Virtual Reality and Wearable Technologies to Support Adaptive Responding of Children and Adolescents With Neurodevelopmental Disorders: A Critical Comment and New Perspectives

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INTRODUCTION

Children and adolescents with neurodevelopmental disorders (NDD) are commonly described as cognitively, socially, emotionally, and communicatively impaired. Usually, attention deficits hyperactivity disorders (ADHD), autism spectrum disorders (ASD), and cerebral palsy (CP) are included. Furthermore, learning difficulties are observed, and academic failures are documented (Rey-Casserly et al., 2019). Additionally, their chronic clinical conditions may represent a relevant burden for both caregivers and families, next to a significant threat for their health and a cost for medical services (Hickie et al., 2019; Kim et al., 2019). Covid-19 pandemic dramatically and suddenly exacerbated their fragile health conditions due to unavailability of medical or rehabilitative services and preventive measures such as quarantine and social distancing (Ehrler et al., 2021; Jaffee, 2021; Masi et al., 2021). In fact, their quality of life may be seriously hampered and both caregivers and families's burden may drastically increase (Dhiman et al., 2020; Townsend, 2020; Farajzadeh et al., 2021; Zimmer et al., 2021). Technology-aided options provide the opportunity to independently administrate and self-regulate useful interventions for both assessment and rehabilitative purposes (Rahman et al., 2020). Beside assistive technology-based programs (Stasolla and Bottiroli, 2020), one may envisage the use of virtual reality setups (VR) and/or wearable technologies (WT) (Vona et al., 2020).

VR offers several advantages as ecological validity, experimental control, and behavioral responses tracking (Yaremych and Persky, 2019). Wearable technologies may be easily transportable and may represent a valid option for monitoring and recovery of an adaptive responding (Gorman et al., 2002). A concise review of the literature available along the last five years (i.e., 2017–2021) was carried out. Ten contributions were critically discussed (i.e., five on VR and five on WT, see **Table 1**). Although ADHD and ASD populations were widely targeted, cerebral palsy and rare genetic diseases were still uninvestigated (Valentine et al., 2020). Moreover, communication, emotional, social skills, and posture were evaluated (Berenguer et al., 2020). Conversely, challenging behaviors, positive occupation (e.g., request and choice capacities), and leisure options were relatively ignored (Airaksinen et al., 2020).

References	Population	Targeted Behaviors	Group	Main Outcomes
Airaksinen et al. (2020)	ASD	Posture	WT	Device effectiveness
Billeci et al. (2018)	ASD	Joint attention	WT	Protocol study
Berenguer et al. (2020)	ASD	Well-being	VR	Technology suitability
Colombini et al. (2021)	ADHD + ASD	Visual interactions	VR	Setup affordability
Dellazizzo et al. (2020)	ADHD + ADHD	Cognitive functioning	VR	Low evidence quality
Di Palma et al. (2017)	ASD	Socio-cognitive tasks	WT	Device efficacy
Gualniera et al. (2021)	RTT	Emotional dysregulation	WT	Technology suitability
Romero-Ayuso et al. (2020)	ADHD + ASD	Self-regulation	VR	Protocol study
Sgandurra et al. (2018)	CP	Motor movements	WT	Protocol study
Wiguna et al. (2020)	ADHD	Executive functions	VR	Setup reliability

Along last decade, evidence-based research on the use of digital tools to promote adaptive skills and communication opportunities in individuals with neurodevelopmental disabilities meaningfully increased (Lussier-Desrochers et al., 2020). An illustrative example is represented by Operto et al. (2020) who emphasized that hat a longer time of exposure to digital tools was related to lower mimic-gestural skills in children from 8–17 months and to lower language skills in children between 18 and 36 months, regardless of age, gender, socio-economic status, content, and modality of use.

A critical comment on the literature available within this framework was detailed and constructively argued. A new home-based cognitive rehabilitation software recently proposed in patients with neurodegenerative diseases and a virtual reality setup as a technological-aided strategy (Bernini et al., 2021; Stasolla et al., 2021) were presented as a perspective solution during Covid-19 pandemic era. Thus, social distancing and quarantine preventive measures forced and confined children and adolescents with NDD in their homes. Professionals and clinicians may remotely supervise and evaluate their patients through telerehabilitation strategies (Caprì et al., 2021; Varela-Aldas et al., 2021).

VIRTUAL REALITY

VR, including augmented reality (AR), recently emerged as crucial means of suitable intervention in different area of public health, namely (a) assessment, (b) diagnosis, (c) recovery, and (d) well-being. With regard to rehabilitative program, VR has been widely used to favorably address NDD such as attention deficits hyperactivity disorders (ADHD) and autism spectrum disorders (ASD). VR ensures individuals with NDD with sensory experiences, computer-mediated in artificial environments, enhancing virtual interactions similarly to the real life. AR, as part of VR, enables an interaction in a physical condition, differently from the artificial context provided by VR. That is, VR usually requires the use of specific headsets, which may not be easily wearable for individuals with NDD. Conversely, AR may be considered as simpler because it refers to smartphones, tablets, and I-PAD, which are more adaptable to the real world (Liu et al., 2017; Mesa-Gresa et al., 2018; Akin and Gokturk, 2019).

Berenguer et al. (2020) systematically reviewed the literature on this specific topic among children and adolescents with ASD and emphasized the effectiveness of AR-based programs to promote and support health, well-being, and quality of life in individuals with ASD. Wiguna et al. (2020) proposed a four-step method as a mixed method research design aimed at combining qualitative and quantitative approaches to reduce bias and collect reliable data. An ADHD-VR digital game diagnostic-tool prototype with a deep learning application for children was successfully developed. Dellazizzo et al. (2020) carried out a meta-analysis and summarized the current state of evidence on VR-based interventions for psychiatric disorders by assessing the quality of feasibility and suitability evidenced by the meta-analysis itself. Results demonstrated that the quality of evidence varied between low and moderate. Lower quality evidence was explained by limited number of randomized controlled trials, lack of follow-up and control groups, the heterogeneity and publication bias.

Romero-Ayuso et al. (2020) assessed a protocol-study to evaluate self-regulation ability in children with NDD (i.e., specifically ADHD and ASD participants were targeted) aged between 6 and 11 years. A randomized controlled trial was conducted based on a non-immersive virtual reality system where virtual objects could be managed by children in a natural way using their hands. Two different groups (i.e., experimental and control groups) were planned. A ten-week program was designed. Dependent measures included self-regulation and the acceptance of the technology. Colombini et al. (2021) generated and examined the LEAP Motion technology. The LEAP Motion controller represented a higher affordable USB capture device capable of detecting and recording, through a virtual reality-based system, natural interactions with digital contents, via an optic tracking of both hand and finger movements. NDD and neurodegenerative diseases (i.e., ADHD, ASD, mild cognitive impairments, and dementia) were targeted.

WEARABLE TECHNOLOGIES

WT represent a basic option and play a primary role in daily life and in the healthcare industry. Covid-19 pandemic suddenly interrupted the healthcare services and negatively affected medical systems. Actually, the provision and diffusion of the vaccine progressively improved our health conditions and social interactions. However, WT have the potential to support and provide safety and assistance to both healthcare professionals and users. For instance, communication with distant partners, real-time remote monitoring, symptoms predictions, assessment,

and recovery objectives may be easily pursued (Lancioni et al., 2020; Aoyagi et al., 2021; Atashzar et al., 2021; Michelin et al., 2021; Ueafuea et al., 2021).

Billeci et al. (2018) evaluated the feasibility of using WT for monitoring and recording of autonomic activity in toddlers with ASD during joint attention stimuli presentation. Twenty ASD toddlers and 20 age- and gender-matched typically developed children were recruited and observed at baseline, and during Joint attention task through non-intrusive chest strap for electrocardiography (ECG). Results showed the feasibility and effectiveness of WT to characterize the autonomic activity in ASD toddlers. Sgandurra et al. (2018) created a new medical device to provide an early, intensive, and customized intervention carried out at home by parents of infants with congenital brain damage but managed remotely by expert clinicians. A new protocol including a sample of infants at high risk of cerebral palsy was proposed through a randomized controlled trial finalized at systematically comparing a technological system to a massage intervention. Forty-two infants were enrolled. An 8-wesek program was planned with three data points, at the baseline, at the end of the intervention, and at two and 18 month-follow-up, respectively.

Di Palma et al. (2017) conducted a study, WT-based, to acquire signals during therapeutic sessions supported by interactive serious games and to correlate the autonomic activity to the engagement of the child during socio-cognitive tasks for an assessment of the intervention effect and for the customization of the therapy. Five ASD-high functioning children aged between 6 and 8 years were recruited. A wearable chest for ECG was used. A longitudinal observation along six months was recorded. Data emphasized the feasibility and the suitability of the device to be applied in clinical settings. Gualniera et al. (2021) used a web-based technology to measure the phenotype and non-invasive WT to evaluate emotional-behavioral autonomic dysregulation (EBAD) through electrodermal activity (EDA) and heart rate variability (HRV) in ten girls with Rett syndrome (RTT), after different pharmacological treatments. Results demonstrated the suitability and the effectiveness of the adopted technology. Airaksinen et al. (2020) described the implementation of an infant WT in 22 infants of seven months of age at risk of ASD and cerebral palsy to monitor their posture and movements. The technology was sensitive to the infants' movements and postures.

DISCUSSION

Data of the reviewed studies on both technological issues (i.e., VR and WT) evidenced the affordability, effectiveness, and suitability of the adopted technologies to ensure children and adolescents with NDD with adaptive skills. Results were largely satisfactory although along the contribution of Dellazizzo et al. (2020) a low evidence quality emerged. Cognitive and executive functions, communication and emotional competences, posture and motor movements were broadly targeted in individuals with ADHD and ASD. Conversely, participants with cerebral palsy and rare

genetic diseases (e.g., Rett syndrome) were still uninvestigated as well as request and choice opportunities, leisure options, and challenging behaviors considered as a primary or a secondary outcome (Lancioni et al., 2007, 2008; Chiapparino et al., 2011; Stasolla et al., 2017; Perilli et al., 2019). The contribution of Colombini et al. (2021) combined technological solutions for NDD, neurodegenerative diseases and acquired brain injuries.

Recently, Stasolla et al. (2021) developed new virtual reality-aided solutions to remotely evaluate and recovery cognitive functioning among individuals with neurodegenerative diseases to promote cognitive empowerment (Fabio et al., 2020). Internet access and leisure option were embedded in patients with neurological disorders. Additionally, Bernini et al. (2021) implemented HomeCoRe (i.e., Home Cognitive Rehabilitative software) as an innovative approach and a valid strategy for home-based cognitive rehabilitation in neurodegenerative impairments in clinical settings, specifically useful in the Covid-19 pandemic era. Finally, Bottiroli et al. (2021) developed *Smart Aging*, a serious game platform that generates a 3D VR environment in which users may perform a set of screening tasks finalized at a broadly and global cognition's evaluation. A suitable extension might be proposed for children and adolescents with NDD. For example, one may envisage an adapted version to evaluate request, choice, and leisure opportunities and internet access. Similarly, challenging behaviors and positive participation could be recorded as primary and secondary outcomes, respectively (Stasolla et al., 2014, 2015). Alternatively, telerehabilitation strategies can be implemented or combined to remotely supervise and recovery individuals with NDD (Iannizzotto et al., 2020).

Despite the encouraging and promising perspectives, some limitations should be claimed. First, the current opinion paper was based only on ten contributions (i.e., including empirical studies, literature reviews, and protocol studies). Second, only VR and WT options were considered. Third, only children and adolescents were targeted. Fourth, only last five years range interval was embedded. In light of the above, further research on the effects of new technologies to promote adaptive skills in children and adolescents with NDD and to reduce both families and caregivers' burden can be considered highly warranted. Both assessment and rehabilitation purposes should be considered. Telemedicine combined with VR can be included as a suitable issue within this framework for individuals with neurological disorders (Matamala-Gomez et al., 2021).

Accordingly, new research perspectives should deal with the following topics: (a) participants, behaviors, and technology extensions, (b) follow-up, maintenance, preference checks, and generalization phases, and (c) social validation procedures involving external raters with a personal or a professional experience (Stasolla et al., 2019).

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

REFERENCES

Airaksinen, M., Räsänen, O., Ilén, E., Häyrinen, T., Kivi, A., Marchi, V., et al. (2020). Automatic posture and movement tracking of infants with wearable movement sensors. *Sci. Rep.* 10:169. doi: 10.1038/s41598-019-56862-5

Akin, N. T. A., and Gokturk, M. (2019). Comparison of theory of mind tests in augmented reality and 2D environments for children with neurodevelopmental disorders. *Adv. Intell. Syst. Comput.* 781, 257–264. doi: 10.1007/978-3-319-94334-3_26

Aoyagi, Y., Inamoto, Y., Shibata, S., Kagaya, H., Otaka, Y., and Saitoh, E. (2021). Clinical manifestation, evaluation, and rehabilitative strategy of dysphagia associated with COVID-19. *Am. J. Phys. Med. Rehabil.* 100, 424–431. doi: 10.1097/PHM.0000000000001735

Atashzar, S. F., Carriere, J., and Tavakoli, M. (2021). Review: how can intelligent robots and smart mechatronic modules facilitate remote assessment, assistance, and rehabilitation for isolated adults with neuro-musculoskeletal conditions? *Front. Robot. AI* 8:610529. doi: 10.3389/frobt.2021.610529

Berenguer, C., Baixauli, I., Gómez, S., Andrés, M. E. P., and De Stasio, S. (2020). Exploring the impact of augmented reality in children and adolescents with autism spectrum disorder: a systematic review. *Int. J. Environ. Res. Public Health* 17, 1–15. doi: 10.3390/ijerph17176143

Bernini, S., Stasolla, F., Panzarasa, S., Quaglini, S., Sinforiani, E., Sandrini, G., et al. (2021). Cognitive telerehabilitation for bOlder adults with neurodegenerative diseases in the COVID-19 era: a perspective study. *Front. Neurol.* 11:623933. doi: 10.3389/fneur.2020.623933

Billeci, L., Tonacci, A., Narzisi, A., Manigrasso, Z., Varanini, M., Fulceri, F., et al. (2018). Heart rate variability during a joint attention task in toddlers with autism spectrum disorders. *Front. Physiol.* 9:467. doi: 10.3389/fphys.2018.00467

Bottiroli, S., Bernini, S., Cavallini, E., Sinforiani, E., Zucchella, C., Pazzi, S., et al. (2021). The smart aging platform for assessing early phases of cognitive impairment in patients with neurodegenerative diseases. *Front. Psychol.* 12:635410. doi: 10.3389/fpsyg.2021.635410

Caprì, T., Nucita, A., Iannizzotto, G., Stasolla, F., Romano, A., Semino, M., et al. (2021). Telerehabilitation for improving adaptive skills of children and young adults with multiple disabilities: a systematic review. *Rev. J. Autism Dev. Disord.* 8, 245–252. doi: 10.1007/s40489-020-00214-x

Chiapparino, C., Stasolla, F., de Pace, C., and Lancioni, G. E. (2011). A touch pad and a scanning keyboard emulator to facilitate writing by a woman with extensive motor disability. *Life Span Disabil.* 14, 45–54.

Colombini, G., Duradoni, M., Carpi, F., Vagnoli, L., and Guazzini, A. (2021). LEAP motion technology and psychology: a mini-review on hand movements sensing for neurodevelopmental and neurocognitive disorders. *Int. J. Environ. Res. Public Health* 18:4006. doi: 10.3390/ijerph18084006

Dellazizzo, L., Potvin, S., Mimosa, L., and Dumais, A. (2020). Evidence on virtual reality-based therapies for psychiatric disorders: meta-review and meta-analyses. *J. Med. Internet Res.* 22:e20889. doi: 10.2196/20889

Dhiman, S., Sahu, P. K., Reed, W. R., Ganesh, G. S., Goyal, R. K., and Jain, S. (2020). Impact of COVID-19 outbreak on mental health and perceived strain among caregivers tending children with special needs. *Res. Dev. Disabil.* 107:103790. doi: 10.1016/j.ridd.2020.103790

Di Palma, S., Tonacci, A., Narzisi, A., Domenici, C., Pioggia, G., Muratori, F., et al. (2017). Monitoring of autonomic response to sociocognitive tasks during treatment in children with autism spectrum disorders by wearable technologies: a feasibility study. *Comput. Biol. Med.* 85, 143–152. doi: 10.1016/j.compbiomed.2016.04.001

Ehrler, M., Werninger, I., Schnider, B., Eichelberger, D. A., Naef, N., Disselhoff, V., et al. (2021). Impact of the COVID-19 pandemic on children with and without risk for neurodevelopmental impairments. *Acta Paediatr. Int. J. Paediatr.* 110, 1281–1288. doi: 10.1111/apa.15775

Fabio, R. A., Gangemi, A., Semino, M., Vignoli, A., Canevini, M. P., Priori, A., et al. (2020). Effects of combined transcranial direct current stimulation with cognitive training in girls with Rett syndrome. *Brain Sci.* 10:276. doi: 10.3390/brainsci10050276

Farajzadeh, A., Dehghanizadeh, M., Maroufizadeh, S., Amini, M., and Shamili, A. (2021). Predictors of mental health among parents of children with cerebral palsy during the COVID-19 pandemic in Iran: a web-based cross-sectional study. *Res. Dev. Disabil.* 112:103890. doi: 10.1016/j.ridd.2021.103890

Gorman, P., Dayle, R., Hood, C., and Rumrell, L. (2002). Effectiveness of the ISAAC cognitive prosthetic system for improving rehabilitation outcomes with neurofunctional impairment. *NeuroRehabilitation* 18, 57–67. doi: 10.3233/NRE-2003-18107

Gualniera, L., Singh, J., Fiori, F., and Santosh, P. (2021). Emotional behavioural and autonomic dysregulation (EBAD) in Rett syndrome—EDA and HRV monitoring using wearable sensor technology. *J. Psychiatr. Res.* 138, 186–193. doi: 10.1016/j.jpsychires.2021.03.052

Hickie, I. B., Scott, E. M., Cross, S. P., Iorfino, F., Davenport, T. A., Guastella, A. J., et al. (2019). Right care, first time: a highly personalised and measurement-based care model to manage youth mental health. *Med. J. Aust.* 211, S3–S46. doi: 10.5694/mja2.50383

Iannizzotto, G., Nucita, A., Fabio, R. A., Caprì, T., and Bello, L. L. (2020). Remote eye-tracking for cognitive telerehabilitation and interactive school tasks in times of COVID-19. *Information (Switzerland)* 11:296. doi: 10.3390/info11060296

Jaffee, S. R. (2021). Editorial: "in our time": has the pandemic changed the way we write and read mental health and neurodevelopmental disorder research reviews? *J. Child Psychol. Psychiatry.* 62, 481–483. doi: 10.1111/jcpp.13424

Kim, S. W., Jeon, H. R., Youk, T., and Kim, J. (2019). The nature of rehabilitation services provided to children with cerebral palsy: a population-based nationwide study. *BMC Health Serv. Res.* 19:279. doi: 10.1186/s12913-019-4111-4

Lancioni, G. E., Belardinelli, M. O., Chiapparino, C., Angelillo, M. T., Stasolla, F., Singh, N. N., et al. (2008). Learning in post-coma persons with profound multiple disabilities: two case evaluations. *J. Dev. Phys. Disabil.* 20, 209–216. doi: 10.1007/s10882-008-9105-9

Lancioni, G. E., Singh, N. N., O'Reilly, M. F., Sigafoos, J., Alberti, G., Chiariello, V., et al. (2020). Extended smartphone-aided program to sustain daily activities, communication and leisure in individuals with intellectual and sensory-motor disabilities. *Res. Dev. Disabil.* 105:103722. doi: 10.1016/j.ridd.2020.103722

Lancioni, G. E., Singh, N. N., O'Reilly, M. F., Sigafoos, J., Chiapparino, C., Stasolla, F., et al. (2007). Enabling a young man with minimal motor behavior to manage independently his leisure television engagement. *Percept. Mot. Skills* 105, 47–54. doi: 10.2466/pms.105.1.47-54

Liu, R., Salisbury, J. P., Vahabzadeh, A., and Sahin, N. T. (2017). Feasibility of an autism-focused augmented reality smartglasses system for social communication and behavioral coaching. *Front. Pediatr.* 5:145. doi: 10.3389/fped.2017.00145

Lussier-Desrochers, D., Dupont, M. -., Lachapelle, Y., Massé, L., Martineau, A., and Pépin-Beauchesne, L. (2020). "Creation process for a technology design model promoting active participation of end users with neurodevelopmental disorders: achievements and pitfalls," in *Universal Access in Human-Computer Interaction: Application and Practice*, eds M. Antona and C. Stephanidis (New York, NY: Springer), 48–57. doi: 10.1007/978-3-030-49108-6_4

Masi, A., Mendoza Diaz, A., Tully, L., Azim, S. I., Woolfenden, S., Efron, D., et al. (2021). Impact of the COVID-19 pandemic on the well-being of children with neurodevelopmental disabilities and their parents. *J. Paediatr. Child Health* 57, 631–636. doi: 10.1111/jpc.15285

Matamala-Gomez, M., Bottiroli, S., Realdon, O., Riva, G., Galvagni, L., Platz, T., et al. (2021). Telemedicine and virtual reality at time of COVID-19 pandemic: an overview for future perspectives in neurorehabilitation. *Front. Neurol.* 12:646902. doi: 10.3389/fneur.2021.646902

Mesa-Gresa, P., Gil-Gómez, H., Lozano-Quilis, J., and Gil-Gómez, J. (2018). Effectiveness of virtual reality for children and adolescents with autism spectrum disorder: an evidence-based systematic review. *Sensors (Switzerland)* 18:2486. doi: 10.3390/s18082486

Michelin, A. M., Korres, G., Ba'ara, S., Assadi, H., Alsuradi, H., Sayegh, R. R., et al. (2021). Face guard: a wearable system to avoid face touching. *Front. Robot. AI* 8:612392. doi: 10.3389/frobt.2021.612392

Operto, F. F., Pastorino, G. M. G., Marciano, J., de Simone, V., Volini, A. P., Olivieri, M., et al. (2020). Digital devices use and language skills in children between 8 and 36 month. *Brain Sci.* 10, 1–13. doi: 10.3390/brainsci10090656

Perilli, V., Stasolla, F., Caffò, A. O., Albano, V., and D'Amico, F. (2019). Microswitch-cluster technology for promoting occupation and reducing hand biting of six adolescents with fragile X syndrome: new evidence and social rating. *J. Dev. Phys. Diasbil.* 31, 115–133. doi: 10.1007/s10882-018-9634-9

Rahman, M. M., Usman, O. L., Muniyandi, R. C., Sahran, S., Mohamed, S., and Razak, R. A. (2020). A review of machine learning methods of feature selection and classification for autism spectrum disorder. *Brain Sci.* 10, 1–23. doi: 10.3390/brainsci10120949

Rey-Casserly, C., McGuinn, L., Lavin, A., LaMonte Askew, G., Baum, R., Berger-Jenkins, E., et al. (2019). School-aged children who are not progressing academically: considerations for pediatricians. *Pediatrics* 144:e20192520. doi: 10.1542/peds.2019-2520

Romero-Ayuso, D., Alcántara-Vázquez, P., Almenara-García, A., Nuñez-Camarero, I., Triviño-Juárez, J. M., Ariza-Vega, P., et al. (2020). Self-regulation in children with neurodevelopmental disorders "SR-MRehab: un colegio emocionante": a protocol study. *Int. J. Environ. Res. Public Health* 17, 1–23. doi: 10.3390/ijerph17124198

Sgandurra, G., Beani, E., Giampietri, M., Rizzi, R., Cioni, G., Cecchi, F., et al. (2018). Early intervention at home in infants with congenital brain lesion with CareToy revised: a RCT protocol. *BMC Pediatr.* 18:295. doi: 10.1186/s12887-018-1264-y

Stasolla, F., and Bottiroli, S. (2020). Fostering daily life skills in young and older adults with neurodegenerative diseases through technological supports. *Int. J. Ambient Comput. Intell.* 11, 1–15. doi: 10.4018/IJACI.2020100101

Stasolla, F., Caffò, A. O., Perilli, V., Boccasini, A., Damiani, R., and D'Amico, F. (2019). Assistive technology for promoting adaptive skills of children with cerebral palsy: ten cases evaluation. *Disabil. Rehabil. Assist. Technol.* 14, 489–502. doi: 10.1080/17483107.2018.1467972

Stasolla, F., Damiani, R., and Caffò, A. O. (2014). Promoting constructive engagement by two boys with autism spectrum disorders and high functioning through behavioral interventions. *Res. Autism Spectr. Disord.* 8, 376–380. doi: 10.1016/j.rasd.2013.12.020

Stasolla, F., Damiani, R., Perilli, V., D'Amico, F., Caffò, A. O., Stella, A., et al. (2015). Computer and microswitch-based programs to improve academic activities by six children with cerebral palsy. *Res. Dev. Disabil.* 45–46, 1–13. doi: 10.1016/j.ridd.2015.07.005

Stasolla, F., Matamala-Gomez, M., Bernini, S., Caffò, A. O., and Bottiroli, S. (2021). Virtual reality as a technological-aided solution to support communication in persons with neurodegenerative diseases and acquired brain injury during COVID-19 pandemic. *Front. Public Health* 8:35426. doi: 10.3389/fpubh.2020.635426

Stasolla, F., Perilli, V., Damiani, R., and Albano, V. (2017). Assistive technology to promote occupation and reduce mouthing by three boys with fragile X syndrome. *Dev. Neurorehabil.* 20, 185–193. doi: 10.3109/17518423.2015.1133724

Townsend, E. (2020). Debate: the impact of school closures and lockdown on mental health in young people. *Child Adolesc. Ment. Health* 25, 265–266. doi: 10.1111/camh.12428

Ueafuea, K., Boonnag, C., Sudhawiyangkul, T., Leelaarporn, P., Gulistan, A., Chen, W., et al. (2021). Potential applications of mobile and wearable devices for psychological support during the COVID-19 pandemic: a review. *IEEE Sens. J.* 21, 7162–7178. doi: 10.1109/JSEN.2020.3046259

Valentine, A. Z., Brown, B. J., Groom, M. J., Young, E., Hollis, C., and Hall, C. L. (2020). A systematic review evaluating the implementation of technologies to assess, monitor and treat neurodevelopmental disorders: a map of the current evidence. *Clin. Psychol. Rev.* 80: 01870. doi: 10.1016/j.cpr.2020.101870

Varela-Aldas, J., Buele, J., Ramos Lorente, P., Garcia-Magarino, I., and Palacios-Navarro, G. (2021). A virtual reality-based cognitive telerehabilitation system for use in the COVID-19 pandemic. *Sustainability* 13:283. doi: 10.3390/su13042183

Vona, F., Silleresi, S., Beccaluva, E., and Garzotto, F. (2020). *Social MatchUP: Collaborative Games in Wearable Virtual Reality for Persons With Neurodevelopmental Disorders.* (Cham: Springer). doi: 10.1007/978-3-030-61814-8_4

Wiguna, T., Wigantara, N. A., Ismail, R. I., Kaligis, F., Minayati, K., Bahana, R., et al. (2020). A four-step method for the development of an ADHD-VR digital game diagnostic tool prototype for children using a DL model. *Front. Psychiatry* 11:829. doi: 10.3389/fpsyt.2020.00829

Yaremych, H. E., and Persky, S. (2019). Tracing physical behavior in virtual reality: a narrative review of applications to social psychology. *J. Exp. Soc. Psychol.* 85:103845. doi: 10.1016/j.jesp.2019.103845

Zimmer, A., Youngblood, A., Adnane, A., Miller, B. J., and Goldsmith, D. R. (2021). Prenatal exposure to viral infection and neuropsychiatric disorders in offspring: a review of the literature and recommendations for the COVID-19 pandemic. *Brain Behav. Immun.* 91, 756–770. doi: 10.1016/j.bbi.2020.10.024