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TRADITIONAL VERSUS MECHATRONIC TOYS IN CHILDREN WITH AUTISM SPECTRUM DISORDERS

Dariusz Mikołajewski
Head, Department of ICT, Institute of Mechanics and Applied Computer Science, Kazimierz Wielki University, Kopernika 1, 85-001 Bydgoszcz, Poland, e-mail: *darek.mikolajewski@wp.pl*
Piotr Prokopowicz
Assistant Professor, Department of Data Bases and Computational Intelligence, Institute of Mechanics and Applied Computer Science, Kazimierz Wielki University, Kopernika 1, 85-001 Bydgoszcz, Poland, e-mail: *piotrekp@ukw.edu.pl*
Emilia Mikołajewska
Assistant Professor, Department of Physiotherapy, Ludwik Rydygier Collegium Medicum in Bydgoszcz, Nicolaus Copernicus University, Toruń, ul. Jagiellońska 13-15, 85-067 Bydgoszcz, Poland, e-mail: *emiliam@cm.umk.pl*
Grzegorz Marcin Wójcik
Head, Department of Neuroinformatics, Maria Skłodowska-Curie University, ul. Akademicka 9/509, 20-033 Lublin, Poland, e-mail: *gmwojcik@umcs.pl*
Jolanta Masiak
Head, Independent Neurophysiology Unit, Department of Psychiatry, Medical University in Lublin, ul. Głuska 1 (SPSK No 1), 20-439 Lublin, Poland, e-mail: *jolanta.masiak@umlub.pl*

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Abstract: Functional and developmental outcomes in children (both healthy and with developmental disorders) can be significantly improved thanks to use of appropriate toys. There is need for new generation of toys providing development of motor, cognitive, and social skills. There is also need for more objective assessment of their positive influence functional and cognitive achievements of children because current evidence remains incomplete. Mechatronic tools, such as robots and artificial animals, should receive increased attention of scientists and clinicians due to improved performance of children with autism spectrum disorders. Development of novel toy-related technologies can stimulate new approaches applied in the area of diagnosis, intervention and care. This study aims at assessment how mechatronic toys can be better incorporated into therapy of children with autism spectrum disorders - ASD.

1 Introduction

Developmental outcomes in children can be significantly improved thanks to pre-planned application of appropriate toys. Aforementioned toys can be available, low-cost, fun, and functional, they can provide proper sets of stimulation and promote requested child behavior. Toys are wile accepted by infants and children, they cause easier medical examination, moreover toy itself can constitute diagnostic tool. Current milestones in infant and children development allow to assess, plan the therapy, and re-assess e.g. physiological and pathological patterns of movement thanks to subjective observation.

New generations of toys can support objective assessment and development of motor, cognitive, and social skills. True influence of toys to healthy and disturbed development still remains incomplete now. There is need for new theories, devices, concepts of use, and research since current knowledge and experience may constitute weak basement for novel, more efficient intervention strategies. Rehabilitation robots and other therapeutic devices supported by virtual reality (VR) systems are popular way of neurorehabilitation [1], [2].

Toy-oriented changes can include:

- upper limb uses in infants, reflected in hand and join kinematics,
- arm movements associated with toy using (reaching, grasping),
- cognition skills e.g. ability to insert objects into holes,
- searching behavior e.g. for disappearing object/toy or a button to light a set of distant lights or to retrieve the toy,
- imitation for object manipulation,
- creative thinking,
- transferring the toy between children,
- group toy using,
- task sharing (co-operation) during play.
- replication of target actions to achieve action effects
- conflicts concerning sharing an single attractive toy [1], [2].

Toys in the therapy of children with developmental disorders may play various role:

- support diagnosis and therapy through e.g. increased motivation and stimulation,

- make easier child-therapist interaction,
- ease exercises performed with child by therapist/parents/caregivers,
- influence positively to responsiveness during toy play (e.g. music toys),
- improve interaction (eye contact, touch, manipulation, and posture) and reduced playfulness (e.g. in autistic children),
- support toy/object exploration in children with Down syndrome.

Age-dependant individual or group toy-related behaviours can include:

1. 5- to 6-month-old infants: searching for a disappearing toy,
2. 7-month-old infants: pushing a button to get a toy,
3. 10- to 12- month-old infants: imitating object manipulation,
4. toddlers (13- to 36-month-old):

- performing aforementioned activities faster and creatively, with various grasp, variety of objects,
- simple group behaviour: group toy using, imitating/repeating, passing a toy between children, group cooperation during a play,

5. 19-month-old toddlers: replicating action to achieve established effect,
6. toddlers and older children: increased responsiveness to musical toys,
7. older children: fighting over aa attractive toy.

Eclectic/mixed approach to intervention in children with developmental disorders provides:

- use of toys as monitors and sources of stimulation,
- combined methods, techniques and tools (assistive technology, toys, elements of environment, etc.),
- patient-tailored approach [1], [2].

Autism spectrum disorder (ASD) impacts 1 in 68 children in the U.S., with tremendous individual and societal costs [3]. ASD is a complex neuropsychological disorder characterized mainly by:

- qualitative alterations in social interaction and interpersonal communication,
- decreased object recognition,
- atypical motor behaviors, less mature object manipulation, and reduced grasping activity,
- limited or absent speech [4], [5].

Toys are often used in therapy of children with ASD, e.g. social robots are utilized as therapeutic tools in order to enhance social skills and communication [4], [5].

This study aims at assessment how mechatronic toys can be better incorporated into therapy of children with ASD.

2 Review

Six main data bases as well as recent news articles were searched using specified key words. Inclusion criteria consisted of scientific article in electronic or printed media directly studying or reviewing the use of traditional or mechatronic toys in children with ASD. The current literature was critically appraised, and quality of selected articles was assessed and manually filtered for relevance by 2 reviewers.

Intelligent multifunctional toys are the next step toward increased use of toys in the development and therapy of children. Simultaneous monitoring and stimulation of particular skills will optimize achievements accessible for each particular patient, both healthy and with developmental disorder. Moreover, user-friendly supporting devices shaped as toys may be constant element of the environment of dependent children (Table 1, Table 2).

Table 1. Selected robot-related studies in ASD children.

Results	Reference
Difficulties with social interaction: mechanical toy less valuable than communicative or non-communicative person	Vernetti 2017 [6]
Alternative, movement-based, rhythm and robotic interventions influence social communication skills	Srinivasan et al. 2016 [7]
Social attention was greater in the rhythm followed by the robot	Srinivasan et al. 2016 [8]
Robots can facilitate increased verbal interaction and responses to faces of robots	Jung et al. 2016 [9]
Robots can potentially be applied to a large scope of objectives for children with ASD	Huijnen et al. 2016 [10]
Minimalistic artificial environment (toy robot) can be considered as the root of neuronal organization and reorganization with the potential to improve brain activity	Giannopulu et al. 2016 [11]
Person recognition may emerge through imitative experience, intercorporeal mapping, and statistical learning	Boucenna et al. 2016 [12]
Rhythm and robot groups showed improved interpersonal synchrony performance	Srinivasan et al. 2015 [13]
Individuals with ASD process motion rather than emotional signals when facing facial expressions (morphed robotic stimuli)	Han et al. 2015 [14]
Children with ASD may feel more comfortable, and may modify their emotional response, if the robots look like deformed humans	Ueyama 2015 [15]

Robot-mediated Imitation Skill Training Architecture (RISTA) can operate either completely autonomously or in coordination with a human therapist depending on the intervention need.	Zheng et al. 2016 [16]
Children's interaction with a human differed from the interaction with a social robot during a play task	Simut et al. 2016 [17]
Rhythm-based interventions are socially engaging treatment tools to target core impairments in ASD	Srinivasan et al. 2015 [18]
Meter-tall robot (nicknamed ANNIE: Android With Neural Networks, Intellect and Emotions) is useful in the therapy of children with ASD	Frenger 2015 [19]
Interaction between children and Isobot (humanoid robot) improved performance on standardized measures of imitation, planning, and execution of motor behaviors	Laue 2015 [20]
ABI (Penguin for Autism Behavioral Interventions) is a compact humanoid robot taking on an expressive cartoon-like embodiment which can be part of the therapeutic system	Dickstein-Fischer & Fischer 2014 [21]
Novel robotic system capable of dynamic, adaptive, and autonomous interaction during imitation tasks with embedded real-time performance evaluation and feedback	Warren et al. 2015 [22]
Children with ASD are more engaged in the task and they seem to enjoy more the task when interacting with the robot compared with the interaction with the adult	Costescu et al. 2015 [23]
Robot-based intervention resulted in no statistically significant changes in collaborative behaviors of the children with ASD.	Huskens et al. 2015 [24]
As an outcome fo robot-based therapy ASD group showed a significant decrease in social anxiety, although neither group showed a significant increase in social skills	Kaboski et al. 2015 [25]
Novel adaptive robot-mediated interaction technology for facilitating early joint attention skills for children with ASD	Zheng et al. 2013 [26]
Mobile toy robot can be used as a mediator of social stimuli during free, spontaneous game play in order to reduce the impairment of ASD children skills related to social information understanding and interaction	Giannopulu & Pradel 2010 [27]

Table 2. Selected traditional toy-related studies in ASD children.

Results	Reference
Cooperative play toys focus on captivating the interest of ASD children through e.g. reinforcing the sound and light effects to improve the attractiveness of the toys	Tseng et al. 2016 [28]
Importance and utility of examining sex differences in toy use in children with ASD	Harrop et al. 2017 [29]
Toy-based functional communication training	Leon et al. 2013 [30]
Atypical methods of play with toys from the personal collections of children with ASD	McLaren et al. 2013 [31]
Development of visual attention may impact later cognitive outcomes of children with ASD	Sacrey et al. 2013 [32]
Children with AS who exhibited noncompliance when asked to relinquish a preferred toy were exposed sequentially to interventions that included a reduction in response effort, differential reinforcement, and guided compliance – there is need to individualize treatments for compliance	Fischetti et al. 2012 [33]
Experience-dependent learning of feature-based object categories in children with ASD	Fields 2012 [34]
Even 5½-month-old infants demonstrate preferences for 3-dimensional objects (toys) on the basis of affective information depicted in videotaped events	Vaillant-Molina & Bahrick 2012 [35]
Infants later diagnosed with ASD tended to continue looking at a toy during the distress condition despite the salience of social information	Hutman et al. 2012 [36]
A training program designed to teach gaze following used the activation of remote controlled mechanical toys as both prompts and consequences	Klein et al. 2009 [37]
Three different typologies of instruments were designed to assess infants behavior in different perceptual and motor domains	Campolo et al. 2008 [38]

Pairing a vocal sound with a preferred stimulus (e.g., toy) to condition automatic reinforcement	Carroll & Klatt 2008 [39]
Worse executive functioning performance of children with ASD with chronological- and verbal-matched controls in a spatial-reversal task	Coldren & Halloran 2003 [40]
Children with ASD learned to ask questions about hidden objects (closed box with a toy inside)	Williams et al. 2000 [41]
Imitation generalized from reinforced training models to nonreinforced probe models within a response type, but it did not generalize across response types	Young et al. 1994 [42]

3 Discussion

Toy-related play may involve forms from early involving the exploration of objects, early manipulative and relational play, through development of meaningful perceptual representations, to the most advanced development of functional and symbolic play. No doubt early detection and diagnosis of developmental disorders is critical: it enables the implementation of preventive measures and therapy of pathological elements at a very early stage. We should be aware that every day can make a significant difference in further therapy. Effectiveness of the therapy is closely connected with the early and proper diagnosis, patient/parents-therapist relationship (for 24/7 therapy and care purposes), as well as with patient - tailored, advanced methods, techniques and tools applied in a particular case.

Discrepancy between scientific research, current knowledge, and clinical practice within the toy-based therapy can be observed since current research do not cover full spectrum of possible interventions. Robotic system is assessed as well-tolerated by children with ASD, and even may create greater attention than the parent or therapist. Social robots can encourage children with ASD to interact with the robotic tools, stimulate emotional responses, and take the initiative [15]. Also imitation performance can be superior during the robotic interaction [22]. Contexts, both movement-based and socially-based are regarded valuable in promoting motor performance, imitation, and interpersonal synchrony. Mechatronic toys are regarded supplementary way of the therapy thus therapists shouldn't be replaced by robots. Moreover, robots need for so called supervised autonomy [43]. A systematic literature review of the studies on social robotics as a promising method for ASD. Especially children with ASD:

- have a lot of social behaviors toward robots,
- often performed better with a robot-partner rather than a human-partner,
- have, toward robots, behaviors that typically developing children have toward human agents,
- showed reduced repetitive and stereotyped behaviors in the interaction with robots,
- improve spontaneous language [44].

There is still huge number of ethical, social and therapeutic concerns to solve, including children's and parent's expectations about this kind of therapy. Acceptability of this technology is associated with more general human-robot interaction for everyday purposes [43]. Fundamental is regarded ability for robots to convey emotion [45].

Limitation is a lack of detailed schemes describing use of toy (including intelligent toy or robot) in the therapy of infants with developmental disorders. There is many unknown or uncharted applications of toys and associated responses, e.g. robots and artificial animals can cause social interaction requiring interpretation of associated (indirect) social information. From the other hand robot-toys level of control huge, stimuli can follow various pre-planned scenarios, amount and time-span of stimulation can be more precise and individually shaped. Animal robots ("artificial friends") can be as close to the original as possible, but they can meet requirements fulfilled by medical devices.

Another limitation is a few research (especially randomized controlled trials and compartmental studies) concerning application of virtual reality (VR) technologies, computer games, and biofeedback-based devices in pediatric neurorehabilitation. Despite many commercial devices pretend to play role of rehabilitation tools, they need for additional research in clinical pediatric environment. We should check whether age, sex, intelligence quotient of participants affects the outcome of robot-supported therapy [44]. We need more evidences concerning both short-term and long-term results including children in pre-school age and school age. Only better understanding of normal growth and development in healthy and delayed infants and children can provide appropriate stimulation enhancing motor and cognitive skills. Aforementioned knowledge should be also a part of normal preparation of parents and caregivers.

Consciousness concerning ingestions and toy-related injuries is only the basement for safe clinical toy application methodology, including also safe mobility, seating, transfers, etc. in both healthy children and children with developmental disabilities. We should be aware that children with more complicated or severe disorders will require patient-tailored methods, more advanced techniques or tools, carefully re-assessed and modified [1], [2].

From methodological point of view even the most advanced mechatronic toys may be useful for monitoring and measuring behaviours of children with ASD, but cannot be taken as the only determinant. It may play rather role of screening test or supplementary tool. No doubt more advanced clinical tests are needed, e.g. videotaping may be

useful for measurement and analysis of certain behaviours. Diagnosis is individual, despite we know, that weak reactions to stimulus, asymmetrical performance, poor coordination, poor mobility of the upper limbs, varied motor skills and problems in adaptation of posture to the various movements may suppose developing disorders [1], [2].

From the ethical point of view medical knowledge and clinical experience are not enough to assure recovery and respect the children free will and choice. Early identification of developmental problems, proper diagnosis, and communication with paediatric patients with ASD and their parents can be extremely difficult. It may require not only extraordinary abilities of the whole interdisciplinary therapeutic team, but also novel sophisticated tools such as intelligent toys cooperating with the therapist. Despite current concept of child-therapist communication is based on knowledge, experience, and mutual trust, it can be limited by many factors observed in both healthy children and children with developmental disabilities: hunger, thirst, boredom, drowsiness, fear, or even pain, etc. Thus objective and relatively quick assessment of functional achievements can constitute real challenge. New generation of interactive toys can facilitate an easier diagnosis, and further faster development of motor, cognitive, and social skills in young patients with ASD. However, the use of such toys as relatively simple peacemakers is not always proper and enough. Risk are also dehumanization of the health care and a lack of an individual approach to each particular paediatric patient and his/her parents. / caregivers.

Technical limitations concerning imitation of living animals can play significant role. Compartmental study of living dog and a robotic dog in the therapy of children with ASD made by Silva et al. showed, that live dog still has a bigger calming effect on the children with ASD [46]

Therapeutic success is measured by the patients' capacity to return to kindergarten/school, participation in everyday life of their family and community, and finally by the general patient satisfaction. Therapeutic success may be achieved even despite the impossibility of complete recovery.

4 Conclusions

Mechatronic tools, such as robots and artificial animals, should receive increased attention of scientists and clinicians due to improved performance of children with ASD. Development of novel toy-related technologies can stimulate new approaches applied in the area of diagnosis, intervention and care.

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