their self-determination, awareness and skills such as decision-making, self-advocacy, reflective problem-solving (Carter et al, 2009) while developing their social interaction competencies.

3 Opportunities

There is a need for a more thorough consideration of designs of VR based interventions where ASC is concerned. Designs tend to fall into one of two camps: scripted scenarios that expect certain responses, and more flexible scenarios made possible by the addition of external control by a suitable confederate. The former tends to derive designs from a deficit-model view of ASC. Where there is a correct response or behavior that should be exhibited by the participant and the aim of the scenario is to train this correct response. As ASC exists on a spectrum, scripted approaches may address only a narrow part of that spectrum. Such approaches have their place, and it is not the purpose of this paper to reject their importance. However, non-deficit based approaches should also be explored as these have the potential to empower ASC learners by not focusing on their apparent weaknesses. For example, rather than assuming a specific learning outcome, engagement with the VR system may demonstrate behaviors or strengths that were previously unknown to both the learner and teacher. Sandbox like systems with flexible designs that adapt to individual needs allow the learner to explore scenarios and outcomes for themselves and the manner of that exploration potentially informative for educators.

The latter design of VR solutions (illustrated in figure 1) has the potential to provide this while also offering flexible approaches that can cater to the needs of learners across the ASC spectrum. As scenarios are not necessarily scripted (it is up to the confederate), they can be more individually nuanced and tailored to the needs of the learner. Rather than being hamstrung by technology, the design may only be limited by the number of pre-recorded responses and animations that the confederate has to choose from. It would be a significant design challenge to decide on what pre-recorded responses are needed, how many, and how much variation should be catered for. Future work is needed that creates design frameworks to assist in this process. The addition of a suitable confederate can provide a VR mediated learning experience. The interactions of which can further understanding of individual learners by virtue of a teacher (for example) guiding the scenario where they can in turn learn about their charges through the mediated interactions.

Hence, VR as an intervention for learning social skills for those with ASC can offer more than social skills training with defined experience outcomes. It can also broaden understanding of individuals both for themselves and educators through the non-deficit view of thinking. While VR based interventions could also be designed that are intended to further the research field of ASC from medical, psychological and social standpoints.

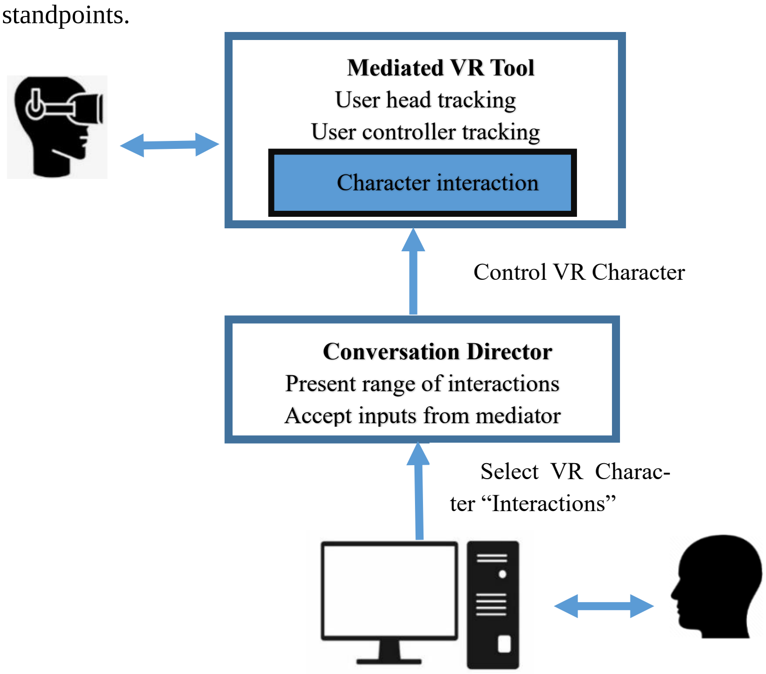

Fig. 1. Architecture of a Mediated VR learning tool

Furthermore, through interaction with VR systems, a wide range of sensory input and modalities are utilized. These data points may be used to create a picture of the experience within VR and therefore raises the question of how these can be integrated into providing the holistic understanding of learners discussed in this paper. The following section reviews the ways in which such techniques could be implemented into VR based interventions for social skill development for ASC learners.

4 Leveraging Machine Learning

While AI could be utilized within scenarios themselves, for example driving interactions in the form of chatbots (Torous et al., 2021), there is significant potential in capturing information about the user and their affective state. The latest VR set-ups provide opportunity to capture a range of behavioral and performance data (Zhang et al., 2018). This can include gaze direction, posture, tracking data etc. Each of this in isolation may be of interest to an educator while observing interaction within a scenario. Gaze direction, for example, is often an important metric of social interaction particularly for learners with ASC and has been used in VR oriented studies in past work (Lahiri, Bekele, Dohrmann, Warren and Sarkar, 2012). While this may be from a deficit perspective, that there is not enough or the right amount of eye-contact, in combination with other data points a more complete picture of the user is possible. The use of affective computing in VR is not new and it has been used to modify the parameters of a scenario in real-time. For example, a VR driving simulator for those with ASC modified the difficulty based on the affective state of individuals during interaction (Bian et al., 2013).

Within the field of personalized education, outside of VR, affective computing has been utilized to assess learner "state". Techniques utilizing affective computing have been used within special education to determine levels of engagement with learning material (Standen et al., 2020). When deployed within a classroom setting, such multi-modal data fusion techniques provide an insight into the learning process of students (Taheri et al., 2020). Where students with individual needs are concerned, this affords educators an important opportunity to learn more about their students which can often be difficult to observe in those with ASC. Utilization of such approaches within the field of VR warrants further exploration, particularly given the range of data points on offer through VR hardware and additional non-invasive sensors such as, eye-gaze, posture analysis, electro-dermal activity, heart rate. This multimodal data fusion approach can utilize predictive AI to provide the mediator with information about their learner's affective state in real-time. What this information might be is an open question from this paper and further research is needed to determine how machine learning approaches can be used to further this understanding using the described non-deficit ways of viewing ASC.

Hence, when using VR through a non-deficit perspective as a mediated learning tool alongside real-time feedback on affective state, there is the potential to create new avenues of understanding ASC learners based on a holistic view of the individual.

5 Conclusions and Recommendations for Further Work

This position paper has outlined the case for considering methods of deploying VR based interventions utilizing a non-deficit based approach to design. From RQ1, it is noted that when taking a deficit based view of learners the focus of interventions is on training a "correct" behavior. While this has an important role to play it should also be augmented with approaches that empower learners on paths to self-discovery, highlighting their strengths and neutral differences. With regard to RQ2, such non-deficit approaches can offer this and by doing so further the understanding of learners for both themselves and their educators where said strengths and neutral difference may previously have been difficult to ascertain.

The example architecture illustrated in figure 1 provides an overarching view of a broader VR design. However, consideration should also be made to the design of the scenarios deployed. Studies cited in this paper focused on areas which are common to the learner, their school, a shop etc. As Parson et al. (2016) noted, such scenarios should be authentic to the learner in order to be relatable. This poses further research questions when considering the spectrum on which ASC exists and how to capture that authenticity for learners across the spectrum while maintaining the flexibility of the systems proposed in this position paper. Furthermore, past work has done well to outline accessibility-based design requirements (Bozgeyikli et al., 2017), however, there remains VR specific research questions dealing with the impact of design on experiential learning. For example, what role does graphical fidelity play in the systems discussed in this paper? What of the design of characters? It is known, for example, that those with ASC engage more with non-anthropomorphic entities such as robots (Hughes-Roberts et al., 2019). Future work should also consider the design and fidelity of character driven experience and examine impact of different character designs. Ultimately, design methodologies, heuristics and broad guidelines are needed across the field of VR to aid in the creation of simulations that are impactful for their target users. In order to complete this holistic understanding of learners (RQ3), there is opportunity to leverage machine learning in order to provide real-time information of their affective state during interaction.

This paper has provided a review of some seminal work. However, further work should include a full systematic review that examines the use of VR and machine learning as interventions in ASC social skill development from the perspectives described here. This review is needed to formally define the terms the field utilizes, categorize VR designs in relation to ASC learning, determine designs based on the two perspectives and formalize design guidelines for non-deficit approaches to creating VR interventions. Outcomes from this will provide researchers and educators the ability to choose from a set of interventions that are suitable to the needs of their target user group.

This paper has set out the case for taking non-deficit based approaches to VR design that leverage machine learning. By doing so, applications can be created that provide opportunities for self-discovery that consider the strengths and neutral differences as well as potential areas for development learners with ASC may have. Furthermore, this process of self-discovery is informative for educators and researchers also who will be able to gain a more holistic understanding of their students/participants.

References

1. Bian, D., Wade, J.W., Zhang, L., Bekele, E., Swanson, A., Crittendon, J.A., Sarkar, M., Warren, Z. and Sarkar, N., 2013, July. A novel virtual reality driving environment for autism intervention. *In International Conference on Universal Access in Human-Computer Interaction* (pp. 474-483). Springer, Berlin, Heidelberg.
2. Bölte, S., 2014. Is autism curable?. *Developmental Medicine & Child Neurology*, 56(10), pp.927-931.
3. Bozgeyikli, L., Raij, A., Katkoori, S. and Alqasemi, R., 2017. A survey on virtual reality for individuals with autism spectrum disorder: design considerations. *IEEE Transactions on Learning Technologies*, *11*(2), pp.133-151.
4. Carter, E. W., Owens, L., Trainor, A. A., Sun, Y., Swedeen, B. (2009). Self-determination skills and opportunities of adolescents with severe intellectual and developmental Disabilities. *American Journal on Intellectual and Developmental Disabilities*, 114, 179–192. doi:10.1352/1944-7558-114.3.179
5. Didehbani, N., Allen, T., Kandalaft, M., Krawczyk, D. and Chapman, S., 2016. Virtual reality social cognition training for children with high functioning autism. *Computers in human behavior*, *62*, pp.703-711.
6. Dinishak, J. 2016. 'The Deficit View and Its Critics'. Disability Studies Quarterly, 36 (4), ISSN: 2159-8371 (Online); 1041-5718 (Print).
7. Fowler, C., 2015. Virtual reality and learning: Where is the pedagogy?. *British journal of educational technology*, 46(2), pp.412-422.
8. Ghanouni, P., Jarus, T., Zwicker, J.G., Lucyshyn, J., Mow, K. and Ledingham, A., 2019. Social stories for children with autism spectrum disorder: Validating the content of a virtual reality program. *Journal of autism and developmental disorders*, *49*(2), pp.660-668.

9. Halabi, O., El-Seoud, S.A., Alja'am, J.M., Alpona, H., Al-Hemadi, M. and Al-Hassan, D., 2017. Design of Immersive Virtual Reality System to Improve Communication Skills in Individuals with Autism. *International Journal of Emerging Technologies in Learning*, *12*(5).
10. Herrero, J.F. and Lorenzo, G., 2020. An immersive virtual reality educational intervention on people with autism spectrum disorders (ASD) for the development of communication skills and problem solving. *Education and Information Technologies*, 25(3), pp.1689-1722.
11. Hughes-Roberts, T., Brown, D., Standen, P., Desideri, L., Negrini, M., Rouame, A., Malavasi, M., Wager, G. and Hasson, C., 2019. Examining engagement and achievement in learners with individual needs through robotic-based teaching sessions. *British journal of educational technology*, 50(5), pp.2736-2750.
12. Ke, F., Moon, J. and Sokolikj, Z., 2020. Virtual reality–based social skills training for children with autism spectrum disorder. *Journal of Special Education Technology*, p.0162643420945603.
13. Lahiri, U., Bekele, E., Dohrmann, E., Warren, Z. and Sarkar, N., 2012. Design of a virtual reality based adaptive response technology for children with autism. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 21(1), pp.55-64.
14. Marín-Morales, J., Higuera-Trujillo, J.L., Greco, A., Guixeres, J., Llinares, C., Scilingo, E.P., Alcañiz, M. and Valenza, G., 2018. Affective computing in virtual reality: emotion recognition from brain and heartbeat dynamics using wearable sensors. *Scientific reports*, *8*(1), pp.1-15.
15. Mesa-Gresa, P., Gil-Gómez, H., Lozano-Quilis, J.A. and Gil-Gómez, J.A., 2018. Effectiveness of virtual reality for children and adolescents with autism spectrum disorder: an evidence-based systematic review. *Sensors*, *18*(8), p.2486.
16. Mitchell, P., Parsons, S. and Leonard, A., 2007. Using virtual environments for teaching social understanding to 6 adolescents with autistic spectrum disorders. *Journal of autism and developmental disorders*, 37(3), pp.589-600.
17. Pan, X., Gillies, M. and Slater, M., 2015. Virtual character personality influences participant attitudes and behavior–an interview with a virtual human character about her social anxiety. *Frontiers in Robotics and AI*, *2*, p.1.
18. Pan, X., Slater, M., Beacco, A., Navarro, X., Rivas, A.I.B., Swapp, D., Hale, J., Forbes, P.A.G., Denvir, C., Hamilton, A.F.D.C. and Delacroix, S., 2016. The responses of medical general practitioners to unreasonable patient demand for antibiotics-a study of medical ethics using immersive virtual reality. *PloS one*, *11*(2).
19. Parsons, S. 2016. “Authenticity in Virtual Reality for assessment intervention in autism: A conceptual review”. *Educational Research Review*, 19, pp. 138-157.
20. Parsons, S. and Cobb, S., 2011. State-of-the-art of virtual reality technologies for children on the autism spectrum. *European Journal of Special Needs Education*, 26(3), pp.355-366.
21. Parsons, S., Leonard, A. and Mitchell, P., 2006. Virtual environments for social skills training: comments from two adolescents with autistic spectrum disorder. Computers & *Education*, 47(2), pp.186-206.
22. Parsons, S., Yuill, N., Good, J. and Brosnan, M., 2020. “Whose agenda? Who knows best? Whose voices?”: Co-creating a technology research roadmap with autism stakeholders. Disability & Society, 35 (2), pp. 201-234.
23. Rosqvist, H. B., Stenning, A. and Chown, N. (2020). Introduction. In Stenning, A., Rosqvist, H. B., and Chown, N. (ed.) (2020). Neurodiversity Studies. Taylor and Francis.

24. Robertson, S.M. 2010. Neurodiversity, Quality of Life, and Autistic Adults: Shifting Research and Professional Focuses onto Real Life Challenges. *Disability Studies Quarterly* 30(1).
25. Standen, P.J., Brown, D.J., Taheri, M., Galvez Trigo, M.J., Boulton, H., Burton, A., Hallewell, M.J., Lathe, J.G., Shopland, N., Blanco Gonzalez, M.A. and Kwiatkowska, G.M., 2020. An evaluation of an adaptive learning system based on multimodal affect recognition for learners with intellectual disabilities. *British Journal of Educational Technology*.
26. Stewart Rosenfield, N., Lamkin, K., Re, J., Day, K., Boyd, L. and Linstead, E., 2019. A virtual reality system for practicing conversation skills for children with autism. *Multimodal Technologies and Interaction*, *3*(2), p.28.
27. Taheri, M.H., Brown, D.J. and Sherkat, N., 2020. Modeling Engagement with Multimodal Multisensor Data: The Continuous Performance Test as an Objective Tool to Track Flow. *International Journal of Computer and Information Engineering*, 14(6), pp.197-208.
28. Torous, J., Bucci, S., Bell, I.H., Kessing, L.V., Faurholt-Jepsen, M., Whelan, P., Carvalho, A.F., Keshavan, M., Linardon, J. and Firth, J., 2021. The growing field of digital psychiatry: current evidence and the future of apps, social media, chatbots, and virtual reality. *World Psychiatry*, 20(3), pp.318-335.
29. Yuan, S.N.V. and Ip, H.H.S., 2018. Using virtual reality to train emotional and social skills in children with autism spectrum disorder. *London journal of primary care*, *10*(4), pp.110-112.
30. Zhang, L., Warren, Z., Swanson, A., Weitlauf, A. and Sarkar, N., 2018. Understanding performance and verbal-communication of children with ASD in a collaborative virtual environment. *Journal of autism and developmental disorders*, 48(8), pp.2779-2789.