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"I may not have a brain gentlemen, but I have an idea" (B.O.B.).

Two years ago my son had an accident and was taken to the intensive care unit at the Children's Hospital in San Diego, California. I was amazed at the high-tech symphony of human and machine activity that took care of my child and that is responsible for saving thousands of lives.

Until recently robots have only been able to operate in highly controlled conditions, like medical and industrial settings. However, as Noel and Amanda Sharkey point out, recent advances in machine learning and machine perception are making possible a new generation of robots that may operate in unconstrained daily life environments. One potential application of such robots is early childhood education, the focus of this document. Educational robots may enrich our children's learning experiences in ways that we are only beginning to comprehend. The development of these robots requires for researchers to take a fresh look at the nature of human intelligence and is forcing them to pay close attention to the problems the brain solves when operating in daily life. It is also encouraging scientists and engineers to move beyond constrained laboratory conditions and to develop technology in close interaction with teachers, parents, and children to best serve their needs. This is the approach we took in the RUBI project, a scientific venture jointly funded by the University of California and Sony corporation during the years 2004 to 2008 (Tanaka et al., 2007). The goal of the project was to explore the possibilities of sociable robots in early childhood education. The challenges were great but not insurmountable and by the end of the project we managed to develop low cost robots that children, parents and teachers were really fond of. Most importantly the robots were able to operate fully autonomously for weeks at a time, teach 18–24 month old children foreign languages, and significantly improve the vocabulary development of their first language (Movellan et al.,

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2009). These were encouraging first steps. We are now preparing for the next phase of the project where these robots will allow for children located in different countries to interact, communicate and learn from each other.

Bringing together toddlers and robots is surely a controversial issue and should be subject to careful scrutiny. Sharkey and Sharkey deserve credit for raising important concerns that need to be debated as this technology develops. However in this dialogue, we shall not forget our responsibility to explore technologies that have a good chance to change the world in a positive manner. Thousands of children would not be alive today were it not for the machines that assist doctors in intensive care units. Educational robots may enrich and provide learning opportunities for our children in ways that we can barely imagine but that we cannot ignore.

The Sharkey and Sharkey paper is a carefully written document whose provocative tone may prove useful to initiate a timely conversation. The paper is not easy to respond to for it is a complex mixture of valid concerns, careful scholarship, Hollywood-like doom scenarios and remarkably strong opinions sometimes based on rather weak evidence. My main concern with the paper is that in its zeal to justify the need for new laws to protect our children the paper presumes the worst from children, families, teachers, researchers and businesses. Yet it presumes infinite wisdom from those who would be writing and enforcing these laws. In doing so the paper forgets about the *raison d'etre* of this new scientific endeavor: the fact that social robots may significantly increase the learning and experiential opportunities of the children of tomorrow (Meltzoff et al., 2009).

1. Early social development

I agree with Sharkey and Sharkey on the issue that matters most: developing and marketing robots to substitute human child care is worrisome. Companies that market social robots as human care substitutes are exposing themselves to a great deal of trouble and they deserve this trouble.

Early in the RUBI project we focused on understanding the quality of the interaction that emerges when toddlers and robots are brought together on a daily basis for sustained periods of time (Tanaka et. al, 2007). Since the children in the project were allowed to interact with social robots on a daily basis, we looked carefully at the literature and consulted world class experts regarding possible reasons for concern. Our support team included a senior ethnographer and a senior developmental psychologist whose work is cited in the Sharkey and Sharkey document. I have a degree in infant development and have had the opportunity to talk informally and exchange impressions on this issue with a wide range of world class professionals. While one always needs to be alert when exploring new

technologies, there is a consensus that for children older than 12 months, there are no special reasons for concern regarding daily exposure to social robots. By this age children have already formed strong attachments to their primary caregivers and are used to a wide range of social and affective experiences. A diversity of social experiences is desirable, including experiences with adults, children, pets and technological artifacts.

Concerns exist about exposing younger infants to social robots on a daily basis for sustained periods of time. Some of these concerns are based on John Watson's seminal work on the role of contingency in early social development (Watson 1972, 1985). He found that 3-month old infants may identify caregivers, and potentially become attached to them, based on simple contingencies. The concern is that sustained exposure to artifacts that are responsive to children could result in these children bonding to the artifacts more than they bond to their human caregivers. This concern extends to simple artifacts, like hanging mobiles and toys, that could respond contingently to infants. I am not aware of any experimental evidence that sustained that exposure to contingency-generating artifacts may be harmful, however given our current state of knowledge the concern is not unreasonable.

2. Mentalism

Sharkey and Sharkey worry about the fact that children believe social robots have mental states and that this is deceptive and harmful to them. Sharkey and Sharkey do not give enough credit to our children. My experience based on controlled laboratory experiments (Movellan et al., 1987), detailing computational modeling (Movellan et al., 2002) and thousands of hours of field studies (Tanaka et al., 2007; Movellan et al., 2009) is that toddlers above 9 months of age have no problem whatsoever assessing the limits of a robot's skills, provided they are allowed to freely interact with it for just a few minutes.

Many social robots do indeed have minds and mental states of the type the sciences of the mind (cognitive science, cognitive psychology, and AI) like to talk about. Ironically there are also many scientists skeptical that humans have minds as conceived by the sciences of the mind. Centuries ago it was obvious to most Europeans that white people had a soul (they had doubts about people of darker complexion). Arguing whether robots have a mind may prove as useful as arguing which races, if any, have a soul. It may just be more productive for scientists to focus on understanding the computational problems that the brain solves when operating in daily life environments. As a neuroscientist friend of mine told me "We may not have a mind but we sure have a brain".

3. Emotion

Affect and emotion are processes whose importance is becoming particularly apparent as we develop robots that operate in daily life. The work on social robots is in fact providing critical clues to better understand the computational basis of affect and emotion. The early robot designs in the RUBI project did not have an emotion engine. We found that children would test the physical limits of RUBI, shaking her head, pulling her arms, etc. If left alone the early robot designs could not survive the children for more than a few hours. The solution we found was to use inertial sensors so that RUBI could detect when she was in physical danger. When that happened a state variable would be triggered (for convenience we called the state "fear") and would take control of RUBI's behavior, driving her to stop playing with the children and to cry until comforted. Children quickly learned to treat RUBI in a manner that did not compromise her well being and to comfort her when she cried. This allowed for RUBI to operate autonomously in the classrooms for weeks at a time, providing the children with a new range of educational and social interaction activities. Over time as we continue working on RUBI's emotional engine we are planning for her emotional states to serve as a reward signal for her own learning processes. It is reasonable to claim that RUBI's emotion engine is a deception. If so it is a useful deception that allows her to survive, to learn and to improve the lives of the children she interacts with. Should alien scientists come to Earth and study early social interaction, they may also conclude that human emotions are clever deceptions.

4. Gloom and doom

Throughout history new technologies have predictably provoked alarmist rhetoric, some of which reads funny after the fact. For example, in 1908, J.P. Sousa warned people about "the menace of mechanical music" – at the time gramophones and player Pianos – and drew predictions that it would destroy the "national throat" (Sousa, 1908). In 1982 the introduction of the VCR drew testimonies in the US Congress that it would be to the American public as the Boston strangler was to the woman home alone (Anderson, 2009). While I agree with the core concerns in the Sharkey and Sharkey paper, I strongly disagree with its sometimes offensive and alarmist tone. In their zeal to point out the dangers of social robotics, Sharkey and Sharkey assume the worst of parents, researchers, and businesses. For example, they suggest that parents do not like TV because it does not hypnotize their children for long enough periods of time. There will always be unconscionable parents that do not care for their children. In these cases the problem is the parents, not the

robots. Most parents do care for their children and take steps to make sure they live balanced lives. Parents are concerned when their children watch too much TV, when they don't have enough friends, when they don't care enough about academic studies, or when they don't look happy. Throughout history parents, teachers and children have adapted to new technologies such as books, gramophones, radios, TVs, video games and the Internet. Parents, teachers and children will also adapt to educational robots. They will help shape the technology and they will use it as a tool to balance and enrich the life experiences of children.

5. Legalism and common sense

Sharkey and Sharkey suggest that robot makers intentionally trick parents into feeling it is OK to abandon their children. They unscrupulously design deceptive robots that seem so lifelike to parents that they forget these robots are not really human. The "Hello Kitty Robot" is given as an example of things to come. According to Sharkey and Sharkey the Hello Kitty Website markets the robot as "a perfect robot for whoever does not have a lot of time [sic] to stay with their child". I contacted the robot manufacturer and I feel it is important to set the record straight. They were surprised that anybody would market their robot as a child care product. The company targets the robot to women in their thirties who grew up with Hello Kitty character goods. Their website explicitly says that the robot may not work properly for people under 16 years of age (see supplementary materials). The website Sharkey and Sharkey referred to in their paper seems to be that of an independent store.

Developing commercially viable sociable robots has so far proven to be a very challenging task. After significant investment in this technology, companies like Sony and iRobot have abandoned the idea for the time being. Most robot manufacturers stay away from marketing their products as substitutes for human child care. Those that do not will rightfully expose themselves to a great deal of trouble. Lawsuits are already a very effective mechanism for protecting consumers. For example, Disney marketed the Baby Einstein DVDs as educational and beneficial for early childhood development, with no scientific evidence to back up this claim. To prevent a lawsuit, Disney is now offering refunds totaling hundreds of millions of dollars.

Sharkey and Sharkey champion the need for new international laws to regulate robot–child interaction. While laws play a critical role in civilized society, well intentioned laws designed to protect us from new technologies often end up being ludicrous or having unintended consequences. For example, when the first

automobiles were being developed a law appeared in England requiring that a man had to walk with a red flag in front of every moving vehicle. It was most disturbing to read that due to some laws designed to protect children from sexual abuse, teachers in the UK are reluctant to physically restrain children from hurting each other. It is ironic that these laws could give an advantage to robots over human teachers on their ability to protect and comfort children. Laws, and the government bureaucracies that enforce them, suffer from the same problem that traditional AI programs do: they can't capture the richness, flexibility and wisdom of common sense.

It is unwise to invent new laws to protect children from unknown future threats. If we are going to regulate our children's interaction with social robots we may also have to regulate their interactions with dogs, cats and hamsters. Should governments warn us that robots have no mental states? How about hamsters? Do they have mental states? Sharkey and Sharkey worry about some problem countries, like South Korea, that "strongly resist interference in family lives by outsiders". I was surprised that anybody would consider this to be a problem. I would hope for as many cultures as possible to adhere to the wisdom of this aspect of South Korean culture.

6. Conclusions

1. Educational sociable robots may be a powerful tool to enrich early childhood education environments. There is already scientific evidence suggesting that they can be effective. As scientists and engineers we have a responsibility to shape this emerging technology so it can be as effective as possible.
2. The idea of robots to substitute for or completely eliminate human child care is worrisome. Companies that pursue this venue are exposing themselves to significant and well deserved legal trouble.
3. There are no particular reasons for concern in letting children above 12 months of age interact with sociable robots on a regular basis. As with any other artifacts parents and teachers should exercise common sense. The key here is to use technology to increase, not decrease, the diversity and richness of experiences that children are exposed to.
4. While there is no empirical evidence about long term harm, care should be exercised when exposing young infants (less than 12 months of age) to social robots or other responsive artifacts for long periods of time on a daily basis. Lacking empirical evidence, the 12 month dividing line appears to be a conservative but reasonable rule of thumb.

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Supplementary materials

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