ASSETS: G: Designing Embodied Musical Interaction for Children with Autism

Grazia Ragone

Department of Informatics, School of Engineering & Informatics, University of Sussex, Brighton, United Kingdom

ABSTRACT

Music therapy can help autistic children1 in developing communication, expression, and motor skills. However, children experiencing motor or cognitive difficulties can face challenges playing conventional musical instruments [4]. We designed an interactive musical system, OSMoSIS (Observation of Social Motor Synchrony with an Interactive System), so that, regardless of motor abilities, children can generate sounds by moving in the environment either freely or guided by a facilitator. OSMoSIS plays sounds based on body movements tracked using the Microsoft Kinect motion capture system. Central to the design of OSMoSIS is that it supports observation of Imitation as the repurposing of movements/behaviors observed in other individuals, and Interactional Synchrony (IS), as the synchronization of movements – in time and shape - that arise in social interaction, which may open new avenues for research on therapy for autistic children, by allowing recording and analysis of the therapist and child's movements. From our preliminary testing with 10 autistic children (aged 5 – 11 years old), we observed that our system increases children's engagement and interaction, leading to an increase in children's positive affect and use of social cues such as gaze, facial expression, and body language. We also draw conclusions about the enhancement of those behaviors as indicators of the increase of motivation of autistic children while interacting in the OSMoSIS environment.

CCS CONCEPTS • Human computer interaction (HCI): HCI design and evaluation methods, Interaction paradigms, Interaction devices, HCI theory, concepts and models, Interaction techniques, Interactive systems and tools, Empirical studies in HCI

1 Introduction

Autism Spectrum Conditions (ASCs) are a wide range of neurodevelopmental disorders manifesting with sensory, cognitive, social and communication skills [5]. They are due to a mix of genetic and environmental factors [6]. Beyond this medical definition, autism can be considered as one of a range of variations in functioning, well expressed by the term neurodiversity [7]. Furthermore, recent studies suggest autistic children experience significant motor difficulties, ranging from heightened clumsiness to abnormal motor coordination, postural insecurity, and weak performance measured by standardized testing of motor functioning (fine motor skills: coordination of small muscles, wrist, hands, feet – i.e. fingers with eyes; gross motor skills: movement and coordination of the arms, legs, and other large body parts) [8]. Although motor difference is not defined as a core indicator of ASCs, when present, it may affect ability to engage in learning activities as well as the development of social interaction [9]. Furthermore, observational studies suggest differences in motor skills may be among the first markers of ASCs [10,11,12]. Overall, motor skills are not (yet) a core component of the support provided to autistic children, but there is potential to advance understanding of this area of ASCs and benefit autistic children.

As part of these efforts to better understand motor functioning differences and its impacts on children's lives, autism researchers are investigating interactional synchrony (IS) (also known as motor synchrony), defined as the coordination of movements and behaviors, in time and shape, between two or more interacting people [13]. Zampella and colleagues [14] suggest autistic children showed lower levels of IS than allistic (non-autistic) peers, both with familiar and unfamiliar partners, and that lower IS is correlated with higher symptom severity. Studies suggest that IS enables to explain how differences in motor skills impact other core indicators of autism such as language: motor difficulties lower IS, which impairs partnerships between the child and other in early years through which social interactions usually develop [13,14,15]. Interactional synchrony requires coordinating one's movements and behaviors with those of social partners and it requires additional skills such as social attention,

---

1 We address to children with Autism Spectrum Conditions (ASC) also called Autism Spectrum Disorders (ASD) using the expression "autistic children." Different expressions are in use [1], and there are lively debates regarding the use of person-first or identity-first language. While participants in our study did not express a preference, this study utilizes either, person-first and label-first language to reflect that many self-advocacy groups have recently uttered that the popular person-first language is not respecting their sense of self while many professionals in the field still prefer it [2,3]. There are many debates regarding which one is best practice. We use autistic people or ASCs, which was preferred by a majority of autistic people.

imitation, and turn taking [16,17,18]. Interactional synchrony can be intentional (when the goal of the activity is explicitly defined as synchronization) or spontaneous (occurring without any task instruction) [19]. In this study we are interested in spontaneous synchrony occurring within the interaction between the child and the researcher.

Another aspect we focus on in this study, is direct imitation, which is also affected in autism. It may be associated with the core social communication, affective, and cognitive impairments in autism [20,21]. Autistic children showed lower imitation scores compared to allistic peers. As with IS, imitation interconnects both the social and motor domains, which are the main areas characterizing the autism spectrum. Imitation can also be intentional (as when a child imitates modeled behaviors with an antecedent stimulus eliciting an imitation) or spontaneous (as when a child imitates modeled behaviors without an antecedent stimulus eliciting an imitation) [22]. In the literature [23] we define two kinds of imitative actions; one is made from transitive (with an object) and the other from intransitive actions. In this study we refer to intentional and intransitive imitative actions. We designed an interactive musical system, OSMoSIS (Observation of Social Motor Synchrony with an Interactive System), so that, regardless of motor abilities, children can generate sounds by moving in the environment either freely or guided by a facilitator. In the first evaluation study of OSMoSIS, reported on here, we focus on imitation in association with positive or negative affect of the child while interacting with the researcher, comparing the conditions of OSMoSIS activated with sounds on and OSMoSIS deactivated with sounds off.

Moreover, as autistic children tend to be less likely to seek social approval and to be motivated by pleasurable social interactions [24,25], we suggest scaffolding the imitation and IS might improve the motivation of children in learning context, such as the embedded movement-based intervention with OSMoSIS, as well as to use them as indicators to measure motivation. The study presented here it is part of a doctoral research project which explores how such a system might support the development of children's motivation, imitation, and IS skills. Finally, given the above evidence supporting the interplay between the motor and social domains [10,11,12], further investigations are essential to examine the potential value of motor skills, which IS and imitation play a key role, to improve motor and social skills in autistic children. There is still little evidence on comprehensive intervention that target motor performance and IS. Music therapy, which is concerned with improving motor skills and increasingly proposed to autistic children [26] is a great domain to investigate given these aims.

1.1 Related research

While autistic children enjoy music and have auditory processing skills similar to their allistic peers [27], they can face barriers to musical expression using traditional musical instruments. [28]. This is due to a mix of cognitive and motor difficulties and difficulties in accessing instruments and training [28]. Technology can help overcome motor constraints and enable anyone in creating complex musical sounds [29]. Recent research in Human Computer Interaction (HCI) suggests using touch or gesture interaction is appropriate for children with a range of cognitive and motor difficulties, including autistic children [30,31]. For instance, Soundbeam Imitation Intervention (SII) is an ultrasonic beam, perceived as an invisible keyboard, that plays sounds each time the user moves the body or the fingers [31]. BendableSound [32] use an elastic display encouraging autistic children to be more coordinated when touching a fabric to play sounds.

However, not enough attention was paid to full body interaction or used an artificial intermediary, either a robot or an avatar. Full body interaction, without such intermediary, is important for our goals because it has twofold benefit in fostering social behaviors and promote physical activity which is also associated to positive health outcomes. OSMoSIS would offer more opportunities for autistic children to physically exercise, which is a limitation often encountered in the autism population compared to the counterpart [33]. Another system developed with similar intent was 'Pictogram Room' aiming to teach self-awareness, body schema and postures, communication, and imitation. Unlike the Pictogram Room [34], where the child works through educational activities and games, controlling a virtual avatar with his or her movements, OSMoSIS focuses on the interaction between humans and aims to contributes itself to be a research assessment tool.

HCI researchers [30,34,35] often use the Microsoft Kinect (Kinect V2) [36] motion tracking system, [37] with autistic user as a low-cost motion sensing device, which allow the interaction through gestures without any additional wearable equipment. Our study using OSMoSIS is closer to studies where there is an interactive sonification of the children's spontaneous movements [38]. Also, it can be included in the group of Motion-based touchless games (MBTG). In this study, we are interested in understanding the potential of OSMoSIS, a MBTG system, that instead focuses on the interaction between the child and the researcher without using any avatar. The aim of this study is also to not direct the child's attention on the technological part of OSMoSIS, which 's devices are placed in an unobtrusive angle in the room. Although, we recognize the importance of technology, at the same time we want to stress the attention on the way children interact with other humans instead of avatar and eventually understand new ways to enhance children's interaction.

Moreover, there is still little research which investigated the usability of interactive systems associating music in Motion-based touchless games (MBTG) design, in addressing IS interactional synchrony as well as imitation in autism which play a salient role in motor, communication and social area for the achievement of therapeutic goal. This was quite surprising due to the various studies [39,40,41] documenting the effectiveness of music as a vehicle of interaction, and social and emotional development, without need of verbal communication, which is often not the preferred means of communication for autistic people [42,43].

2 Problem and motivation

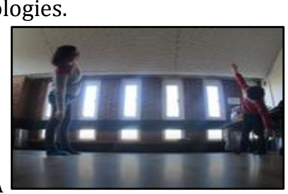
Previous research on supporting autistic children's musical expression, largely focus on individual interactions using screen, avatar or robot [44,45,46,47]. Bringing autism research on IS and imitation to HCI opens new opportunities for research and design, as it reframes music intervention as an interaction between two persons. This enables to: (1) study IS and the potential benefits for autistic children of interventions aiming to develop it; and (2) design systems engaging the whole body in interaction, which might have other qualitative effects such as motivation for physical activity and for participating in interventions. However, the design of systems supporting these goals remain to be investigated. Our system, OSMoSIS, is one step in this direction. Furthermore, as a first step, we evaluate its impact on children's engagement in music therapy. We assume that increased frequency of imitations associated with positive affect, would denote higher interactional synchrony. Specifically, in this paper, we present the design of the system and answer the following research questions:

(RQ1): Does a system generating sounds during activities designed to promote interactional synchrony, increase imitations between autistic children and the activity facilitator? (RQ2): What is the relationship between indications of motivation and instances of interactional synchrony and imitation associated with positive and negative affect?

This research has the potential to improve music therapy practice and deepen our understanding of autism. OSMoSIS can become part of an inter disciplinary approach and even been implemented with VR and other technologies once we demonstrate its efficacy in enhancing children motivation and interaction. This scenario can be the future of the therapy.

3 Uniqueness of the approach

This research approach is novel in terms of design, but also by its origin. The researcher and designer of the system is herself a music therapist. Rooting the research in practice was key to identify these new opportunities for the design of technologies.

A 

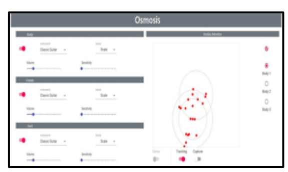
B 

Figure 1: (A) Interaction with OSMoSIS environment and (B) GUI

The OSMoSIS system consists in an immersive technology which uses a bespoke software and Kinect technology with both hardware design and the SDK camera which allow to detect, track, and recognize human motion dynamically in real-time (Figure 1B). OSMoSIS due to Kinect technology, captures the body movements of one or more individuals, into sounds. Currently those sounds are guitar, marimba, woodblock, water drops and flowing water. The data generated by Kinect represents the coordinates (X, Y) of 25 body joints of up to two bodies. OSMoSIS then plays specific notes coming from different traditional and not musical instruments, stored into a sound library, selecting their pitches in proportion to the calculated distances. It also stores anonymized data on the cloud using MongoDB. The processed data is then used to generate sounds before being finally stored for further analysis. OSMoSIS software performs real time geometric calculations to determine the distances between some of those joints to allow the development of a new tool for the evaluation of IS which makes our system unique.

4. Method

4.1 Participants

We used a within-subject study design, with a group of 10 autistic children (2 females), aged 5 to 11 years old, (M age = 8.27; SD =1.42) recruited in England, in the city of Brighton & Hove. Participants were voluntarily enrolled in the study, and all parents consented to the study on behalf of their children. Each child attended to 4 sessions lasting no more than 30 minutes.

4.2 Material

OSMoSIS, presented here, uses the Kinect motion capture feature to support autistic children develop IS and Imitation skills while guided from a facilitator or to creatively compose and express themselves through musical harmonies with their bodies (Figure 1A). Usually, the room where the study was conducted, presented no distractions for children and mono-colored walls. There was only a table where the researcher hid the laptop and in one corner of the room a wireless speaker was placed to allow the experience even more immersive.

4.3 Coding Scheme

We developed a coding scheme for the purpose of systematically observing affective behavior reactions from children while interacting with the researcher when the OSMoSIS software was active and so generating sounds as well as when it was not generating sounds. The researcher sought to identify components of behaviors (imitation, No response, Solitary play and Positive or Negative affect) that might prove useful in understanding how such behaviors function in the context of child-researcher interaction. The researcher proposed the same movements/exercises either with sounds or without sounds following the same pattern. The children's responses were coded as:

Imitation – when the child intentionally mimics the movements/behaviors proposed from the researcher.

No response – when the child ignores or does not respond to the facilitator's proposal.

Solitary Play – when the child is engaged in solitary play.

Positive Affect - instances of explicit behaviors displaying happiness, humor, pleasure.

Negative Affect - instances of explicit behavior displaying anger, annoyance, coldness, frustration or disdain (not confusion or concentration about the task).

Each of the first three codes can be associated to Positive or Negative Affect, which are mutually exclusive.

4.4 Design and procedure

Each session started with a welcome song from the researcher, recalling each child's name, and an alternation of 10 minutes interaction between the child and the facilitator/researcher, with the Sounds On (system activated) and 10 minutes interaction with Sounds Off (system deactivated) and a farewell song at the end. During the study, the researcher acted as a facilitator supporting and guiding children to interact in the augmented environment which was responding in real time to their gestures. The aim of the researcher was to present gestures and simple exercises associated with specific sounds (Figures 2,3,4,5) which would trigger the curiosity in children to imitate or to improvise themselves through free and guided movements to create new melodies and musical patterns.

Figure 2 - Moving arms

Figure 3 - Hopping

Figure 4 - Jumping

Figure 5 – Full body movement

In our current study, we used a third-party observation analysis software (Motion Energy Analysis software - MEA) [48] and Interact [49], along with OSMoSIS to investigate only a few aspects of motor and social skills such as IS and imitation associated to either positive or negative affect. The analysis with MEA for the IS is still ongoing, here we report a partial analysis of the whole study. Also, our research aims to investigate new ways to code the motivation in autistic children which results as, still, under investigated in previous studies. Eventually, we aim to develop a new framework with the support of OSMoSIS which ultimately may be useful to develop a tailored treatment, targeting the motor skills and related domains such as social and communication ones.

5 Results

We report the analysis of our first study with OSMoSIS, which shows that almost all the children enjoyed the experience and showed more instances of imitation and positive affect when the system was activated (Sounds On) in comparison of when the system was no active (Sounds Off). Each child had individual interesting responses to the environment and interesting feedback whenever verbal language was present. We used the term 'Sounds On' to indicate when the OSMoSIS' sounds generator was activated and 'Sounds Off' when it was deactivated. Our hypothesis tests used a Pearson's chi-squared to determine significant relationship between the categorical data to evaluate differences in children's responses when the system was activated (Sounds On) versus when it was not activated (Sounds Off) [X-squared = 51.264; p-value < 0.001]. The frequency of instances of Solitary play was not significantly different between the two conditions. However, the response of solitary play was significantly associated with positive affect when the sounds were on, compared to when the sounds were off.

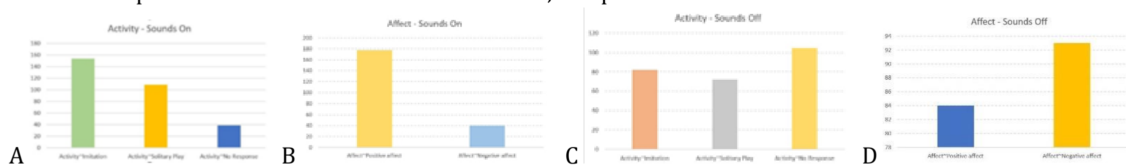


Figure 6 - Data Visualizations of Activity (A,C) and Affect (B,D) with System activated (Sounds On) and deactivated (Sounds Off)

Our analysis (Figure 6) also demonstrated that the system had the capacity to positively impact the interactions of autistic children and suggested there is further potential to support their learning. Our analysis on IS is still ongoing and will be presented soon in another context. Also, based on previous research which measured motivation through the eye contact associated to social stimuli [50], the current study adds to evidence evaluating individual frequency of instances of Positive Affect (where eye contact played a key role) associated to positive engagement response of imitation to the researcher social and motor stimuli.

6 Expected contributions

Through this study we expect to make the following contributions:

- Highlight how our findings can be used to design and evaluate interactive educational systems for children.
- Present insights on how sensing technologies such as OSMoSIS have the capacity to monitor children's affective and behavioral processes and discuss its potential in HCI and CCI research.
- We also aim to further integrate the fields of assistive technology to promote a framework, a guideline for future designers and autistic users.

7 Discussion

Our approach and findings reflect characteristics of previous research [51] of scaffolding strategies, through play-based instructions, used to socially engage autistic children. This work indicates that the stimuli of real-time sounds synchronized with children's movements increased their motivation to follow the researcher's action. This also provides converging evidence that using music during play-based activities increases instances of autistic children's social relating (Positive affect) (Figure 6B). The researcher's alternating sounds corresponding to each specific movement, provided opportunities for children to respond reciprocally with imitative interactions where children were allowed to choose to participate or not participate in each single interaction, without explicit demands to comply by imitating and without extrinsic offers for reinforcement [52]. The adult's model for action paired to several sounds, established the opportunity for the child to choose to imitate or being engaged in solitary play associated with positive affect where the child was experiencing free ways of moving and creating melodies. Also, the investigation of IS in autism is promising to promote both social and motor outcomes. OSMoSIS, as assessment tool as well as intervention, can be a useful tool to aid researchers, music therapists, occupational therapists, teachers, or caregivers to achieve either therapeutic or playful goals with autistic users.

REFERENCES

1. Lorcan Kenny, Caroline Hattersley, Bonnie Molins, Carole Buckley, Carol Povey, and Elizabeth Pellicano. 2015. Which terms should be used to describe autism? Perspectives from the UK autism community. Autism (July 2015), 1362361315588200. DOI: http://dx.doi.org/10.1177/1362361315588200

2. Vivanti, G. (2020). Ask the Editor: What is the Most Appropriate Way to Talk About Individuals with a Diagnosis of Autism? Journal of Autism and Developmental Disorders, 50(2), 691–693. https://doi.org/10.1007/s10803-019-04280-x

3. Jim Sinclair. 2013. Why I dislike “person first” Language. Autonomy, the Critical Journal of Interdisciplinary Autism Studies 1, 2 (Oct. 2013). http://www.larry-arnold.net/Autonomy/index. Php/autonomy/article/view/OP1

4. Magee, W.L., 2006, Electronic technologies in clinical music therapy: a survey of practice and attitudes. Technology and Disability, 18(3), 139-146.

5. American Psychiatric Association. (2013). Diagnostic and Statistical Manual of Mental Disorders. American Psychiatric Publishing

6. Fakhoury Marc. 2015. Autistic spectrum disorders: A review of clinical features, theories and diagnosis. International Journal of Developmental Neuroscience 43 (June 2015), 70–77. DOI:http: //dx.doi.org/10.1016/j.ijdevneu.2015.04.003

7. Singer, Judy (1999). "'Why can't you be normal for once in your life?' From a 'problem with no name' to the emergence of a new category of difference". In Corker, Mairian; French, Sally (eds.). Disability Discourse. McGraw-Hill Education (UK). pp. 59–67. ISBN 9780335202225.

8. Fournier et al., 2010, Motor coordination in autism spectrum disorders: a synthesis and meta-analysis, Journal Autism Developmenytal Disorder.

9. Leonard, H. C., & Hill, E. L. (2014). Review: The impact of motor development on typical and atypical social cognition and language: a systematic review. Child and Adolescent Mental Health, 19(3), 163–170. https://doi.org/10.1111/camh.12055

10. Lloyd, M., MacDonald, M., & Lord, C. (2013). Motor skills of toddlers with autism spectrum disorders. Autism : the international journal of research and practice, 17(2), 133–146. https://doi.org/10.1177/1362361311402230

11. Chawarska, K., Shic, F., Macari, S., Campbell, D. J., Brian, J., Landa, R., Hutman, T., Nelson, C. A., Ozonoff, S., Tager-Flusberg, H., Young, G. S., Zwaigenbaum, L., Cohen, I. L., Charman, T., Messinger, D. S., Klin, A., Johnson, S., & Bryson, S. (2014). 18-month predictors of later outcomes in younger siblings of children with autism spectrum disorder: A baby siblings research consortium study. Journal of the American Academy of Child and Adolescent Psychiatry, 53(12), 1317-1327.e1.

12. Teitelbaum, P., Teitelbaum, O., Nye, J., Fryman, J., Maurer, R.G., 1998, Movement analysis in infancy may be useful for early diagnosis of autism, Proceedings of the National Academy of Sciences of the United States of America, 95, 23, pag. 13982-13987, November 1998.

13. Fitzpatrick, P., Frazier, J.A., Cochran, D.M., Mitchell, T., Coleman, C., and Schmidt, R.C., (2016) ‘Impairments of Social Motor Synchrony Evident in Autism Spectrum Disorder’. Frontiers in Psychology 7, no. 1323 (2016). https://doi.org/10.3389/fpsyg.2016.01323.

14. Zampella, C. J., Csumitta, K. D., Simon, E., & Bennetto, L. (2020). Interactional Synchrony and Its Association with Social and Communication Ability in Children With and Without Autism Spectrum Disorder. Journal of Autism and Developmental Disorders, 50(9), 3195–3206. https://doi.org/10.1007/s10803-020-04412-8

15. Vivanti, G., Trembath, D. and Dissanayake, C., "Mechanisms of imitation impairment in autism spectrum disorder," Journal of Abnormal Child Psychology, vol. 42, no. 8, pp. 1395–1405, 2014.

16. Isenhower, R. W., Marsh, K. L., Richardson, M. J., Helt, M., Schmidt, R. C., and Fein, D., "Rhythmic bimanual coordination is impaired in young children with autism spectrum disorder," Research in Autism Spectrum Disorders, vol. 6, no. 1, pp. 25–31, 2012

17. Steiner, A. M., Gengoux, G. W., Smith, A., & Chawarska, K. (2018). Parent-Child Interaction Synchrony for Infants At-Risk for Autism Spectrum Disorder. Journal of Autism and Developmental Disorders, 48(10), 3562–3572. https://doi.org/10.1007/s10803-018-3624-8Berger, N. I., and Ingersoll, B., "An exploration of imitation recognition in young children with autism spectrum disorders," Autism Research, vol. 6, no. 5, pp. 411–416, 2013

18. Berger, N. I., and Ingersoll, B., "An exploration of imitation recognition in young children with autism spectrum disorders," Autism Research, vol. 6, no. 5, pp. 411–416, 2013

19. McNaughton, K. A., & Redcay, E. (2020). Interpersonal Synchrony in Autism. Current Psychiatry Reports, 22(3), 12. https://doi.org/10.1007/s11920-020-1135-8

20. Meltzoff, A.N., and Gopnik, A., "The role of imitation in understanding persons and developing a theory of mind," in Understanding Other Minds: Perspectives from Autism, pp. 335–366, Oxford University Press, Oxford, UK, 1993.

21. Rogers, S.J., and Pennington, B. F. "A theoretical approach to the deficits in infantile autism," Development and Psychopathology, vol. 3, no. 2, pp. 137–162, 1991.

22. Stephens, C. E. (2008). Spontaneous imitation by children with autism during a repetitive musical play routine. Autism: The International Journal of Research and Practice, 12(6), 645–671. https://doi.org/10.1177/1362361308097117

23. Vivanti, G., Nadig, A., Ozonoff, S., & Rogers, S. J. (2008). What do children with autism attend to during imitation tasks? *Journal of Experimental Child Psychology*, *101*(3), 186–205. https://doi.org/10.1016/j.jecp.2008.04.008

24. Dawson, G., Meltzoff, A.N., Osterling, J., Rinaldi, J. & Brown, E . (1998) 'Children with Autism Fail to Orient to Naturally Occurring Social Stimuli', Journal of Autism and Developmental Disorders 28 (6): 479–85.

25. Dawson, G. & Adams , A. (1984) 'Imitation and Social Responsiveness in Autistic Children', Journal of Abnormal Child Psychology 12 (2): 209–26.

26. James, R., Sigafoos, J., Green, V., Lancioni, G., O'Reilly, M., (2015). Music Therapy for Individuals with Autism Spectrum Disorder: a Systematic Review. Review Journal of Autism and Developmental Disorders. 2, 1, 39 – 54.

27. Bacon, A., Beaman, C. P., & Liu, F. (2020). An Exploratory Study of Imagining Sounds and 'Hearing' Music in Autism. Journal of Autism and Developmental Disorders, 50(4), 1123–1132.

28. Gold, C., Wigram, T., & Elefant, C. (2006). Music therapy for autistic spectrum disorder. Cochrane Database of Systematic Reviews, Issue 2. Art. No.: CD004381. DOI: 10.1002/14651858.CD004381.pub2

29. Srinivasan, S. M., & Bhat, A. N. (2013). A review of "music and movement" therapies for children with autism: Embodied interventions for multisystem development. Frontiers in Integrative Neuroscience, 7. https://doi.org/10.3389/fnint.2013.00022

30. Cibrian, F.L., Vazquez, V., Cardenas, C., Tentori, M., 2016. Designing a Musical Fabric-Based Surface to Encourage Children with Autism to Practice Motor Movements. In Proceeding of the 6th Mexican Conference on Human Computer Interaction, September (2016).

31. Forti, S., Colombo, B., Clark, J., Bonfanti, A., Molteni, S., Crippa, A., Antonietti, A., & Molteni, M. (n.d.). Soundbeam imitation intervention: Training children with autism to imitate meaningless body gestures through music. Advances in Autism.

32. Cibrian, F.L. et al., 2017 BendableSound: An elastic multisensory surface using touch-based interactions to assist children with severe autism during music therapy. Int J Hum-CompStudies. 107, May (2017), 22–37

33. Must, A., Phillips, S. M., Carol, C., & Bandini, L. G. (2015). Barriers to physical activity in children with autism spectrum disorders: Relationship to physical activity and screen time. Journal of Physical Activity & Health, 12(4), 529–534. https://doi.org/10.1123/jpah.2013-0271

34. Herrera, Casas, Sevilla, Rosa, Pardo, Plaza, Jordan, Le Groux, G. (2012). Pictogram Room: Natural Interaction Technologies to Aid in the Development of Children with Autism. ResearchGate.

35. Ragone, G., Good, J., & Howland, K. (2020). OSMoSIS: Interactive sound generation system for children with autism. Proceedings of the 2020 ACM Interaction Design and Children Conference: Extended Abstracts, 151–156. https://doi.org/10.1145/3397617.3397838

36. Microsoft Corporation. Kinect hardware. https://developer.microsoft.com/en-us/windows/kinect/hardware.

37. Hossein H., M., Khademi, M., 2016, A Review on Technical and Clinical Impact of Microsoft Kinect on Physical Therapy and Rehabilitation, Journal of Medical Engineering.

38. Sigrist, R., et al., 2014. Sonification and haptic feedback in addition to visual feedback enhances complex motor task learning. Experimental Brain Research. 233,3 (2014), 909-925.

39. Accordino, R., Comer, R., & Heller, W. B. (2007). Searching for music's potential: A critical examination of research on music therapy with individuals with autism. Research in Autism Spectrum Disorders, 1, 101-115.

40. Whipple, J. (2004). Music in intervention for children and adolescents with autism: A meta-analysis. Journal of Music Therapy, 41, 90-106.

41. Swedberg Yinger, O. (2018). Music Therapy: Research and Evidence-Based Practice. Elsevier. https://doi.org/10.1016/C2016-0-01352-9

42. Molnar-Szakacs, I., and Heaton, P., (2012) 'Music: A Unique Window into the World of Autism'.© 2012 New York Academy of Sciences, no. 1252 (2012): 318–24. https://doi.org/10.1111/j.1749-6632.2012.06465.x.

43. Hoelzley, P.D., (1993). Communication potentiating sounds: Developing channels of communication with autistic children through psychobiological responses to novel sound stimuli. Canadian Journal of Music Therapy 1, 54–76.

44. Grierson, M., & Kiefer, C. (2013). NoiseBear: A wireless malleable multiparametric controller for use in assistive technology contexts | Semantic Scholar. , New York, NY, USA, 2923–2926. Corpus ID: 9179489. https://doi.org/DOI:10.1145/2468356.2479575

45. Villafuerte, L., Markova, M., & Jordà, S. (2012). Acquisition of Social Abilities Through Musical Tangible User Interface: Children with Autism Spectrum Condition and the Reactable. In Conference on Human Factors in Computing Systems—Proceedings. https://doi.org/10.1145/2212776.2212847

46. Peng Y-H, Lin C-W, Mayer NM, Wang M-L. (2014) Using a humanoid robot for music therapy with autistic children. In: 2014 CACS International Automatic Control Conference (CACS 2014) [Internet]. Kaohsiung, Taiwan: IEEE Conference Publication; 2014. Available from: https://ieeexplore.ieee.org/document/7097180

47. Da Silva, M. L., Gonçalves, D., Guerriero, T., & Silva, H. (2012). A Web-based Application to Address Individual Interests of Children with Autism Spectrum Disorders—ScienceDirect. Proceedings of the 4th International Conference on Software Development for Enhancing Accessibility and Fighting Info-exclusion (DSAI 2012) (Special issue). https://doi.org/10.1016/j.procs.2012.10.003

48. Ramseyer, F. T. (2020). Motion energy analysis (MEA): A primer on the assessment of motion from video. Journal of Counseling Psychology, 67(4), 536–549. https://doi.org/10.1037/cou0000407

49. Mangold (2020). INTERACT User Guide. Mangold International GmbH (Ed.) www.mangold-international.com

50. Chevallier, C., Parish-Morris, J., McVey, A., Rump, K. M., Sasson, N. J., Herrington, J. D., & Schultz, R. T. (2015). Measuring social attention and motivation in autism spectrum disorder using eye-tracking: Stimulus type matters. Autism Research, 8(5), 620–628. https://doi.org/10.1002/aur.1479

51. Pierucci, J. M. (2016). Mothers' Scaffolding Techniques Used During Play in Toddlers with Autism Spectrum Disorder. Journal of Developmental and Physical Disabilities, 28(2), 217–235. https://doi.org/10.1007/s10882-015-9459-8

52. McCathren, R. B. (2000). Teacher-Implemented Prelinguistic Communication Intervention. Focus on Autism and Other Developmental Disabilities, 15(1), 21–29. https://doi.org/10.1177/108835760001500103