Neurological priming of ASD patients in human-robot interaction studies reveal need for novel approach in technology regulation

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Abstract

The International Federation of Robots recently predicted that by 2011 there will be more than 17 million service robots globally. This burgeoning robotic era has the potential to influence large portions of society, not the least of which are crucial aspects of the medical and public health fields, including the diagnosis and treatment of the prevalent Autism Spectrum Disorder (ASD). A number of groups are already exploring the possibility of treating severe forms of ASD, characterized by impaired social interactions and communication, via therapeutic robots specifically designed to help prime motor skills in young children with ASD. The success of these priming actions is thought to rely on the malleability of the Mirror Neuron System (MNS). However, the same actions that can correct severe abnormalities in ASD patients under clinical care, could result in reinforcing slight abnormalities in those with undiagnosed ASD, if subjected to these robotics interactions in an uncontrolled environment. While substantial research as to what degree these robotics interactions could both hurt or help the prevalence rate of severe forms of autism is noticeably lacking, many experts acknowledge the need to move forward carefully in allowing public accessibility to robots with these possible capabilities. The scientific community now has a narrow window of time while the robotics industry is still in the early stages of development to perform prospective studies on the effects of human-robot interactions on human psychology and neural networking. This paper proposes an initial approach of a well defined and directed "policy dialogue" to evaluate new technologies, which can be applied to the regulation process for a wide array of new technical consumer products. Understanding the potential repercussions of service robot proliferation while still early in the development of this new technological terrain will allow interdisciplinary involvement and discussion which should ultimately result in safer, more effective, and more ethical incorporation of robots into society.

The Disorder: An introduction to autism

In 1943, Dr. Leo Kranner identified the first case of "autistic disturbances of affective contact" in the United States [1]. Over the next 6 decades, Dr. Kranner's initial condition grew to be known as Autism Spectrum Disorder (ASD) and is now diagnosed as five distinct conditions [2]. ASD diagnoses include the 560,000 individuals in the United States between the ages of 0 and 21 who are currently suffering from "substantial impairments in social interaction and communication." Despite the high prevalence rate of 1 in 150 8-year-old children in the U. S., the standard diagnostic procedure for ASD is fully reliant on the clinician's intuitive feel of the patient's capacity for functional social interaction [1,3]. The disrupted neurological mechanism of the disorder is largely unknown, but many experts believe the dysfunction of the Mirror Neuron System (MNS), which is thought to be essential in associating the actions of others to the observer's corresponding actions, to be the underlying neural explanation for phenotypic abnormalities. While it is generally believed

that there are both genetic and environmental factors responsible for the onset of autism, a lack of definitive evidence regarding specific cause(s) of the disorder further complicates treatment [1].

The Treatment, the Complication, the Solution: An overview

Despite these daunting statistics, there is a strong public health effort to treat as many aspects of ASD as possible. Amongst the variety of behaviorally based treatments made available to parents of autistic children is a treatment that, while still in the preliminary development stage, is intriguing in its dependence on the interaction of humanoid robots with autistic children [4]. While studies report encouraging findings for the development of a future treatment option, a significant amount of additional research is needed to verify the findings. There also needs to be an exploration of the long-term effects of these human-robot interactions on children with varying degrees of ASD severity, and on those without the disorder. Both forms of research must be pursued before these robots can be made publicly available as a treatment option.

Even though there are no robot products currently being marketed as treatments for autism, there are several robotic products, freely marketed as children's toys, which encompass the same characteristics that allow for an effective clinical treatment of autism via human-robot interaction. While this technology could provide a valuable treatment for autism, studies revealing the malleability and developmental function of the MNS in the first few years of life suggest that robots may have the capability of increasing the prevalence of ASD amongst children who are simply *at risk* for developing autism but are not yet diagnosed. This is a potential public health problem if these studies are later confirmed and robotic toys of this description have already made it into homes of children at risk for autism, the potential long-term effects of interactions with these robots unbeknownst to consumer parents. There is no current system of review or regulation for technology products that can be marketed as a treatment for a severe clinical condition to one consumer group and as a child's robotic toy to another.

Before either of these consumer markets expand much further, there needs to be an open and transparent Policy Dialogue initiated that is responsible for demanding more scientific and clinical research into the long-term effects on different populations via human-robot interactions. If deemed necessary, this dialogue group would also preemptively develop a set of qualifications and regulations for technological products that fall into this category, not to be enacted unless the scientific evidence proves them necessary for public health concerns. While this is not a direct policy measure, it is the necessary first step towards beneficial policy action. By proactively developing them now, we will increase the efficiency, and ultimately the effectiveness, when regulating technological products that could have severe repercussions on children living with ASD.

The Data: Human-robot interactions can help prime children with ASD

Some of the most promising data to date for the use of robots as treatment for ASD was found in a simple visuopriming study conducted in 2007. In this study, Dr. Pierno's group at the University of Padua compares the use of a robot versus a human as examples for children to imitate when performing a "reach-and-grasp" action towards a plastic sphere [5]. They found faster movement duration and anticipated peak velocity in children with autism, meaning a more normal functioning of the mechanism dysfunction in ASD, when primed by a robotic but not by a human arm movement [5]. The opposite pattern of that found for normal children [5]. These findings are supported by several studies showing that persons with autism typically demonstrate impaired performance compared to controls during imitation tasks [6,7,8]. Autistic children's improvement in performing tasks based on imitation, also known as priming, when directed by robots instead of

humans is the basis for current development projects of robots specific for autism treatment [9]. Those involved in the studies suggest that robot models are more effective at priming autistic children because of the exactly identical repetition of movements performed by robots compared the inherent variability in human movements [5,6].

Pierno et al. suggest that autistic children need consistently identical movements for priming to be successful because their individual neural mechanisms underlying the coding pattern of observed actions might be tailored to process socially simpler stimuli [5]. This neural mechanism alluded to is the Mirror Neuron System (MNS), whose structure and function suggest that our understanding of the actions of others derives from translating them into the vocabulary of our own actions [5, 10, 11]. Many interpret the misdirected gaze, preferred robotic priming, and general disturbance in social interactions seen in autistic patients as results of a malfunctioning MNS [5, 8, 10,11]. Robots may help autistic children because the invariability of their actions facilitates the recognition of the action goal, thus bypassing the need for mirror neurons to internalize the external action as their own, resulting in successful priming [5].

The Data: MNS may allow for adverse priming affects in at-risk populations

While these findings may prove to be powerful tools in treating autism, the structure of the MNS suggests that robotic priming of children without autism may have the opposite effect, actually increasing autistic tendencies in those children predisposed, even if just slightly, to the condition. If an abnormal MNS is the reason why robotic priming is helpful for autistic patients, the same degree of robotic priming exposure to an only slightly abnormal MNS may aggravate rather than help the condition. It may reinforce the dependency on invariable movement to understand action intention, rather than training to pick up on subtle motor or social cues.

While no studies directly addressing this possibility have been published, a recent study by Zecca et al. shows that subjects recognize emotions portrayed by human agents (98% success) to a significantly higher degree than for the robot agents (85% success) [12]. Zecca et al. argue that the difference for these recognition rates is because of a decreased response in the normal MNS to robotic emotions [12]. If this decreased response to emotion is allowed to prime children with slight autism, either emotionally or for motor skills, it may set a high threshold for external recognition of emotions or action intentions, therefore increasing the severity of the condition.

While the absence of research directly addressing this possibility hinders the usefulness of this conclusion in a policy setting, scientific experts across several fields recognize both the potential psychological and neurological development danger inherit in these robotic technologies and the need to encourage additional research before mass marketing of these products. One such expert is Dr. Nouchine Hadjikhani, a professor of radiology at Harvard and a leading researcher in determining the neurological basis of autism through fMRIs. She is a strong advocate of extensive studies to address the potential harm robots can cause to autism patients, because of the innumerable aspects to the disorder and subsequent treatments [13]. UC Berkeley's Dr. Marian Diamond, a renown neuroanatomist and histologist, has also drawn from her comprehensive research into anatomical effects of enriched environments to warn against the possible effects of excessive screen usage, and has acknowledged that human-robot interactions may have the same capacity to change the brain via the MNS [14]. She believes that the lack of research being conducted to investigate these possibilities is due to the difficulty of project design and low priority academically, rather than to a lack of necessity or urgency [14]. Both researchers, along with most other experts, also put a strong emphasis on societal education of these ambiguous and yet influential public health issues.

The Market: Robots with priming capabilities are sold without research or regulation

Before any action is taken to either encourage or bar the sale of robots with specific priming capabilities, more research is need to verify or disprove the long-term, neurological and psychological effects of both the intended benefits and the potential risks. However, this is not currently the case, as there are many consumer robot products on the market that perform either physical motions or exhibit emotions in the robotic manner seen in the studies above [15, 16, 17]. While these robots may eventually help some populations of children with severe forms of autism, they also may harm populations of children undiagnosed and yet vulnerable. Allowing these products to be sold without any warnings, review, or regulation, when there is no research to verify their safety and there is reason to believe that they may have severe, long-term adverse effects, is a potential technological and public health problem. This problem must be addressed now, before the robotics market has reached its full potential and the integration of these products into society and lifestyles complicates the implementation of regulations.

Possible Solutions Revealed and Rejected: A historical case study

While there are no published suggested solutions to this problem, there are a number of possibilities that can be derived from the handling of similar historic situations. Analogous problems in the past have seen no action taken until overwhelming scientific evidence, usually accompanied with legal action from abused consumer groups, forces policy reform and regulation. By examining extensively studies past public health regulatory scenarios, we can determine what combination of approaches is most fitting for the current situation. One of the most advantageous case studies is the regulation history of asbestos usage in construction, shipyards, manufacturing, and car repair [18].

In 1989, 65 years after the first study of the occupational risks of asbestos was published, The Environmental Protection Agency conducted a series of "Policy Dialogue" meetings on the issue of asbestos exposure on workers that included perspectives from real estate developers, banks, insurance companies, unions, asbestos manufacturers, public interest groups, and asbestos consultants, and contractors [19, 21]. While a need for increased transparency and worker awareness was established, it wasn't until 5 years later that the permissible exposure was reduced to the current standard [18, 20].

Though the culmination of these proceedings and regulations resulted in restriction of this very harmful material, the process would have benefited from an earlier introduction of a policy dialogue group that would then have revealed the need for more research and the future system of regulation earlier, thus preventing much of the unnecessary exposure that occurred during the 1970s and 1980s. The exposure that was allowed to continue because of the delayed analysis and policy measures has resulted in up to 20,000 asbestos-related lung cancers and 10,000 mesotheliomas per year in the industrialized countries of Western Europe, Scandinavia, North America and Australia [22]. Once enacted, elements of this solution are effective at preventing the harmful effects of asbestos at the present, but the delay in starting a dialogue resulted in an inefficient process and unnecessary workers' exposure.

The other general type of solution, though much more unlikely, is the preemptive enactment of restrictions on the appropriate sectors of the robotics market. There are at present a number of different types of regulations on consumer products. For example, the U.S. Food and Drug Administration (FDA) is responsible for regulating food, drugs, medical devices, vaccines, and cosmetics [23]. The U.S. Consumer Product Safety Commission regulates products that "pose a fire, electrical, chemical, or mechanical hazard or can injure children" [24]. The Bureau of Alcohol, Tobacco, Firearms, and Explosives is responsible for regulation of said products [25]. One of the

unifying elements of these regulatory agencies, is that significant amounts of research is required before policy action is taken to either limit access of a product to certain individuals or to ban its presence on the market all together. This would be a unlikely and detrimental action to take, as there is not enough definitive evidence to support any type of policy action, nor is there an existing agency with a department equipped to evaluate this unique hybrid of a technology/public health problem.

A Proposed Solution: Dialogue first, policy second

Without any formal action or discussion, it is likely that the progression of robotic product development, and the corresponding clinical research, will follow the pattern of the historical asbestos example. While it is traditional to err on the side of market freedom rather than the heavy-handed regulation suggested in the second possible solution, without the supporting scientific evidence to justify such policies, the first solution is far from preferable for the previously stated reasons of inefficiency and ineffectiveness. In addition, even if the scientific evidence was present to warrant direct government intervention, there is no precedent for this type of regulation as none of the current regulatory agencies deal with situations of this nuanced technological/public health nature that is directly dependent not on immediate physical danger or harmful chemicals, but on long-term neurological effects.

I propose the development of a formal Policy Dialogue that is analogous to that used for asbestos but initiated now, before decades of abuse is allowed to occur. A policy dialogue is a "carefully constructed, deliberative meeting that addresses both politically controversial and technically complex aspects of an issue in a dispute" [26]. Even though there is no direct dispute in this case, the structure of policy dialogues is an ideal model because it allows an open exchange of information and encourages decision-making that strongly influences the trajectory of a possible solution to a challenging issue [26]. The participants should include but is not limited to neurobiologists, pediatric psychiatrists, cognitive scientists, robotics experts, ASD patient advocates, policy makers (preferably from the FDA, as these robots overlap most closely with their category of medical devices), and someone to oversee the group who has significant experience in running policy dialogues.

Their discussion will not only determine how much scientific evidence is necessitated before regulatory action is needed, but will also outline a system of review for this novel category of technology/public health regulation. Given current knowledge, there are a number of conclusions that the dialogue could result in, with a strong possibility for a variety of hybrids. Some of the general possibilities include the development of legislation for increased funding of related research, requirement of advisory stickers on robotic products with predetermined similarities to robots used in clinical settings, strict regulation or restriction of related products on the market or in development until research into their potential effects is conducted, or no government involvement whatsoever, and instead advocating for a patient awareness campaign.

Unlike most Policy Dialogues for pharmaceutical products that are assembled in response to pressure from abused consumer groups, this dialogue's strength would lie in its immediate initiation. While the exact timeline for the dialogue should be dependent on the individual concerns that the participants bring to the table, the dialogue should begin at least with an Evaluative Phase, where all facets of the problem are defined in detail and general areas of necessary research outlined. The direction of the dialogue's next steps would benefit from the conclusions drawn by this initial step, rather than being rigidly defined prior to the conversation. This dialogue is unique, not because of the structure or participants, but for its preemptive rather than reactionary nature. This would allow it to move forward efficiently and effectively because the potential side-effects of the products would not have come to pass yet, leading to relatively little contention, which is a major problem for

dialogues involving abused or extremely emotionally involved groups, between the varying participants.

While this is not a direct policy action, this is a necessary first step in determining whether a policy action will be necessary, as in the case of asbestos. Given the serious public health implications of the problem, the limiting nature of the research available, and the lack of a regulatory precedent for this type of product, this policy dialogue presents itself as the most feasible and productive solution at the moment. By initiating this open discussion now, it will encourage more high-profile scientific studies to be conducted, while also engaging policy makers in thinking about future trajectories for solutions, rather than waiting for external pressure from abused consumer groups.

Future Implications

Even though this is a preliminary step, the formation of a formal Policy Dialogue, whose end goal is to design a new process for regulation of products with a hybrid technological/public health quality, will enable us to categorically rethink the way we approach consumer safety. As more research reveals increasingly complex and nuanced aspects of the brain's process of cognition and learning, it is going to become very important to address these factors when considering consumer safety from a neurobiological perspective. We already do this for chemicals and radiation that can alter the body's biological processes. Examining and regulating severe, long-term effects on the brain could be the new frontier for consumer safety. The most logical starting place for the development of a model for a review and regulation system appropriate to these new considerations is through examination of the intersection of the burgeoning robotics market and the "hot button" issue of the growing prevalence of autism. A Policy Dialogue to address the public health issues of this new technological treatment of ASD will both ensure an efficient and effective method of regulation if necessitated and will lay a solid foundation for the expansion of this regulatory field in the future in anticipation of further research findings.

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Request:
A travel grant to meet with several faculty members at Columbia University to develop an interdisciplinary approach to the initiation of a Policy Dialogue addressing the problems brought up in the accompanying paper.

Reason:
There are several departments or associated groups at Columbia whose varying perspectives could be drawn upon to develop an efficient and effective interdisciplinary dialogue.

One group is the Initiative for Policy Dialogue, which is based at Columbia. There are several departments internal to the Initiative that would have beneficial experiences to draw upon. For example, I could meet with Ann Florini, Task Force Chair of the Transparency Program. The Task Force brings together scholars and activists to improve understanding of what transparency can accomplish and how it can be increased. While the issue of transparency is not directly addressed in my proposal, the formation of the policy dialogue that I suggest would highly benefit from someone with significant experience in initiative to increase transparency. Dr. Florini's experience would ensure an open discussion and would keep at the forefront of the dialogue the need to ensure transparency, and regulation if necessary, of robotics products that may harm potential populations of consumers.

Another group is the Division of Brain Stimulation and Thereaputic Modulation at the Medical Center. There are over 30 faculty in this department whose backgrounds range from child welfare to psychopharmacology to neurobiology, and whose current all revolve around the investigation of ASD or related syndromes.

Columbia University would be an advantageous place to begin work on this important issue because of the presence and close physical proximity of two very prestigious institutes that are directly related to this Policy Dialogue. Columbia also has a renowned law school and a meeting with one of their staff, if achieved, may prove beneficial in bringing in a legal perspective. These meetings would be an essential first step in developing a interdisciplinary group of experts to look critically at the scientific evidence, to evaluate the appropriate measures to take in terms of research and regulation, and to develop a plan for review of the appropriate robotic products, eventually leading to a policy implementation.