

Synthesizing and restructuring the conversation around the use of robots in the education and therapy of individuals with Autism Spectrum Disorders

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Introduction

In 2010, the *New York Times* reported that a “handful of laboratories around the world” were developing robots geared towards use as “highly informed instructors that would be effective in... repetitive therapies used to treat developmental problems like autism.”¹ Five years later, *The Guardian* claimed that social robotics “holds the key to early diagnosis and treatment of autism.”² By then, dyads of children with Autism Spectrum Disorders (ASD) and social robots had become the frequent subjects of articles in mainstream media. The degree of human interest inherent in this subject coupled with a growing global fascination with robots makes it unsurprising that this phenomenon entered mainstream media and remained there.

Sensationalist rhetoric aside, researching the role of robots in classrooms and more specifically as tools in the education of children with ASD is interesting and important for three primary reasons. First, and quite simply, developments in education for students with ASD is of the utmost importance. One in sixty-eight children in the United States has ASD.³ A national survey conducted in the Fall of 2011 found that 90.9% of individuals with ASD between the ages of six and twenty-one are enrolled in a public school system in the United States.⁴ It is imperative that they receive the education they require. If robots can be as helpful in this capacity as the aforementioned articles claim, and as various bodies of research have shown them to be, then it is clear that educators and therapists should make use of this new technology.

¹ Carey, Benedict, and John Markoff. "Students, Meet Your New Teacher, Mr. Robot." *The New York Times*. July 10, 2010. Accessed May 02, 2016. http://www.nytimes.com/2010/07/11/science/11robots.html?_r=0.

² Tucker, Eleanor. "How Robots Are Helping Children with Autism." *The Guardian*. February 01, 2015. Accessed May 02, 2016. <http://www.theguardian.com/lifeandstyle/2015/feb/01/how-robots-helping-children-with-autism>.

³ "Interview with Dr. Chris McDougle." Telephone interview by author. April 20, 2016.

⁴ "Fast Facts." National Center for Education Statistics. Accessed May 02, 2016. <https://nces.ed.gov/fastfacts/display.asp?id=59>.

Second, integrating new educational technology into existing public school curriculum and infrastructure is not trivial. It is difficult for a variety of reasons. The new technology must be used in an economical, effective, and enduring way.⁵ To do so, it is necessary to have a rigorously specific idea of how the technology is going to be helpful, how it fits into existing infrastructure, to learn from the experiences of others who have previously adopted it, and to understand a great deal about the technology itself.⁶

Third, a conversation about integrating robots into classrooms fits into a much larger, widely impactful, and often controversial conversation about education technology more broadly. Because the discussion of robots as educational and/or therapeutic agents is still fairly new, now is an opportune time to consider how this technology can best be utilized. Since new technology often emerges and becomes widely used before being properly researched and discussed, this technology often becomes more controversial than perhaps it should, and consequently, is wasted.⁷ Proactive discussion and consideration of the use of robots in the education of children with ASD could, therefore, serve as a model for how to proactively discuss emergent technologies in addition to saving robots from misuse and public schools from wasting valuable funds.

A conversation about the use of robots as tools in public schools' special needs classrooms necessarily implicates a variety of disciplines. As such, this paper will draw upon: (1) academic literature from the fields of robotics, education, and psychology specifically devoted to

⁵ Haduong, Paulina, Zoe Emma Wood, Sandra Cortesi, Leah Plunkett, Dalia Topelson Ritvo, and Urs Gasser. "Student Privacy: The Next Frontier - Emerging & Future Privacy Issues in K-12 Learning Environments." *SSRN Electronic Journal SSRN Journal*, May 20, 2015, 3-7. doi:10.2139/ssrn.2638022.

⁶ Ibid.

⁷ For one compelling example of this, see: Strauss, Valerie. "\$100 Million Gates-funded Student Data Project Ends in Failure." *Washington Post*. April 21, 2014. Accessed May 02, 2016. <https://www.washingtonpost.com/news/answer-sheet/wp/2014/04/21/100-million-gates-funded-student-data-project-ends-in-failure/>.

the development of robots for use in the education of children with Autism Spectrum Disorders, (2) academic literature from the fields of robotics, education, and psychology specifically devoted to testing the effectiveness of these robots, (3) legal writings concerning the education of differently abled individuals, specifically, the *Individuals with Disabilities Education Act*, (4) broad discussion of education technology, drawing from academic publications in the field of education as well as newspaper articles and blog posts, and (5) original interviews with clinicians, educators, and robotics industry professionals.⁸

This paper is organized into four parts. The first will trace the development of robots in the education of individuals with ASD within the academic sphere. The second will do the same within the realm of industry. Together, these sections will demonstrate the fact that disparate strands of research largely distinct from the clinical or educational fields have dictated the development of this robotic technology. A third section will briefly but necessarily explain that robots are viable in the public education system from a legal perspective. Finally, a fourth section will bring together expert voices from the clinical, educational, and industrial fields to explain how and why educational and clinical experts should lead the conversation about the use of educational robots in ASD therapy and education.

⁸ It is important to note that, in this paper, parents are sadly missing from the conversation. Currently, the Topcliffe School in Birmingham, England, which uses two educational robots, is in the process of sending out my questionnaire to parents, but it will not be ready in time for *this* iteration of this paper.

I. *Academic Development*

The application of social robotics to the education and therapy of young people with ASD seems an unlikely discovery, and it was. It ostensibly began with Kirsten Dautenhahn, a researcher in the field of artificial intelligence at the University of Hertfordshire in Hertfordshire, United Kingdom. It follows that her understanding of robots' use in this capacity stemmed from the field of artificial intelligence and not from that of early childhood development.

In a 1995 paper called *Getting to Know Each Other – Artificial Social Intelligence for Autonomous Robots*, Dautenhahn first lays out her argument for the importance of developing artificial *social* intelligence, specifically for autonomous robots.⁹ Social intelligence can be defined in opposition to “technical intelligence,” which by 1995 had long allowed robots to complete discrete tasks specific to one domain.¹⁰ In her argument for the importance of the development of social intelligence, Dautenhahn stipulates that “the scenarios being imagined for ‘real world’ robots... require to a high extent aspects of communications and cooperation between robots and robots and between robots and humans.”¹¹ While there was, by 1995, considerable existent ability to control robots in well-structured environments, there was a considerable dearth of “robots which, due to the complexity of the task and/or the environment, ... show[ed] a certain degree of ‘intelligence’ with respect to flexibility, adaptability, robustness and ‘autonomy.’”¹²

Dautenhahn puts forward two primary reasons for the importance of developing social intelligence for robots. First, “social intelligence is a prerequisite for scenarios in which groups

⁹ Dautenhahn, Kerstin. "Getting to Know Each Other—Artificial Social Intelligence for Autonomous Robots." *Robotics and Autonomous Systems* 16, no. 2-4 (1995): 333-56.

¹⁰ Ibid.

¹¹ Ibid.

¹² Ibid.

of autonomous robots should cooperatively solve a given task or survive as a group.”¹³ Second, “social intelligence is assumed to be an important factor in the development of intelligence and the evolution of the primate species.”¹⁴ Her first reason reflects the needs of a vaguely futuristic world in which robots have been employed to perform tasks collaboratively. The second reason reflects her own, fairly abstract interest in the development of human intelligence and how that could work as a model for the development of social artificial intelligence. Neither reason necessarily has very much at all to do with the education of children with ASD.

In a subsequent paper published in 1997 with the perplexing title *I Could Be You: The Phenomenological Dimension of Social Understanding*, Dautenhahn pushes the development of social intelligence for robots forward. She identifies two elements central to creating social robots: “identification of ‘conspecifics’ [or, proxy species] “as a prerequisite for building up social relationships” and “using imitation as the basis of individual recognition and social learning.”¹⁵ Each of these motivations will become essential to her eventual connection of social robotics to the education of individuals with ASD.

In this 1997 article, Dautenhahn spends a considerable amount of time discussing theories of empathy, embodiment and communication.¹⁶ Her point is that social intelligence in robots should be empathic and experiential.¹⁷ Dautenhahn devotes part of this article to a brief discussion of ASD. She uses her understanding of ASD as a kind of metaphor, or broad case study, for understanding empathy, embodiment, and communication. To use her language, individuals with ASD are “conspecifics.” She explains that people with an ASD generally have

¹³ Dautenhahn, Kerstin. "I Could Be You: The Phenomenological Dimension Of Social Understanding." *Cybernetics and Systems* 28, no. 5 (1997): 417-53.

¹⁴ Ibid.

¹⁵ Ibid.

¹⁶ Embodiment refers to the way in which physicality relates to lived experience, and in turn, to memory and important social understandings.

¹⁷ Dautenhahn, *I Could Be You: The Phenomenological Dimension of Social Understanding* (1997).

different degrees of empathy, embodiment, and communication than those without ASD. At this point she appears primarily interested in physically lived experience, and how those with an ASD relate to and learn from their environments. Her interest in ASD in this paper remains fairly abstract, and her brief exploration into the topic is designed to complicate and bolster her theories of cognition and how they can become manifest in social intelligence for robots. Thus she reaches the hypothesis that “teaching” social intelligence to robots may be in some ways similar to teaching social intelligence to individuals with ASD. This is evidently an uncomfortable and controversial hypothesis, and in light of how Dautenhahn would soon begin to use her social robots, the nature of the hypothesis should be noted. The question of whether it should cast a pessimistic or troublesome light upon the eventual use of robots in the education of young students with ASD is one that I do not know how to answer; I can only say with certainty that it should be understood at least for the sake of a more complete historical narrative.

Finally, in a 1999 paper entitled *Applying Mobile Robot Technology to the Rehabilitation of Autistic Children*, Dautenhahn makes the long-awaited leap.¹⁸ This leap goes largely unexplained, but by way of an explanation, Dautenhahn writes that “the need for repetitive actions and a stable environment provide a strong argument for using robotics in the rehabilitation process of autistic people, and children in particular.”¹⁹ Although understanding of ASD has increased significantly since 1999, and as a result Dautenhahn’s description of ASD is overly reductive, she did manage to create a tool – robots with some degree of artificial social intelligence – that has been shown by her and by many others in the years since 1999 to be

¹⁸ Dautenhahn, Kerstin, and Iain P. Werry. "Applying Mobile Robot Technology to the Rehabilitation of Autistic Children." 1999. Accessed May 2, 2016. https://www.researchgate.net/publication/228592755_Applying_Mobile_Robot_Technology_to_the_Rehabilitation_of_Autistic_Children.

¹⁹ Ibid.

effective to varying degrees in the education of children with ASD. It also marks a major shift in the way in which Dautenhahn considered artificial social intelligence, and robots for that matter. In 1997, individuals with ASD were simply a model for the development of social intelligence in robots. Two years later, robots became pedagogical models for individuals with ASD.

Dautenhahn decided to base her new, pedagogical robotic platform upon the TEACCH method, which “emphasizes the use of a teacher who guides the child’s behavior in such a way that a response is given, and repetition grounds this response so that it becomes natural and part of the ‘normal’ routine.”²⁰

Dautenhahn’s initial goal was to create a robotic platform that provides a child with “a secure environment within certain bounds, leading to a secure environment while still giving enough room for the child to interact and control specific aspects directly.”²¹ This platform would, ideally, “bridge the gap between the unpredictable external world and the internal world” of the student.²²

Ultimately, Dautenhahn identified two central roles that her robot would perform when interacting with children. First, “it must provide a stable environment in which the child feels secure... [there must be] limited environmental changes and so repetitive actions must be used.”²³ Second, “[i]t must also hold the child’s attention and not become boring for the child. It must stretch the child’s existing interactive and communicative abilities.”²⁴

It should be noted that, from the beginning, robots for autism education were built in such a way that bodes well for their eventual use in classrooms. Dautenhahn put forward a platform

²⁰ Ibid.

²¹ Ibid.

²² Ibid.

²³ Ibid.

²⁴ Ibid.

that could be both preprogrammed to perform a series of interactive tasks, as well as be directly manipulated by a teacher/caregiver or a child from moment to moment. This suggests that a teacher could, with one or two of Dautenhahn's robots, interact meaningfully and in an individualized way with multiple students at a time. That is not to say that these robots are, or were ever, meant to replace teachers by any means. Dautenhahn notes that "the aim of this project is not to replace people, simply to use the technology to aid caretakers."²⁵ This should be taken as a guiding principle in this field because, as this paper discusses later, a prevailing concern on the part of parents, educators, and clinical therapists alike is that robots might replace humans in this field for financial reasons. Thus, Dautenhahn conceived of a tool not only for individuals growing up with an ASD, and not only for their parents and guardians. She put forward a tool with the potential to be of great help in classrooms which seek to serve a wide range of differently abled students.

Dautenhahn concluded her 1999 paper with aspirations for future iterations of robots effective in the education of young students with an ASD. She noted that "it would be advantageous if the robot's behavior could adapt over the length of a single session."²⁶ She also vehemently advocated for the development of more minute control over factors such as speed, distance moves, and time between behaviors in order to better accommodate a wide variety of students. Finally, Dautenhahn suggested adding more behaviors to the robot's repertoire in order to keep children from becoming bored, in addition to increased self and environmental awareness on the part of the robot.²⁷

²⁵ Ibid.

²⁶ Ibid.

²⁷ Ibid.

Dautenhahn's research in 1998 and 1999 developed into the AuRoRA (Autonomous Robotic platform as a Remedial tool for children with Autism) Project, which exclusively pursues the development of robots (and software and curriculum for those robots) as personal aids and education technology for children with an ASD.

Most currently, Dautenhahn describes the AuRoRA Project as having the primary goal to “engage children with autism in a variety of ways, helping them to develop and increase their communication and social interaction skills.”²⁸ In keeping with the aforementioned guiding principle, the project's website explains that “humans are the best models for human social behavior, but their social behavior is very subtle, elaborate, and widely unpredictable.” Thus, “the use of a robotic platform is an attempt to bridge the gulf between the stable, predictable and safe environment of a simple toy, and the complex and unpredictable world of human communication and interaction.”²⁹ Dautenhahn describes the project's current methodology as long-term evaluations with small groups of children with autism, presented in case study form.³⁰

Predictably, the technology has come a long way since Dautenhahn's robot, and the topics of publications within the AuRoRA project range widely. Dautenhahn and her team have led explorations into topics such as: *A conversation analytic perspective on interaction between a humanoid robot, a co-present adult and a child with an ASD*; *Using a humanoid robot to elicit body awareness and appropriate physical interaction in children with autism*; and most recently, *Tactile Interactions with a Humanoid Robot – Novel Play Scenario Implementations with Children with Autism*.³¹ Most of the AuRoRA Project's current work revolves around a

²⁸ Dautenhahn, Kerstin, and Ben Robins. "The AuRoRA Project - About." The AuRoRA Project - About. Accessed May 02, 2016. http://homepages.herts.ac.uk/~comqbr/aurora/index.php?option=com_content&view=article&id=18%3Aabout&catid=2&Itemid=102.

²⁹ Ibid.

³⁰ Ibid.

³¹ Ibid.

humanoid called KASPAR, which is their most technically advanced take on a robot equipped to work as an educational agent with a young person with an ASD. While Kaspar has been trialed in schools for research purposes, it is not possible to buy Kaspar.

Dautenhahn's AuRoRA Project represents a single line of research and discovery in this field, and seems to be the first of its kind. Yet, alongside the AuRoRA project are growing numerous robotic platforms all geared toward the education of children with ASDs. They come in many forms: education technology startups, academic institutions, and collaborations between the two. Though some of these platforms draw upon Dautenhan's work, most developed independently.

Hideki Kozima and Hiroyuki Yano, at the Communications Research Laboratory in Kyoto, were seemingly the next predominant developers of robots for ASD education and therapy. Similar to and independent of Dautenhahn, they were initially interested in social intelligence. More specifically, they focused their initial research in this area on facial expressions, and around the time of their transition to ASD-related research, were working towards the creation of a robot that could display various facial expressions and was able to point to objects.

Very shortly after Dautenhahn's launch of the AuRoRA Project, Yano published a paper entitled *Toward the Realization of Situation-Sharing Communications Technology*. The paper's first chapter is called *Research on Communication Mechanism of Embodied Interaction*, and expresses dissatisfaction with the state of communications with robots.³² Yano claims that "to achieve truly 'human-like' communication, a dialogue system should have embodiment... by

³² Yano, Hiroyuki, Yoshi Fujiwara, Satoshi Maekawa, Hideki Kozima, and Jun Yoshimoto. "Toward the Realization of Situation-Sharing Communications Technology: Research on Communication Mechanism of Embodied Interaction." *Journal of National Institute of Information and Communications Technology*, September 1, 2001. Accessed May 2, 2016.

adding embodiments to a communication system, it may be possible to enhance the depth of interaction.”³³

The guiding idea of Yano’s study is to combine developmental psychology with robotics in order to inform the growth of communication in robots. He focuses primarily on finger movement during speech, and “identified and estimated finger motions using surface electromyograms of the forearm. We then applied the results to a computer interface.”³⁴ By capturing these signals, Yano and his team were able to build a system that “allow[s] amputees and handicapped persons to control artificial hands, operate equipment, and use various kinds of computer interfaces.”³⁵ What is important to understand about Yano’s 2001 paper is that he and his team found that embodiment “make[s] it possible for the system to understand physical and psychological situations simultaneously, thereby allowing it to interact effectively with human beings.”³⁶ This finding begins to approach Yano’s research towards the early research of Dautenhahn.

Two years later, Kozima and Yano collaborated on a paper entitled *Can a robot empathize with people?*³⁷ At this point, it is clear that Kozima and Yano had made a connection with Dautenhahn, as her aforementioned article from 1997 is their first citation. Kozima and Yano’s 2004 article “explores the mechanism of empathy from the viewpoint of epigenetic robotics,” and interestingly references childhood ASD in its introduction: “Because they do not have enough access to other people’s mental states, autistic children have difficulty in developing the ability to understand other minds and thus display certain disorders in pragmatic

³³ Ibid.

³⁴ Ibid.

³⁵ Ibid.

³⁶ Ibid.

³⁷ Kozima, Hideki, Cocoro Nakagawa, and Hiroyuki Yano. "Can a Robot Empathize with People?" *Artif Life Robotics Artificial Life and Robotics* 8, no. 1 (2004): 83-88.

communication in daily life.”³⁸ Additionally, the paper’s second and fifth citations are articles specifically about ASD. Ostensibly, Kozima and Yano used existing knowledge of ASD in order to inform their understanding of the development of empathy for the purposes of this paper, much like Dautenhahn controversially did in her discussion of “conspecifics.”

For *Can a robot empathize with people?* Kozima and Yano built Infanoid (an upper-torso humanoid robot) and Keepon (a small, “creature-like” robot) which each have the functions of eye contact and joint attention. According to Kozima and Yano, each of these traits is central to the development of empathy.³⁹ They observe fourteen children and infants interacting with these robots, and draw from these interactions a “model of empathy.”⁴⁰ Ultimately, Kozima and Yano conclude that empathy is important for, most relevantly, imitative learning, which is in turn important for learning language.

Finally, in 2005, Kozima and two colleagues published an article entitled *Interactive Robots for Communication-Care: A Case-Study in Autism Therapy*.⁴¹ The introduction aptly explains that “most researchers working on human-robot interactive communications are motivated to make scientific contribution (for understanding human cognition) and/or engineering contribution (for making interactive robots smarter). When these two motivations form synergy, one could make significant social contribution for making people’s quality of life better and easier.”⁴² This very concisely summarizes the processes by which both Kozima and Yano and Dautenhahn reached the point of developing robotic platforms for use in Autism therapy. Kozima reintroduces Keepon in his 2005 article, and chronicles the interactions of

³⁸ Ibid.

³⁹ Ibid.

⁴⁰ Ibid.

⁴¹ Kozima, H., C. Nakagawa, and Y. Yasuda. "Interactive Robots for Communication-care: A Case-study in Autism Therapy." *IEEE International Workshop on Robot and Human Interactive Communication, 2005.*, 2005. Accessed May 2, 2016.

⁴² Ibid.

Keepon with children with ASD over a time period of a year and a half. He concludes that Keepon, despite its simplicity, has “the potential to stimulate the autistic children’s ‘sense of wonder’, to make them aware that the ‘wonder’ will be shared with others, and to help them engage in interpersonal communications in the real social context.”⁴³

Yano, Kozima, and Dautenhahn embody two essential and independent though overlapping strains of academic research surrounding socially intelligence in robots that developed in turn into robotic platforms for use in therapy for those with an ASD. The similarities between the two, namely the paradigmatic shift from humans as models to robots as models, shed light on the organic way in which this phenomenon came to be.

⁴³ Ibid.

II. *Industry Development*

The next paradigm to consider in the development of educational robots belongs to the industry sphere. This paradigm began both after and mostly separate from academic research on the topic. There is a hugely lucrative and growing industry around educational technology, and the potential of educational robots has not been lost on this industry.⁴⁴ The three most prominent robotics companies creating robots as tools for autism education are Robokind, Aldebaran, and Origami Robotics.

Robokind refers to itself as an “Advanced Social Robotics” company.⁴⁵ It is home to Robots4Autism, which calls itself on its website an academic researched-based project; a “research-based, robot delivered curriculum.”⁴⁶ Over the phone, Robokind’s CEO Fred Margolin explained that his company grew out of Hanson Robotics, a pioneer in robotic facial expressions, where his son was the head engineer.⁴⁷ Hanson was making half-million dollar robots for research purposes. A businessman by education, Margolin did not think that Hanson had “much of a business plan for the future.”⁴⁸ He conceived a concept called “Advanced Social Robotics,” in which “robots with faces was a bridge to create human to machine interaction on an entity to entity basis.”⁴⁹ The idea from the start was to market the robots to schools. In 2011, Margolin and his son formed the company, and immediately began to create expression-capable robots of about three-feet in height.⁵⁰ Around the same time, the media-sensationalized research into robots as tools for ASD education and therapy caught Margolin’s attention. He promptly “took a

⁴⁴ Chen, Angela. "The Ever-Growing Ed-Tech Market." *The Atlantic*. November 6, 2015. Accessed May 03, 2016. <http://www.theatlantic.com/education/archive/2015/11/quantifying-classroom-tech-market/414244/>.

⁴⁵ "Advanced Social Robots." Accessed May 02, 2016. <http://www.robokindrobots.com/>.

⁴⁶ "Robots4Autism -." Robots4Autism. Accessed May 02, 2016. <http://www.robokindrobots.com/robots4autism-home/>.

⁴⁷ "Interview with Fred Margolin." Telephone interview by author. April 15, 2016.

⁴⁸ Ibid.

⁴⁹ Ibid.

⁵⁰ Ibid.

prototype robot, and... went to the [Dallas] Autism Treatment Center,” where Dr. Carolyn Garver, a Ph.D in Health Studies and licensed childcare administrator, worked with him.⁵¹ “We saw the amazing engagement that the robot created with regard to the children,” explained Margolin, and thus began “a much bigger project than of course we imagined.”⁵² Though Margolin’s first understanding of the potential for the use of robots in ASD education and therapy most likely came, indirectly, from Dautenhahn or Yano and Kozima by way of the media, he pursued the idea independently of this research, thus creating his own distinct strand to the narrative of these robots.

The Robokind website explains concisely that “using Robots4Autism, children improve their social and behavioral skills and gain the confidence they need to succeed academically and socially” and boasts a “comprehensive intervention program that uses purpose-built humanoid robots to deliver developmental instruction modules that teach critical functional skills.”⁵³

Robokind claims that, with its robot, Milo, “you can increase the number of hours of instruction children receive, improve the effectiveness of instruction,” and “reduce the cost of high-quality 1:1 instruction.”⁵⁴ The site also claims that “children using the Robots4Autism curriculum show observable increases in engagement: eye contact, body language and friendliness.”⁵⁵

Additionally, “working with Milo, children act more appropriately in social situations, self-motivate, self-regulate, and generalize in the population.”

These are some very large claims to make. These claims are, in fact, larger and more explicitly stated than in any recent or contemporary research on the topic. While this is likely just

⁵¹ "Autism Treatment Center." Autism Treatment Center. Accessed May 02, 2016. <http://www.atcoftexas.org/leadership.html>.

⁵² “Interview with Fred Margolin.”

⁵³ “Robots4Autism”.

⁵⁴ Ibid.

⁵⁵ Ibid.

representative of distinction between academic conservatism and commercial demands, it does assign the role of the robot as an educational agent akin to a clinical therapist or teacher, which in turn undermines Dautenhahn's guiding principle. Still, Robokind in part backs up these claims by citing four articles that candidly discuss the current state and progress of educational robots.

The first of these articles, written in late 2014 and originally published on Advance Healthcare Network, provides a broad overview of educational robots. It situates robots in the context of Technology Aided Instruction and claims that "Technology-Aided Instruction is now classified as one of the 27 intervention practices that have sound scientific evidence for increasing social skills in children with ASD."⁵⁶ The article claims that humanoid robots are more affordable than ever, which "makes viable the possibility of robots being used as a co-therapist to improve social intelligence in children with ASD."⁵⁷ It explains that "by harnessing the power of an intrinsically motivating object in the form of a human-like robot, clinicians may have the potential to better reach and motivate clients that might otherwise be difficult to engage or who might have anxiety and discomfort practicing social skills with other humans."⁵⁸ The article invokes Robokind's Robots4Autism project, explaining that its curriculum addresses "relevant social skills for school-aged children with autism."⁵⁹ Notably, the article hedges its enthusiasm by claiming that, despite the breakthroughs that these robots have made in Autism education, "a child's therapy program cannot be composed solely of sessions with a robot," and notes that the "Facilitator Manual in the Robots4Autism package outlines suggested extension

⁵⁶ Rollins, Pamela R. "Social Robotics." Social Robotics. October 20, 2014. Accessed May 02, 2016. <http://speech-language-pathology-audiology.advanceweb.com/Features/Articles/Social-Robotics.aspx>.

⁵⁷ Ibid.

⁵⁸ Ibid.

⁵⁹ Ibid.

activities to support therapists', teachers' and parents' interactions with the child subsequent to completion of each Robots4Autism module."⁶⁰

The second article, published in *Autism: Open Access* in 2014, is extremely brief and candidly, does not say anything very helpful. Its most important takeaway is the concept of transference. It notes that "skills generalization has rarely been observed outside of a controlled environment such as classrooms or clinics," implying that it is dubious that robots will be the answer to skills generalization, and concludes that "the robot should always be a mediator of the interaction between the child and other person."⁶¹

The third article is published by Robokind.⁶² The fourth is written by David Hanson, founder and owner of Hanson Robotics. Hanson's paper makes an important distinction between robots that do not look like people and robots that look quite a lot like people, with the explanation that "most robots used in autism research are not very humanlike, but instead are intentionally far from realistically humanlike in appearance, often under the untested assumption that realism will be disconcerting to individuals with ASD."⁶³ While robots that are not realistically humanlike have been shown to be effective in imparting language, imitation and learning skills to children with ASD, Hanson tests in his paper prototypical autism treatments using robots that *do* look intentionally like humans using mechanisms such as Frubber (a material developed by Hanson Robotics specifically for the purpose of creating robotic facial expressions), gestural bodies and eyes, face tracking, adaptive expressions, and conversational

⁶⁰ Ibid.

⁶¹ Costa, Sandra. "Robots as Tools to Help Children with ASD to Identify Emotions." *Autism-Open Access Autism Open Access* 2014 04, no. 02 (2014). Accessed May 2, 2016. doi:10.4172/2165-7890.1000e120.

⁶² This is only accessible upon request, and I forgot to request it until too late.

⁶³ Hanson, David, Daniele Mazzei, Carolyn Garver, Arti Ahluwalia, Danilo De Rossi, Matt Stevenson, and Kellie Reynolds. "Realistic Humanlike Robots for Treatment of ASD, Social Training, and Research; Shown to Appeal to Youths with ASD, Cause Physiological Arousal, and Increase Human-to-Human Social Engagement." 2012. Accessed May 2, 2016. Research Gate.

A.I.⁶⁴ “The key premise is that realistic robots can provide a highly accurate simulation of a human-to-human social encounter, with special benefits of controlled repeatability, tireless repetition, and absence of therapist-frustration or other controlled negative affect toward a patient or client.”⁶⁵ The article concludes that “realistic and nearly realistic humanlike robots can [be] well accepted by individuals with autism spectrum disorders at the mid-to-high end of the spectrum,” and that “additional studies are warranted.”⁶⁶

Milo has a small presence in the media. An early 2015 Guardian article reports that “some children with autism who had never spoken directly to an adult teacher spoke to Milo.”⁶⁷ A late 2015 article in CNET reported that “research shows the robot is making a difference in improving social skills,” and a CNN article at about the same time ran the headline “Robots help in fight against autism.”^{68, 69} It shows a video about Milo with the caption: “robots are successfully helping children with autism in ways that humans haven’t been able to” (CNN).

Aldebaran enters the conversation with NAO, a humanoid robot that is *not* designed specifically for realistic facial expressions. Aldebaran is home to a project devoted to creating tools for the therapy and education of children with ASD. Their Autism Solution for Kids Initiative (ASK) presents NAO as an “interactive, educational and easily implemented tool to engage kids through customized packages and applications for the Special education.”⁷⁰ In an interview via email, Alexandra Sugurel, a robotics engineer at Aldebaran, shared the following anecdote about the beginning of Aldebaran’s involvement with ASD education and therapy:

⁶⁴ Ibid.

⁶⁵ Ibid.

⁶⁶ Ibid.

⁶⁷ Tucker, "How Robots Are Helping Children with Autism." (2015).

⁶⁸ Carey, Bridget. "Meet Milo, a Robot Helping Kids with Autism." CNET. May 13, 2015. Accessed May 02, 2016. <http://www.cnet.com/news/meet-milo-a-robot-helping-kids-with-autism/>.

⁶⁹ "Robots Help in Fight against Autism - CNN Video." CNN. April 2, 2015. Accessed May 02, 2016. <http://www.cnn.com/videos/tech/2015/04/02/lead-pkg-foreman-robots-help-fight-autism.cnn>.

⁷⁰ Ask Nao. Accessed May 02, 2016. <https://asknao.aldebaran.com/>.

At a company public event, a little boy ran up to NAO and started interacting with him. This was not something out of the ordinary, as children are usually curious and happy to play with him. However, the mother of the child seemed very moved. When our staff approached her she shared the story of her son who was diagnosed with ASD and the challenges faced due to the difficulty of communication. This was one of the few times she had seen him so enthusiastic. Nobody at that time knew exactly how the robot could help, but he clearly had a positive impact. Soon after, the company explored partnerships with university researchers and special education schools in the quest to learn how robotics could help.⁷¹

Again, though Aldebaran turned to research institutions and schools to develop their robots, it discovered the phenomenon of educational/therapeutic robots completely by happenstance and developed them independently of any existing research, thus creating yet another distinct strain of thought in the field.

Aldebaran focuses on slightly different features than RoboKind and its claims are a bit more mundane. The ASK website claims that “NAO is a great help for teachers that really appreciate eliminating monotonous tasks,” and that the curriculum that it provides in accompaniment to NAO is “structured to make children with disabilities comfortable and confident.”⁷²

Interestingly, Aldebaran emphasizes its robots’ use in classrooms more so than in private therapy, which makes it distinct from RoboKind. The website claims that the curriculum accompanying NAO is Core-aligned, thus insinuating that its integration into public school classrooms in states that have adopted the common core would not be a problem.⁷³ That said, it is not clear from the website how exactly the NAO robot is meant to function in a classroom setting. Presumably, Aldebaran leaves this to educators to determine.

⁷¹ "Interview with Alexandra Sugurel." E-mail interview by author. April 2016.

⁷² Ibid.

⁷³ Ibid.

NAO has a particularly prolific media presence, and in this way is the “face” of robots in ASD education. “Autistic children may learn better from robots than from human teachers” reports Judith Burns in a 2012 article for the BBC.⁷⁴ She is referring to a then-emerging trial run at the Topcliffe School, a primary school in Birmingham, England. A 2014 article for the Boston Globe reports that “the French [robotics] company... has found NAO to be exceptional in an unexpected role as a classroom aide for children with autism.”⁷⁵ It reports that Aldebaran created the ASK at its Boston office, and donated NAO robots to the Moody School in Haverhill, Massachusetts, among three others. A 2015 Forbes article about NAO claims that “researchers believe robots can trigger social responses in autistic children more effectively than people can” and a 2014 Telegraph article, which also reports on NAO’s use at Topcliffe, cites a quote from a Topcliffe teacher who says that ““these children find it difficult to communicate in any shape or form, to get them suddenly talking to something else, well, it is the breakthrough, and it has been for at least three children in this school.””^{76,77}

Origami robotics produces a product unlike that of Aldebaran, Hanson, or RoboKind. It creates Romibo, a small, fuzzy, robotic mound with antennae and a screen that displays expressive eyes. Romibo is able to track eye contact. Developed at a National Science Foundation research and engineering laboratory, Romibo was designed explicitly to be affordable.⁷⁸ While NAO and Milo cost about \$10,000 each, Romibo can be bought for \$698,

⁷⁴ Burns, Judith. "Robots in the Classroom Help Autistic Children Learn." BBC News. November 8, 2012. Accessed May 02, 2016. <http://www.bbc.com/news/education-20252593>.

⁷⁵ Borchers, Callum. "NAO from Aldebaran Robotics Connects with Autistic Children - The Boston Globe." *BostonGlobe.com*. N.p., 14 June 2014. Web. 02 May 2016.

⁷⁶ Mullin, Emily. "How Robots Could Improve Social Skills in Kids With Autism." *Forbes*. Forbes Magazine, 25 Sept. 2015. Web. 02 May 2016.

⁷⁷ Griffiths, Andrew. "The Robot Teacher Connecting with Autistic Children." *The Telegraph*. Telegraph Media Group, 14 Feb. 2014. Web. 02 May 2016.

⁷⁸ "Home." Origami Robotics. Accessed May 02, 2016. <http://www.origamirobotics.com/>.

and Origami is attempting to drive its price down to between \$200 and \$300.⁷⁹ Origami promotes Romibo as being a tool for applied behavior analysts, speech-language pathologists, classroom teachers, occupational therapists, LCSW, art, and music therapists, and trauma interventionists.⁸⁰ Specifically in regard to its role in the classroom, Origami claims that “Romibo can prompt and praise while you attend to students who need extra help.”⁸¹

Romibo doesn't have a large media presence, but the Pittsburgh Post-Gazette reports that “a growing number of children, including some in Pittsburgh, are seeing their social skills soar with the help of Romibo.”⁸² For children with ASD, the article explains, “Romibo can help improve language skills and teaches social behaviors.”⁸³

Robokind, Aldebaran, and Origami each developed educational robots according to distinct strains of thought. Aldebaran, with its more modest claims of success, has the strongest relationship to clinical and academic research, and should now consult with educational practitioners. Robokind, which has delved further into uncharted territories with its facial expressions, should continue to pursue clinical research as well as research in the form of case studies in schools in order to ensure that its technology not develop faster than or away from what is actually desired by educators and therapists.

⁷⁹ Joss, Laurel. "Romibo - Researchers Seek Funding for Affordable Therapy Robot." Autism Daily Newscast. July 09, 2013. Accessed May 02, 2016. <http://www.autismdailynewscast.com/romibo-researchers-seek-funding-for-affordable-therapy-robot/715/laurel-joss/>.

⁸⁰ Origami Robotics.

⁸¹ Ibid.

⁸² Uchegbu, Amaka. "Fuzzy Robot Friend Romibo Helps Improve Youngsters' Social Skills." Pittsburgh Post-Gazette. July 15, 2015. Accessed May 02, 2016. <http://www.post-gazette.com/news/health/2015/06/16/Romibo-is-a-fuzzy-robot-friend-for-growing-number-of-children/stories/201506030234>.

⁸³ Ibid.

III. *Legal Context*

The *Individuals with Disabilities Education Act* (IDEA), which was first enacted in 1975 but most recently revised in 2004, is a binding federal statute that shapes special needs education in the entirety of the United States.⁸⁴ As such, it in many ways determines the viability of educational robots in American public school systems. Specifically, two sections within IDEA relate to the integration of technology into the daily educational routines of students: The Least Restrictive Environment clause and the Assistive Technology Clause.

Before discussing either of these clauses, however, it is necessary to understand the concept of an Individualized Education Program. IDEA gives all students who are part of the public school system in the United States and who require specialized accommodations in school the right to an Individualized Education Program (IEP). The statute defines an IEP as a “written statement for each child with a disability that is developed, reviewed, and revised.”⁸⁵

As a student, in order to obtain an IEP, one must undergo a lengthy process. This process begins with an initial evaluation, which consists of procedures “to determine whether a child is a child with a disability” and “to determine the educational needs of such child.”⁸⁶ Next come reevaluations, which occur “if the local educational agency determines that the educational or related services needs... of the child warrant a reevaluation” or “if the child’s parents or teacher requests a reevaluation.”⁸⁷ After reevaluation come a series of administrative evaluations to ensure the thoroughness of the evaluation and reevaluation. At this time, the school district begins its “determination of eligibility and educational need.”⁸⁸ Finally, an investigation is made

⁸⁴ "Your Child's Rights." Autism Speaks. Accessed May 03, 2016. <https://www.autismspeaks.org/what-autism/your-childs-rights>.

⁸⁵ Individuals with Disabilities Education Act, §§ 10-614-614 (2004).

⁸⁶ Ibid.

⁸⁷ Ibid.

⁸⁸ Ibid.

into the particular type of learning disability had by the student in question. This is by no means a thorough summary of the steps toward obtaining an IEP, nor does it do justice to the actual process underwent by thousands of families sending their children with ASD to public school in the United States; it is just a very general explanation of the steps towards obtaining an IEP.⁸⁹ Now it is time to address the two aforementioned clauses.

First is the Least Restrictive Environment clause. IDEA entitles children with an IEP to experience the least restrictive environment possible.⁹⁰ IDEA defines least restrictive environment to mean “to the maximum extent appropriate, children with disabilities, including children in public or private institutions or other care facilities, are educated with children who are not disabled, and special classes, separate schooling, or other removal of children with disabilities from the regular educational environment occurs only when the nature or severity of the disability of a child is such that education in regular classes with the use of supplementary aids and services cannot be achieved satisfactorily.”⁹¹ This means that, according to IDEA, students with an IEP should be “place in the environment in which he or she has the greatest possible opportunity to interact with children who do not have a disability and to participate in the general education curriculum.”⁹² This can sometimes be accomplished by providing a student with accommodations such as a one-on-one aid that remains at the side of the student throughout the school day.

Here is an important implication of educational robots. It would be controversial to argue that robots like NAO could replace an aforementioned aid; Dautenhahn stated explicitly at the

⁸⁹ A comprehensive guide to obtaining an IEP recommended by Autism Speaks can be found here: https://www.autismspeaks.org/sites/default/files/gp_iep_guide.pdf

⁹⁰ “Your Child’s Rights.”

⁹¹ Individuals with Disabilities Education Act.

⁹² “Your Child’s Rights.”

very inception of the idea of robots being used in this capacity that her aim was “not to replace people, simply to use the technology to aid caretakers.” Moreover, the clinical experts interviewed for this paper, and whose conversation surface shortly, almost entirely dismissed this notion. Still, one might see how in more economically challenged districts, robots like NAO or Milo could be used in the place of an aid because they are, relatively speaking, inexpensive.

Next is the Assistive Technology clause. IDEA states that “almost 30 years of research and experience has demonstrated that the education of children with disabilities can be made more effective by supporting the development and use of technology, including assistive technology devices and assistive technology services, to maximize accessibility for children with disabilities.”⁹³ The statute goes on to define assistive technology as “any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of a child with a disability.”⁹⁴ The statute also defines assistive technology service as “any service that directly assists a child with a disability in the selection, acquisition, or use of an assistive technology device.”⁹⁵

Evidently, educational robots fit into, collectively, the definitions of assistive technology and assistive technology services. Because IDEA requires that assistive technology be procured for students when it is deemed helpful, and because of the potential of educational robots to provide a less restrictive classroom environment for individuals with ASD, IDEA will actually be quite helpful in putting educational robots into classrooms, contingent of course upon more

⁹³ Individuals with Disabilities Education Act.

⁹⁴ Ibid.

⁹⁵ Ibid.

research that specifies if and specifically how educational robots are a positive force in the education and therapy of individuals with ASD.

IV. *Conversation*

A strange phenomenon marks the dialogue around the use of robots in ASD therapy and education: industry professionals with no clinical or educational training suddenly have a loud voice in the discussion of best practices in the field. Although external perspectives can be productive, this phenomenon demands skepticism. It also causes educational practitioners and clinical therapists to have to constantly react to the new technology rather than proactively determine its form. This section will provide skepticism (and tempered enthusiasm) by flipping the typical order of the conversation. Voices from the clinical world will speak first, followed by educators, before then adding back voices from industry. Putting these stakeholders in conversation with each other in this order yields necessary insight into how and where educational robots might be useful in ASD education and therapy and exposes both the overlaps and discrepancies between the desires of educators and clinicians and the direction of industry.

a. *Clinical*

Dr. Chris McDougle agreed to speak with me over the phone. He is the Director of the Lurie Center for Autism at Massachusetts General Hospital (MGH) in Boston, a “multidisciplinary program designed to evaluate and treat children, adolescents and adults with a wide variety of conditions including autism and autism spectrum disorders.”⁹⁶ He has been involved in clinical work in Autism for about twenty-five years, and has had the fairly unique experience of working with individuals from the age of three to the age of eighty in a clinical capacity.⁹⁷ As such, Dr. McDougle is able to contextualize the robots in a field familiar to

⁹⁶ "Lurie Center for Autism." - Massachusetts General Hospital, Boston, MA. Accessed May 03, 2016. <http://www.massgeneral.org/children/services/treatmentprograms.aspx?id=1614>.

⁹⁷ McDougle Interview

overwrought promises of “breakthroughs,” and to provide well-supported insight into potential concerns and excitements. Although he has not worked directly with educational robots, he is familiar with the concept, and moreover, has thought a great deal about the use of technology in ASD therapy and education.

Given his long experience in the field of ASD therapy, Dr. McDougle first reacted to the idea of robots as breakthroughs in ASD education and therapy somewhat skeptically. “Over the course of twenty-five years, there have been a number of treatments that are going to be revolutionary, that appear on the pages of major newspapers, that lead to investments, and the majority of those have not been successful, or as initially hoped,” he explained.⁹⁸ Moreover, autism is heterogeneous as a diagnostic group, both with regard to the way it presents clinically as well as what causes it.⁹⁹ As such, any new and promising idea in Autism therapy is more likely to benefit a small subset of individuals than the field of Autism therapy as a whole. Thus, to be effective, an agent in ASD education and therapy must “be sensitive enough” and “adaptable enough” to work with a wide variety of individuals.¹⁰⁰ It is because of this need for sensitivity and adaptability that human connection will remain of the utmost importance in ASD education.¹⁰¹ Additionally, robot therapy does not seem particularly innovative to Dr. McDougle. It brings to mind Thomas the Tank Engine. “A lot of our patients were really into that when they were younger,” he explained, because “the faces on [the] trains were consistent and predictable.”¹⁰² Furthermore, there are practical concerns. “Patients can, when they’re frustrated, be aggressive, and throw things, and breaks things. I don’t know how sturdy these things are, but

⁹⁸ Ibid.

⁹⁹ Ibid.

¹⁰⁰ Ibid.

¹⁰¹ Ibid.

¹⁰² Ibid.

if you're going to work with the whole spectrum, if you're paying \$5,000, you don't want to have to keep buying them.”¹⁰³

This is not to say that Dr. McDougle's perspective on robots in ASD education and therapy is entirely pessimistic. In fact, he enthusiastically identified several areas in which these robots might contribute to the field. For instance, because they act as a bridge between individuals with ASD and their therapists and teachers, robots might be useful in speech therapy. “Why not bring the robot into speech therapy as a tool, that way you're trying to maximize what people are already doing,” suggested Dr. McDougle. Moreover, “the fact that these robots are visual by nature, stimulus for reciprocal interaction” is intriguing because most children with ASD are visual learners. Dr. McDougle also identified a potential financial benefit to education robots, postulating that using robots could bring quality ASD therapy to “other socioeconomic groups with less resources in a more efficient manner.”¹⁰⁴ Finally, McDougle touched upon the burgeoning use of data in Autism therapy and education. A therapist can only observe a patient during their limited time together. This makes assessment difficult. Thus, the ongoing collection and analysis of data throughout the daily life of a patient might be helpful in objectively answering the question: “Is the therapy working?”

Dr. Kirstin Birtwell, a clinical psychologist at the MGH Lurie Center, works closely with an early-stage nonprofit technology startup called the Autism Affinities Project which provides an iOS platform facilitating conversation between parents and children with ASD. Her relationship to this nonprofit provides a valuable model for the ideal relationship between the clinical and industry realms in the world of ASD education and therapy.

¹⁰³ Ibid.

¹⁰⁴ Ibid.

The Affinities Project emerged from a new take on a longstanding observation that many individuals with ASD have circumscribed, or restricted interests.¹⁰⁵ Historically, allowing individuals with ASD to remain within the boundaries of their circumscribed interest was highly discouraged by clinical professionals. “We’ve tried to figure out ways to... decrease the interference of these behaviors,” explained Birtwell, “and actually we have not been able to do [that] so successfully.”¹⁰⁶ Rather than understanding the interests of ASD individuals as problems, the Affinities Project understands them as “windows of opportunity” through which to connect with the proprietors of those affinities.¹⁰⁷ Ron Suskind, who founded the project with inspiration from his son, explains on the project’s website, “our son Owen, like so many with autism, has an ‘affinity’ – an abiding connection to Disney movies that has made life richer in the two decades since his diagnosis, both in the solo hours he spends furiously sketching the sidekicks and in the time he spends interacting with others using vocabulary and emotions grown out of Disney soil.”¹⁰⁸

Dr. Birtwell works as a consultant for the Affinities Project. “My role is really to bring some research acuity to what they’re doing,” she explained.¹⁰⁹ “I think they’ve got a lot of really great anecdotal evidence from some of the people they’ve trialed [the project] with – they’ve been trialing it with a lot of parent-child dyads in the community – and it hasn’t really been under scrupulous research inquiry.”¹¹⁰ The research deficit that Birtwell highlights is actually quite common in the field of education technology for ASD education and therapy. Research in

¹⁰⁵ "Interview with Kirstin Birtwell." Telephone interview by author. April 22, 2016.

¹⁰⁶ Ibid.

¹⁰⁷ Ibid.

¹⁰⁸ Suskind, Ron. "Welcome to the Autism Affinities Project." Life Animated. January 23, 2014. Accessed May 03, 2016. http://lifeanimated.net/autism_affinities_project/.

¹⁰⁹ "Interview with Kirstin Birtwell."

¹¹⁰ Ibid.

this field “has really just been all over the place,” she explained.¹¹¹ “A lot of... non-clinical individuals have come up with really great ideas, and then they’ve kind of hit a wall, and that is the clinical field.”¹¹² Birtwell implies that without the involvement of the clinical field in the development of new therapeutic or educational technology, a burgeoning technology cannot survive. This is in large part a financial issue. “If you want insurance companies to reimburse for use with [the] device... you really need to show the insurance companies that it’s worth reimbursing,” Birtwell explained.¹¹³ Rightfully so, public schools also will not take on such a large upfront cost to purchase education technology without research supporting the technology.¹¹⁴

Dr. Birtwell explains that research bridges the gap between the conception of an idea and its widespread implementation. In order to get a new idea into the public school system, “you need money and you need resources and you need advocacy. And without good research to fall back on... those things are really difficult.”¹¹⁵ Unfortunately, there remains somewhat of an impasse between clinicians and companies. “I think it’s an area that has such promise, and I think clinicians are kind of apprehensive and scared of it because it’s a big undertaking,” she explained. Likewise, “companies are hesitant at the same time to pursue colleagues within the professional community because of how difficult that can be as well.”¹¹⁶

While the Affinities Project differs greatly from companies like Aldebaran and Robokind, as a non-profit coming from within the community, it is still an apt model. “They’ve approached the Lurie Center, and they’ve approached Mass General, and said, ‘we have this really good idea

¹¹¹ Ibid.

¹¹² Ibid.

¹¹³ Ibid.

¹¹⁴ Ibid.

¹¹⁵ Ibid.

¹¹⁶ Ibid.

but we know that we're going to need to investigate this scientifically, and we want you guys to do it.”¹¹⁷ The fact that the Affinities Project made this connection before attempting to become successful within the community means that it can be more sure of its role in the community going forward.

Birtwell touched upon some of the challenges of consulting for the Affinities Project. “What’s been difficult for my role at the Affinities Project is that they’ll come to me and say, can we do x, y, and z, and it’ll take three months to get that ironed out through MGH because MGH is such a big system with a lot of red tape. So I think that the collaborations are existing and they’re building and they’re growing in frequency, but they’re difficult.”¹¹⁸ The difficulty comes, then, from an impasse between the way that large research institutions and burgeoning tech companies function; while the latter grow and develop at a fast pace, the former is inhibited by bureaucracy and logistics. Thus, tech companies must understand that, in order to work within this realm, they must slow their pace to conform with the research institutions that are necessary to their growth.

The promise of educational technology in ASD education and therapy makes this difficult relationship worth pursuing.¹¹⁹ “I don’t think that robots or devices are the ultimate answer,” she said, “but to use [them] as this kind of discrete intervention package, or as an environmental support, I think is hugely, hugely helpful.”¹²⁰

Dr. Joshua Diehl, a clinician and researcher at the University of Notre Dame, represents one intriguing yet imperfect iteration of the relationship prescribed by Birtwell. Unlike McDougale and Birtwell, Diehl has worked extensively with robots in both a clinical and an

¹¹⁷ Ibid.

¹¹⁸ Ibid.

¹¹⁹ Ibid.

¹²⁰ Ibid.

educational capacity. His involvement with these robots came as much from interest as from a place of concern. “I had been watching the research develop, and I had a lot of concerns,” he told me over the phone.¹²¹ “When I came to Notre Dame, there were some people in cognitive science who were interested in human robot interaction and they had heard of [their] use with autism so out of curiosity, I did the lit review, and I was actually concerned that the robots were getting so much publicity for the use with autism when there were bits and pieces of kind of nice technology but the clinical aspect of the applications were missing.”¹²² That is to say, much like the motivation for this paper, Diehl was concerned about a certain lack of skepticism in the literature about educational robots, and wanted to temper that with his own experience as an actual expert of autism therapy and education. That said, he also found the literature sufficiently compelling in its exploration of the use of educational robots that he identified potential in the burgeoning technology.

In his literature review, Diehl criticizes existing research as being overly theoretical and sparse, but lauds it for its creativity.^{123,124} He echoes Birtwell in concluding that this research “highlights the important need for rigorous empirical studies that examine the incremental validity of this approach over other available techniques, as well as the generalizability of skills

¹²¹ "Interview with Dr. Joshua Diehl." Telephone interview by author. April 22, 2016.

¹²² Ibid.

¹²³ Diehl, Joshua J., Lauren M. Schmitt, Michael Villano, and Charles R. Crowell. "The Clinical Use of Robots for Individuals with Autism Spectrum Disorders: A Critical Review." *Research in Autism Spectrum Disorders* 6, no. 1 (2012): 249-62. doi:10.1016/j.rasd.2011.05.006.

¹²⁴ Diehl notes in his literature review that “much of the published research in in journals that focus on robotics (e.g., *Autonomous Robots*, *Robotica*) rather than in prominent ASD journals or clinically focused journals.”¹²⁴ For his literature review, Diehl only considered peer-reviewed journal or peer-reviewed published conference proceedings. Additionally, the data had to “(a) be the direct result of a therapeutic intervention, (b) have implications for group identification or diagnosis, or (c) be an empirical study that compares type, speed, and/or frequency of interactive responses to a robot or robot-like characteristics in comparison to a human or other non-robotic object” (Diehl). All considered material was published during or earlier than March, 2011.

Diehl found only fifteen peer-reviewed articles that matched this criteria (Diehl). Of these fifteen, only three involved the participation of more than six individuals with ASD. Also important to note is that “[o]f the 15 studies, only four used a standardized diagnostic measure for diagnostic confirmation... whereas seven relied on community diagnosis or medical records, and four did not report diagnostic confirmation” (Diehl paper).

learned with a robot in relation to those learned from human interaction.”¹²⁵ Moreover, “it will be especially important to clinical applications of robots to fully understand what specific aspects of technology-augmented therapies are critical to whatever effectiveness they promote.” (Diehl)¹²⁶. Diehl concludes on a fairly positive note: “There are many potential advantages to using interactive robots in clinical settings with individuals with ASD. These advantages include the intrinsic appeal of technology to individuals on the spectrum, robots’ ability to produce simple and isolated social behaviors repetitively, and the fact that they can be readily be programmed and adapted so that each child gets individualized treatment.”¹²⁷

Diehl was intrigued enough by his literature review to begin to conduct his own research into the clinical use of robots. He began by imagining an “ideal scenario” in which a clinical therapist could use the robot in a “Wizard of Oz” scenario in which there are no technical glitches and a therapist can interact with a patient entirely through the robot. With this ideal in mind, Diehl and his team selected the NAO robot because of its capacity for remote manipulability and seeming public availability.¹²⁸ Diehl began his clinical research by attempting to mimic with the robot an existing, Gold Standard therapy called Applied Behavioral Analysis (ABA). The question at hand was whether or not there was any benefit of using a robot over a human therapist with this particular technique. Diehl describes the results as follows:

So, what we did was we used the robot almost as a peer. There was somebody controlling the robot in the other room, and the child would practice a skill with the robot, or, they would practice a skill with the therapist and then we would introduce the robot, and the robot was almost like a friend that they could practice with... They could do things over and over again with this robot. And what we found is that, some kids really responded to the robot and some kids didn’t.¹²⁹

¹²⁵ “Interview with Dr. Joshua Diehl.”

¹²⁶ Ibid.

¹²⁷ Ibid.

¹²⁸ Ibid.

¹²⁹ Ibid.

While on the whole, Diehl did not find the robots to be significantly more effective than human therapists, he added that “if you looked at it individually, there were some individuals that had some pretty tremendous gains” when they began working with the robot (Diehl). More specifically, Diehl found that “some of our younger kids would engage with the robot, and it would actually increase their interactions with their therapist. It turned into almost a triadic interaction between the three.”¹³⁰ By contrast, “some of our older kids were less interested in talking with the robot, and more interested in how the robot worked.”¹³¹ Intrigued by this finding, Diehl and his team embarked upon “a short term digression that ended up being the most powerful work that we’ve done to date with the robot.”¹³²

Instead of examining the robot as a potential therapist, which was of seemingly limited interest to Diehl and his team, they decided to exploit the robot as a “special interest.” This, of course, immediately calls to mind the Affinities Project. Just as Birtwell and her colleagues at the Affinities Project aim to facilitate communication by exploring the individual, circumscribed interests of people with ASD, Diehl and his team identified robots as an affinity, albeit a more widespread affinity, through which to facilitate communication between two or more people.

In order to exploit robots as a special interest, Diehl decided to set up a summer camp, a “social, vocation program for people with autism and people without autism.”¹³³ During the program, participants were put into pairs in which one student had ASD and the other did not. In these pairs, participants learned vocational skills by programming facial expressions and speech

¹³⁰ Ibid.

¹³¹ Ibid.

¹³² Ibid.

¹³³ Ibid.

in the robot. Diehl's primary finding was that robots proved to be vitally important in the facilitation of "communicating with their partner."¹³⁴

"At the end of that first camp, we realized that... there were pretty dramatic reductions in social anxiety for individuals with Autism by participating in these camps."¹³⁵ At this point, Diehl was able to tentatively conclude that "instead of using [the robot] as a therapist, we teach them these vocational skills throughout the robot."¹³⁶ For Diehl, educational robots became a more widely accessible affinity.

It is important to note that Diehl pushed his research further to find out whether robots were more effective in this capacity than any learnable technology. He extended the camp to include videogame programming activities, and found that the robots were quite simply more "interesting and engaging" than videogame programming. "Humanoid robots have things such as arms and faces and eyes and things that really mimic social communication that were better than video games because they have those aspects."¹³⁷ He concluded that "if you're trying to teach social communication, it's more analog to be able to [program] a robot... to do these things."¹³⁸

Regarding the role of robots as therapists or teachers, Diehl remains quite skeptical. He acknowledges their potential to teach facial expressions, but mentions that there are videogames¹³⁹ that seek to do the same thing, and wonders "is there something about having this real-looking person-thing right there that has an advantage over and above what can be done with video modeling?"¹⁴⁰ Financially speaking, robots are "not a more affordable way" to bring ASD therapy to schools "because... you're going to have to have somebody who knows enough

¹³⁴ Ibid.

¹³⁵ Ibid.

¹³⁶ Ibid.

¹³⁷ Ibid.

¹³⁸ Ibid.

¹³⁹ Speak about the video games, somehow, "Let's Face It"

¹⁴⁰ Ibid.

to get the robot working, and watch over the robot while the robot is interacting with the child because... we're really far from having a robot sitting in a room and getting a caseload."¹⁴¹ In this, Diehl is more skeptical than McDougle. Finally, thanks to his experience with large scale implementation of robots in a summer camp setting, Diehl was able to lay out some logistical challenges to introducing robots into an existing system. Parents are primarily concerned about two issues: that their children will start to behave like robots, ("they don't want their children to turn into robots"), and that robots will come to replace human contact as a cost cutting measure. To address these concerns, Diehl suggests clear communication to parents regarding how and why the robot is to be used. Describing the robot as "an object of interest to facilitate social interactions" will likely quell parental concerns. Diehl also found that his robots were prone to breaking and technology failures, prompting him to advise that "the technology really needs to get more reliable, more lasting" in order for the robots to be actually affordable and sustainable. Finally, Diehl claims that the technology would need to become far simpler for common use in classrooms. Someone with as little free time as a classroom teacher, he claims, would have trouble learning the technology sufficiently.

Still, according to Diehl, a robot might still have a place in the classroom, as a facilitator of inclusion in play scenarios. "If you talking about play rather than classroom learning," he said, "I do think that's a possibility... One of the things that we see as the biggest benefit of the robot is that children who weren't sharing their interests with other people started looking at their therapist to see if they saw what this cool robot was doing."¹⁴² This position evidently stems from the concept behind Diehl's summer camp, and might translate to play among peers in an elementary school classroom.

¹⁴¹ Ibid.

¹⁴² Ibid.

b. Educational

Building upon the voices of Birtwell, Diehl and McDougle are those of Matthew Espelin and Carrie Plant, who graciously agreed to respond to a series of questions via email. Espelin is a speech-language pathologist at Newton North High School in Newton, Massachusetts.¹⁴³ Plant, meanwhile, is an ASD Resource Base teacher and assistant Integrated Co-teaching lead at the Topcliffe School in Birmingham, England.¹⁴⁴ The input of these accomplished educational practitioners is essential, providing valuable insight into the practical benefits and challenges of integrating new technology into the the daily lives of their students.

Both Espelin and Plant have significant experience using technology in the education of students with ASD. While Espelin has not worked with educational robots, he has vast experience with assistive technology. Explaining the basic technology he uses at Newton North, Espelin cites “iDevices with accessibility features, software to support literacy, writing and language organization development.”¹⁴⁵ Additionally, Espelin has worked with systems termed “high technology” that support expression for nonverbal or minimally verbal students.¹⁴⁶ He explains that technology is especially useful in the education of individuals with ASD because “students with ASD often (not always given [that] everyone is an individual) are visual learners... and communicators” and thus “the use of technology through visuals provide concrete

¹⁴³ In an email, Espelin further described his role at Newton North High School as “provid[ing] diagnostic, therapeutic and consultative supportive services to a population of students presenting with moderate to severe communication impairments [or] secondary cognitive deficits related to diagnoses such as: autism, Down Syndrome, cerebral palsy, seizure disorders, [and] traumatic brain injury. Note also that speech-language pathology is the field Birtwell and McDougle laud for being especially innovative with incorporating technology.

¹⁴⁴ The Topcliffe School is a public primary school in England boasting “the largest resource base in the country supporting children with autism and speech & language.” Integrated co-teaching refers to the method by which a general education teacher and a teacher of special education collaborate in the instruction of a class including students with and students without disabilities. (From <http://www.p12.nysed.gov/specialed/publications/policy/schoolagecontinuum.html>)

¹⁴⁵ “Interview with Matthew Espelin.” E-mail interview by author.

¹⁴⁶ Ibid.

context [for] ideas, thoughts, [and] topics” when “oral language often is abstract, ephemeral and fast paced.”¹⁴⁷ Unlike Espelin, Plant uses NAO robots to adapt a single lesson to the needs and interests of a diversity of students, thus creating a more engaging educational atmosphere.¹⁴⁸ Indeed, Plant’s experience as an educator confirms Diehl’s hypothesis regarding the capacity of robots to facilitate inclusion in play scenarios, and perhaps beyond.

Both Espelin and Plant describe a fairly seamless process of introducing and integrating technology into their schools. When he learns of a new technological tool, Espelin consults the “building-based technology specialist” and the district’s assistive technology specialist to find out more about the educational potential of the new technology. He will occasionally introduce the technology to a group of students as a trial. Regarding IEPs, Espelin adds that “once a team has... agreed upon... the potential benefit of a technology for a student, then the IEP is a wonderful instrument to promote/expedite/ensure follow through with the team’s decision to provide the technology.”¹⁴⁹ Plant also describes positive experiences introducing and integrating new technologies. When the Topcliffe School introduced the robots, “training was [undertaken] and then [the robots] were used within the resource bases in order to build on the skills that children with ASD typically find as a barrier.”¹⁵⁰ At Topcliffe, “the robots were part of everyday learning and skills within the base and just needed to be shown on the visual timetable so that the children were prepared for these changes.”¹⁵¹ In fact, Plant emphatically recommends this immersive approach in which schools integrate robots into existing infrastructure. According to Plant, a school considering adoption of educational robots should ensure “they have time built

¹⁴⁷ Ibid.

¹⁴⁸ "Interview with Carrie Plant." E-mail interview by author.

¹⁴⁹ “Interview with Matthew Espelin.”

¹⁵⁰ “Interview with Carrie Plant.”

¹⁵¹ Ibid.

into the timetable/routine in order for children to explore what the robot does and to create a play list to meet the needs of the individual.”¹⁵²

Espelin and Plant discussed common challenges of technology and robot integration, highlighting some basic but important future developments for educational robots. According to Espelin, students’ ability to “interface with a new technology... at a personal level based on the student’s current [understanding of] technology” often poses a challenge.¹⁵³ It can also be difficult to manage software or hardware when the student rather than the school owns the technology.¹⁵⁴ Meanwhile, at Topcliffe, the robots have “posed challenges in their sometimes unpredictable manner,” and sending the robot in for maintenance disturbs their integration into students’ daily routines.¹⁵⁵ Plant explains that this is particularly concerning when working with children with ASD, for whom routine change can “upset and anxieties.”¹⁵⁶ McDougale and Diehl also highlight robots need for maintenance as a pitfall of using this technology in schools. Plant’s experience confirms that if robots are to be commonly used in ASD education, they must be made more robust to ensure educational consistency, even if this means a simplification of their hardware. Finally, Plant reports that “on rare occasions, some children can dislike the robot,” for reasons neither Plant nor her colleagues can identify.¹⁵⁷ As Diehl and Birtwell suggest, it will be important for future collaborative research to identify circumstances in which robots are not productive additions to ASD education and therapy.

Challenges aside, Espelin thinks that there is potential for Newton North to use robots, strictly contingent upon the role that the robots have been designed to inhabit. “If the adoption of

¹⁵² Ibid.

¹⁵³ “Interview with Matthew Espelin.”

¹⁵⁴ Ibid.

¹⁵⁵ “Interview with Carrie Plant.”

¹⁵⁶ Ibid.

¹⁵⁷ Ibid.

robots increases the social language development and social thinking use and understanding of people with ASD then it should be pursued.”¹⁵⁸ Furthermore, he adds, “I am fascinated by the possibilities [of] data tracking of people with autism completing rote tasks [and] gaining feedback for performance.”¹⁵⁹ Here, Espelin echoes McDougle’s suggestion that robot be used to track the progress of students with ASD. However, Espelin cautioned that “it is my impression that language models provided by humans including social language/social interaction could never be replaced.”¹⁶⁰ Plant, on the other hand, does not share Espelin’s reservations. She maintains that the robots at Topcliffe “have supported the key skills in a fun, interactive and non-threatening manner.”¹⁶¹ Espelin’s mention of data collection, however, stands out as a more unique area for the use of social robots, and echoes McDougle’s desire for their use in objectifying the evaluation of progress.

Putting researchers and clinicians like McDougle, Birtwell, and Diehl in conversation with educators like Espelin and Plant is vitally important to understanding how educational robots can best be used in ASD therapy and education. As a group, these experts largely reject using a robot in the place of a therapist or peer, and offer instead three areas where robots might be of great use. The first, and most concrete benefit of robot use is data collection of rote tasks for the evaluation and analysis of educational and therapeutic progress. Secondly, it seems robots are more useful in play scenarios than in educational scenarios, and might facilitate inclusion play scenarios. Likewise, robots can appeal to a student with ASD’s interest or affinity to increase opportunities for communication. Finally, robots can be used as alternatives to existing software aimed at social and communication related learning if future research confirms that the

¹⁵⁸ “Interview with Matthew Espelin.”

¹⁵⁹ Ibid.

¹⁶⁰ Ibid.

¹⁶¹ “Interview with Carrie Plant.”

being-hood of robots makes them more effective. If clinicians and educators lead the conversation about using robots in ASD education and therapy, which will be more likely if industry creates the technology they ask for, then robots have greater potential to be useful to individuals with ASD. Perhaps clinicians and educators will come to believe robots can take on some of therapists' and educators' responsibilities, and perhaps they will not. Either way, clinicians and educators must dictate the direction of robot technology development so that this technology becomes of maximal utility and so that minimal resources are wasted along the way.

c. Industry

Now it is time to add voices from industry back into the conversation. Fred Margolin of Robokind and Alexandra Sugurel of Aldebaran discuss the challenges of integrating robots into schools, the current state of their companies' technology, and future directions for the use of robots in the education and therapy of individuals with ASD.

From the industry perspective, it is a challenge to get robots into schools because of the many "layers" by which the robot must be approved.¹⁶² "You've got your teachers, your people in special ed, and then you've got your administrators," Margolin explains, and each and every one of these groups needs to approve the technology before it receives funding.¹⁶³ Margolin adds that schools often want to see research before adopting robots. "We're getting research done, and in one case Johns Hopkins is doing the biggest study ever done with robots and children and we're in the middle of it but it takes a year to get research and a paper done," Margolin explains.¹⁶⁴ Thus Robokind is moving in the right direction by pursuing further research at the

¹⁶² "Interview with Fred Margolin."

¹⁶³ Ibid.

¹⁶⁴ Ibid.

request of schools, still, the robots are developing and being disseminated far more quickly than research is coming out. Margolin mentions that Robokind already has robots in about one hundred schools after only five months of selling robots to schools.¹⁶⁵ He adds, “what we found is that a lot of parents want something, but the schools are resistant to getting pressured from parents to do things.”¹⁶⁶ At the same time, the robots are still too expensive for parents to buy outright, so parents depend upon their children’s school to procure the robots.¹⁶⁷ Sugurel adds that “it is important for the school to have a strong Wi-Fi connection to allow the robot to receive automatic updates and communicate with the AskNAO interface system.”¹⁶⁸ She does not comment on any particular challenges of bringing the NAO robots to schools, and mentions only that “any institution that is interested can join the [AskNAO] program.”¹⁶⁹

Both Robokind and Aldebaran provide curriculum to go with their robots. “We created about 102 lessons under 12 modules for different situations” such as “greetings and conversation dynamics,” or “how to perform at a birthday party.”¹⁷⁰ Likewise, Aldebaran provides “interactive applications [which] can be organized as playlists and customized through an interface portal,” according to Sugurel.¹⁷¹ Furthermore, “since applications are different depending on the skill they target, the customization parameter types also vary. For example, a teacher or a caretaker can select how many trials should be given for a question, how many wrong answers before the robot provides the right one, and if the robot should say instructions at the beginning of the applications.”¹⁷²

¹⁶⁵ Ibid.

¹⁶⁶ Ibid.

¹⁶⁷ Ibid.

¹⁶⁸ “Interview with Alexandra Sugurel.”

¹⁶⁹ Ibid.

¹⁷⁰ “Interview with Fred Margolin.”

¹⁷¹ “Interview with Alexandra Sugurel.”

¹⁷² Ibid.

Margolin has many plans for the future of Robokind’s educational robots. Currently, Robokind is developing a feature called “Autism Group,” in which the robot delivers lesson plans to multiple individuals at a time.¹⁷³ This is reminiscent of Dr. Joshua Diehl’s tentative proposal of using robots to facilitate inclusion of individuals with ASD in play scenarios. Additionally, Robokind is in the early stages of developing software featuring an avatar of Robokind’s robot.¹⁷⁴ This software would allow students to repeat lessons learned at school with the robot at home, and would of course be far less expensive than the robots themselves.¹⁷⁵ Finally, Margolin describes a feature called “CompuCompassion,” by which “the robot estimates the emotional state of” a student, and thereby “starts making decisions about whether it will switch to play, or stop the lessons, or in some cases, go onto the next module.”¹⁷⁶ Sugurel was vaguer about future directions for Aldebaran’s robots, offering only that “robotics and technology offer many channels of expression and can be efficient tools to explore and pursue their talents. We hope to empower these amazing children and see them achieve wonders.”¹⁷⁷

¹⁷³ “Interview with Fred Margolin.”

¹⁷⁴ Ibid.

¹⁷⁵ Ibid.

¹⁷⁶ Ibid.

¹⁷⁷ “Interview with Alexandra Sugurel.”

Conclusions

As Dr. Kirstin Birtwell argues of the emerging field of educational robots, a perspective “coming from outside of the field, that is talking about the utility of this, and the direction that it could go... [that] discuss[es] the barriers... is hugely helpful.”¹⁷⁸ This paper aims to provide such a perspective. Thus far, research concerning these robots has come from disparate entities in distinct fields, all spurred by different motivations. The separateness of these findings is currently preventing this new technology from being truly useful to the individuals it seeks to serve. Therefore, this paper begins the process of synthesizing research from different fields regarding the use of robots in education and therapy for individuals with ASD.

Moreover, this paper addresses the problematic trend of industry professionals rather than educational practitioners and clinicians dictating the direction of the development of robotic technology. By contrast, this paper has prioritized the voices of clinicians and educators over those of industry professionals. If educators and clinicians are able to inform the direction of the the development of educational robots, social robotics for the benefit of those with ASD will progress in a way that is maximally productive and minimally wasteful.

Of course, the synthesis of social robotics research and the conversation about the use of robots for those with ASD needs to happen on a much larger scale. Most importantly, the conversation must expand to include parents and students. By considering their perspectives, we will be able to provide robotic technology that adds productively to the field of ASD education and therapy.

¹⁷⁸ “Interview with Dr. Kirstin Birtwell.”

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