The crying shame of robot nannies: an ethical appraisal

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Childcare robots are being manufactured and developed with the long term aim of creating surrogate carers. While total child-care is not yet being promoted, there are indications that it is 'on the cards'. We examine recent research and developments in childcare robots and speculate on progress over the coming years by extrapolating from other ongoing robotics work. Our main aim is to raise ethical questions about the part or full-time replacement of primary carers. The questions are about human rights, privacy, robot use of restraint, deception of children and accountability. But the most pressing ethical issues throughout the paper concern the consequences for the psychological and emotional wellbeing of children. We set these in the context of the child development literature on the pathology and causes of attachment disorders. We then consider the adequacy of current legislation and international ethical guidelines on the protection of children from the overuse of robot care.

Who's to say that at some distant moment there might be an assembly line producing a gentle product in the form of a grandmother - whose stock in trade is love. From *I Sing the Body Electric,* Twilight Zone, Series 3, Episode 35, 1960

1. Introduction

A babysitter/companion on call round the clock to supervise and entertain the kids is the dream of many working parents. Now robot manufacturers in South Korea and Japan are racing to fulfil that dream with affordable robot "nannies". These currently have game playing, quizzes, speech recognition, face recognition and limited conversation to capture the preschool child's interest and attention. Their mobility and semi-autonomous function combined with facilities for visual and auditory monitoring are designed to keep the child from harm. Most are prohibitively expensive at present but prices are falling and some cheap versions are already becoming available.

Children love robots as indicated by the numbers taking part in robot competitions worldwide. Even in a war zone, when bomb disposal robots entered a village in Iraq, they were swamped with excited children (Personal communication, Ronald C. Arkin, 2008). There is a growing body of research showing positive interactions between children and robots in the home (e.g. Turkle et al 2006 a,b), and in the classroom (e.g. Tanaka et al. 2007; Kanda et al, 2009). Robots have also been shown to be useful in therapeutic applications for children (e.g. Shibata *et al.*, 2001, Dautenhahn, 2003; Dautenhahn and Werry, 2004; Marti *et al.*, 2005, Liu et al, 2008). The natural engagement value of robots makes them a great motivational tool for education in science and engineering. We raise no ethical objections to the use of robots for such purposes or with their use in experimental research or even as toys.

Our concerns are about the evolving use of childcare robots and the potential dangers they pose for children and society (Sharkey, 2008a). By extrapolating from ongoing developments in other areas of robotics, we can get a reasonable idea of the facilities that childcare robots could have available to them over the next 5 to 15 years. We make no claims about the precision of the time estimate as this has proved to be almost impossible for robotics and AI developments (Sharkey, 2008b). Our approach is conservative and explicitly avoids entanglement with issues about strong AI and super smart machines. Nonetheless, it may not be long before robots can be used to keep children safe and maintain their physical needs for as long as required.

To be commercially viable, robot carers will need to enable considerably longer parent/carer absences than can be obtained from leaving a child sitting in front of a video or television programme. Television and video have long been used by busy parents to entertain children for short periods of time. But they are a passive form of entertainment and children get fidgety after a while and become unsafe. They need to be monitored with frequent "pop-ins" or the parent has to work in the same room as the child and suffer the same DVDs while trying to concentrate. The robot can extend the length of parent absences by keeping the child safe from harm, keeping her entertained and, ideally, by creating a relationship bond between child and robot (Turkle *et al* 2006b).

We start with a simple example, the Hello Kitty Robot, that parents are already beginning to use if the marketing website is to be believed. It gives an idea of how these robots are already getting a 'foot in the door.' Even for such a robotically simple and relatively cheap robot, the marketing claims are that, "This is a perfect robot for whoever does not have a lot time [*sic*] to stay with their child." (Hello Kitty website). Although Hello Kitty is not mobile, it creates a lifelike appearance by autonomously moving its head to four angles and moving its arms. What gives it an edge is that it can recognise voices and faces so that it can call children by their names. It has a stereo CCD camera that allows it to track faces and it can chat. For children this may be enough to create the illusion that it has mental states (Melson *et al* in press b).

Busy working parents might be tempted to think that a robot nanny could provide constant supervision, entertainment and companionship for their children. Some of the customer reviews of the "Hello Kitty Robot", on the internet made interesting reading. These have now been removed but we kept a copy: (there is also a copy of some of the comments at
http://bittybobo.blogspot.com/search?updated-min=2008-01-01T00%3A00%3A00-08%3A00&updated-max=2009-01-01T00%3A00%3A00-08%3A00&max-results=23
under April 17, 2008)

- Since we have invited Hello Kitty (Kiki-as my son calls her), life has been so much easier for everyone. My daughter is no longer the built in babysitter for my son. Hello Kitty does all the work. I always set Kiki to parent mode, and she does a great job. My two year old is already learning words in Japanese, German, and French.
- As a single executive mom, I spend most of my home time on the computer and phone and so don't have a lot of chance to interact with my 18-month old. The HK robot does a great job of talking to her and keeping her occupied for hours on end. Last night I came into the playroom around 1AM to find her, still dressed (in her Hello Kitty regalia of course), curled sound asleep around the big plastic Kitty Robo. How cute! (And, how nice not to hear those heartbreaking lonely cries while I'm trying to get some work done.)
- Robo Kitty is like another parent at our house. She talks so kindly to my little boy. He's even starting to speak with her accent! It's so cute. Robo Kitty puts Max to sleep, watches TV with him, watches him in the bath, listens to him read. It's amazing, like a best friend, or as Max says "Kitty Mommy!"

> Now when I'm working from home I don't have to worry about Max asking a bunch of questions or wanting to play or having to read to him. He hardly even talks to me at all! He no longer asks to go to the park or the zoo - being a parent has NEVER been so easy! Thank you Robo Kitty!"

We are not presenting these anecdotal examples as rigorous evidence of how a simple robot like Hello Kitty will generally be used. Other parents commenting on the website were highly critical about these mothers being cold or undeserving of having children. Nonetheless this example provides a worrying indication of what might be and what we need to be prepared for. Perhaps it is only a small minority of parents who would rely on such a simple robot to mind their pre-school children. But as more sophisticated robots of the type we describe later become affordable, their use could increase dramatically.

What follows is an examination of the present day and near-future childcare robots and a discussion of potential ethical dangers that arise from their extended use in caring for babies and young children. Our biggest concern is about what will happen if children are left in the regular or near-exclusive care of robots. First we briefly examine how near-future robots will be able to keep children safe from harm and what ethical issues this may raise. Then we make the case, from the results of research on child-robot interaction, that children can and will form pseudo-relationships with robots and attribute mental states and sociality to them. Children's natural anthropomorphism could be amplified and exploited by the addition of a number of methods being developed through research on human-robot interaction, for example, in the areas of conversation, speech, touch, face and emotion recognition. We draw upon evidence from the psychological literature on attachment and neglect to look at the possible emotional harm that could result from children spending too much time exclusively in the company of mechanical minders.

In the final section, we turn to current legislation and international ethical guidelines on the care and rights of children to find out what protections they have from sustained or exclusive robot care. Our aim is not to offer answers or solutions to the ethical dangers but to inform and raise the issues for discussion. It is up to society, the legislature and the professional bodies to provide codes of conduct to deal with future robot childcare.

2. Keeping children from physical harm

An essential ingredient for consumer trust in childcare robots is that they keep children safe from physical harm. The main method used at present is mobile monitoring. For example, the PaPeRo Personal Partner Robot by NEC (Yoshiro et al, 2005) uses cameras in the robot's 'eyes' to transmit images of the child to a window on the parent-carer's computer or to their mobile phone. The carer can then see and control the robot to find the child if she moves out of sight. This is like having a portable baby monitor but it defeats the purpose of mechanical care. There is little point in having a child care robot if the busy carer has to continuously monitor their child's behaviour. For costly childcare robots to be attractive to consumers or institutions, they will need to have sufficient autonomous functioning to free the carer's time and call upon them only in unusual circumstances.

As a start in this direction, some childcare robots keep track of the location of children and alert adults if they move outside of a preset perimeter. The PaPeRo robot comes with PaPeSacks, each containing an ultrasonic sensor with a unique signature. The robot can then detect the exact whereabouts of several children at the same time and know which child is which. Similarly the Japanese Tmsuk robot uses radio frequency identification tags. But more naturalistic methods of tracking are now being developed that will eventually find their way into the care robot market. For example, Lopes et al, (2009) have developed a method for tracking people in a range of environments and lighting conditions without the use of sensor beacons. This means that the robot will be able to follow a child outside and alert carers of her location or encourage and guide her back into the home.

We may also see the integration of care robots with other home sensing and monitoring systems. There is considerable research on the development of smart sensing homes for the frail elderly. These can monitor a range of potentially dangerous activities such as leaving on water taps or cookers They can monitor a person getting out of her bed and wandering. They can prompt the person with a voice to remind them to go to the toilet and switch the toilet light on for them (Orpwood *et al*, 2008). Vision systems can detect a fall and other sensors can determine if assistance is required (Toronto Rehabilitation Unit Annual Report 2008, 40-41). Simple versions of such systems could be adapted for use in robot child care.

One ethical issue arising from such close monitoring is that every child has a right to privacy under Articles 16 and 40 of the UN Convention on Child Rights. It is fine for parents to listen out for their children with a baby alarm. Parents also frequently video and photograph their young children's activities. In most circumstances legal guardians have the right to full disclosure regarding a very young child. However, there is something different about an adult being present to observe a child and a child being covertly monitored when she thinks that she is alone with her robot friend.

Without making too much of this issue, when a child discusses something with an adult, she may expect the discussion will be reported to a third party – especially her parents. But sometimes conversations about issues concerning the parents, such as abuse or injustice, should be treated in confidence. A robot might not be able to keep such confidences from the parents before reporting the incident to the appropriate authorities. Moreover, when a child has a discussion with a peer friend (or robot friend) they may be doing so in the belief that it is in confidence.

With the massive memory hard drives available today, it would be possible to record a child's entire life. This gives rise to concerns about whether such close invigilation acceptable. Important questions need to be discussed here such as, who will be allowed access to the recordings? Will the child, in later life have the right to destroy the records?

Privacy aside, an additional way to increase autonomous supervision would be to allow customisation of home maps so that a robot could encode danger areas. This could be extended with better vision systems that could detect potentially dangerous activities like climbing on furniture to jump. A robot could make a first pass at warning a child to stop doing or engaging in a potentially dangerous activity in the same way that smart sensing homes do for the elderly. But there is another ethical problem lurking in the shadows here.

If a robot could predict a dangerous situation, it could also be programmed to autonomously take steps to physically prevent it rather than merely warn. For example, it could take matches from the hands of a child, get between a child and a danger area such as a fire, or even restrain a child from carrying out a dangerous or naughty action. However, restraining a child to avoid harm could be a slippery slope towards authoritarian robotics. We must ask how acceptable it is for a robot to make decisions that can affect the lives of our children by constraining their behaviour.

It would be easy to construct scenarios where it would be hard to deny such robot action. For example, if a child was about to run across the road into heavy oncoming traffic and a robot could stop her, should it not do so? The problem is in trusting the classifications and sensing systems of a robot to determine what is a dangerous activity. As an extreme case, imagine a child having doughnuts taken from her because the robot wanted to prevent her from becoming obese. There are many discussions to be had over the extremes of robots blocking human actions and where to draw the line (c.f. Wallach and Allen, 2009).

Another ethically tricky area of autonomous care is in the development of robots to do what some might consider to be the 'dull and dirty' work of childcare. They may eventually be able to carry out tasks such as changing nappies, bathing, dressing, feeding and adjusting clothing and bedding to accord with temperature changes. Certainly, robot facilities like these are being thought about and developed in Japan with an eye to caring for their aging population (Sharkey and Sharkey, in press). Performing such duties would allow lengthier absences from human carers but could be a step too far in childcare robotics; care routines are an important component in fostering the relationship between a child and her primary carer to promote healthy mental development. If we are not careful to lay out guidelines, robots performing care routines could exacerbate some of the problems we discuss later in the section on the psychological harm of robot childcare.

Carers who wish to leave their charges at home alone with a robot will need to be concerned about the possibility of intruders entering the home for nefarious purposes. Security is a major growth area in robotics and care robots could incorporate some of features being developed. For example, the Seoul authorities, in combination with the private security company KT Telecop use a school guard robot, OFRO to watch out for potential paedophiles in school playgrounds. It can autonomously patrol areas on pre-programmed routes and alert teachers if it spots a person over a specific height, (Metro, May 31st 2007; The Korea Times, May, 30th 2007). If we combine this with face recognition, already available on some of the care robots, they could stop adults to determine if they were on the trusted list and alert the authorities if necessary.

3. Relating to the inanimate

Another essential ingredient for consumer trust in childcare robots is that children will want to spend time with them. Research has already begun to find ways to sustain long term relationships between humans and robots (e.g. Takayuki *et al*,2004; Mitsunaga, *et al*, 2006; Mavridis *et al*, 2009). Care robots are already being designed to exploit both natural human anthropomorphism and the bond that children can form with personal toys. The attribution of animacy to objects possessing certain key characteristics is part of being human (Sharkey and Sharkey 2006). Puppeteers have understood and exploited the willing or unconscious "suspension of disbelief" for thousands of years as have modern animators and cartoonists. The characteristics they exploit can be visual, behavioural or auditory. Even the vaguest suggestion of a face brings an object to life; something as simple as a sock can be moved in a way that makes it into a cute creature (Rocks, et al, in press). Robots, by comparison, can greatly amplify anthropomorphic and zoomorphic tendencies. Unlike other objects, a robot can combine visual, movement and auditory features to present a powerful illusion of animacy without a controller being present.

Young children emotionally invest in their most treasured cuddly toy. They may have difficulty sleeping without it and become distraught if it gets misplaced or lost. The child can be asked, "what does Bear think about X?". Bear can reply through the child's voice or by whispering in the child's ear or by simply nodding or waving an arm. This is a part of normal childhood play and pretence that requires imagination, with the child in control of the action. As Cayton (2006 p283) points out, "When children play make-believe, 'let's pretend' games they absolutely know it is pretend… Real play is a conscious activity. Ask a child who is playing with a doll what they are doing and they may tell you matter-of-factly that they are going to the shops or that the doll is sick but they will also tell you that they are playing."

A puppet, on the other hand, is outside of the child's control and less imagination and pretence is required. But a child left alone with a puppet soon realises the illusion and the puppet can then be classified in the "let's pretend" category. The difference with a robot is that it can still operate and act when no one is standing next to it or even when the child is alone with it. This could create physical, social and relational anthropomorphism that a child might perceive as 'real' and not illusion.

There is a gradually accumulating body of evidence that children of all ages can come to believe in the reality of a relationship they have with robots. Melson et al (in press a) report three studies that employed Sony's robotic dog AIBO: (i) a content analysis of 6,438 Internet discussion forum postings by 182 AIBO owners; (ii) observations and interviews with 80 preschoolers during a 40-minute play period with AIBO and a stuffed dog; and (iii) observations and interviews with 72 school-age children from 7 to 15 years old who played with both AIBO and a living dog. The majority of participants across all three studies viewed AIBO as a social companion: both the preschool and older children said that AIBO "could be their friend, that they could be a friend to AIBO, and that if they were sad, they would like to be in the company of AIBO".

In a related study, Kahn et al (2006) looked at the responses of two groups of preschoolers – 34-50 months and 58-74 months, in a comparison between an AIBO and a stuffed dog. They found that a quarter of the children, in verbal evaluations, accorded animacy to the AIBO, half accorded biological properties and around two-thirds accorded mental states. But a very similar pattern of evaluation was found for the stuffed dog. The interesting thing here is that the children's behaviour towards the two artefacts did not fit with their evaluations. Based on 2,360 coded behavioural interactions, the children exhibited significantly more apprehensive and reciprocal behaviours with the AIBO whilst they more often mistreated the stuffed dog (184 occurrences versus 39 for AIBO). Thus the verbal reports were not as reliable an indicator as the behavioural observations. The robot was treated more like a living creature than the stuffed dog.

Children can also form relationships with humanoid robots. Tanaka *et al*. (2007) placed a "state-of-the-art" social robot (QRIO) in a day care centre for 5 months. They report that children between 10 and 24 months *bonded* with the robot in a way that was significantly greater than their bonding with a teddy bear. Tanaka et al claim that the toddlers came to treat the robot as one of their peers. They looked after it, played with it, and hugged it. They touched the robot more than they hugged or touched a static toy robot, or a teddy bear. The researchers related the children's relationship with the robot to Harlow's (1958) "affectional responses". They claimed that "long-term bonding and socialization occurred between toddlers and a state of the art social robot" (Tanaka et al, 2007 p. 17957).

Turkle *et al.* (2006a) report a number of individual case studies that attest to children's willingness to become attached to robots. For example, one of the case studies was of a 10 year old girl, Melanie who was allowed to take home a robotic doll, "My Real Baby", and an AIBO for several weeks. The development of a relationship of the girl with the robots is apparent from her interview with the researcher.

> "Researcher: Do you think the doll is different now than when you first started playing with it?
>
> Melanie: Yeah. I think we really got to know each other a whole lot better. Our relationship, it grows bigger. Maybe when I first started playing with her, she didn't really know me so she wasn't making as much [sic] of these noises, but now that she's played with me a lot more, she really knows me and is a lot more outgoing. Same with AIBO" (Turkle et al 2006b pp 352).

In another paper, Turkle *et al.* (2006b) chart the first encounters of 60 children between the ages of five and thirteen with the MIT robots Cog and Kismet. The children anthropomorphised the robots, made up "back stories" about their behaviour, and developed "a range of novel strategies for seeing the robots not only as "sort of alive" but as capable of being friends and companions". The children were so ready to form relationships with the robots, that when they failed to respond appropriately to their interactions, the children created explanations of their behaviour that preserved their view of the robot as being something with which they could have a relationship. For example, when Kismet failed to speak to them, children would explain that this was because it was deaf, or ill, or too young to understand, or shy, or sleeping. Their view of the robots did not even seem to change when the researchers spent some time showing them how they worked, and emphasising their underlying machinery.

Melson and her colleagues (Melson et al, in press b) directly compared children's views of and interactions with a living, and a robot dog. The children did see the live dog as being more likely than the AIBO to have physical essences, mental states, sociality and moral standing. However, a majority of the children still thought of and interacted with AIBO as if it was a real dog; they were as likely to give commands to the AIBO as to the living dog and over 60% affirmed that AIBO had "mental states, sociality and moral standing".

Overall, the pattern of evidence indicates that the illusion of robot animacy works well for children from preschool to at least early teens. Robots appear to amplify natural anthropomorphism. Children who spent time with robots saw them as friends and felt that they had formed relationships with them. They even believed that a relatively simple robot was getting to know them better as they played with it more. A large percentage was also willing to attribute mental states, sociality and moral standing to a simple robot dog. Kahn et al. (2006) suggest that a new technological genre of autonomous, adaptive, personified and embodied artefacts is emerging that the English language is not well-equipped to handle. They believe that there may be need for a new ontological category beyond the traditional distinction between animate and inanimate.

3.1 Extending the reach of childcare robots

There are a number of ways in which current childcare robots interact with children. The main methods involve touch, language with speech recognition, tracking, maintaining eye contact and face recognition among others. Extending social interaction with better computational conversation and the ability to respond contingently with facial expressions could result in more powerful illusions of personhood and intent to a young child. It could make child-robot relationships stronger and maintain them for longer. We discuss each of the current interactive features in turn together with their possible near-future extensions.

Touch is an important element of human interaction (Hertenstein et al, 2006) particularly with young children (Hertenstein, 2002). It has been exploited in the development of robot companions and several of the manufacturers have integrated touch sensitivity into their childcare machines in different ways. It seems obvious that a robot responding contingently to touch by purring or making pleasing gestures will increase its appeal. For example, Tanaka et al. (2007) reported that children were more interested in the QRIO robot when they discovered that patting it on the head caused it to ‘giggle’.

The PaPeRo robot has four touch sensors on the head and five around its body so that it can tell if it is being patted or hit. iRobiQ has a bump sensor, and touch screen as well as touch sensors on the head, arms and wheels. The Probo robot (Goris et al, 2008; 2009) is being developed to recognise different types of affective touch such as slap, tickle, pet and poke. The Huggable (Stiehl et al 2005; 2006) has a dense sensor network for detecting the affective component of touch in rubbing, petting, tapping, scratching and other types of interactions that a person normally has with a pet animal. It has four modalities for touch, pain, temperature and kinaesthetic information.

Ongoing experimental research on touch is finding out the best way to create emotional responses (Yohanan et al, 2005; Yohanan and Maclean, 2008). There is also research on the impact of a robot proactively touching people – like a “gimme five” gesture or an encouraging pat on the shoulder (Cramer et al 2009). Touch technology will improve over the next few years with better, cheaper and smaller sensors available to create higher resolution haptic sensitivity. This will greatly improve the interaction and friendship links with small children.

Robots could even have an advantage over humans in being allowed to touch children. In the UK, for example, there has been considerable discussion about the appropriateness of touching children by teachers and child minders. Teachers are reluctant to restrain children from hurting other children for fear of being charged with sexual offences or assault. Similarly child care workers and infant school teachers are advised strongly not to touch children or hug them. Even music teachers are asked not to touch children’s hands to instruct them on how to hold an instrument unless absolutely necessary and then only after warning them very explicitly and asking for their permission. These restrictions would not apply to a robot because it could not be accused of having sexual intent and so there are no particular ethical concerns. The only concern would be the child’s safety, e.g. not being crushed by a hugging robot.

Another key element in interaction is spoken language. Even a doll with a recorded set of phrases that can be activated by pulling a string, can keep children entertained for hours by increasing the feeling of living reality for the child. We found eight of the current childcare robots that could talk to some extent and had speech recognition capability for simple commands. For example, iRobi, by Yujin Robotics of South Korea responds to 1000 words of voice commands. None had a full blown natural language processing interface, yet they can create the illusion of understanding.

The PaPeRo robot is one of the most advanced and can answer some simple questions. For example, when asked, “What kind of person do you like?” it answers, “I like gentle people”. It can even give children simple quizzes and recognise if their answers are correct. PaPeRo gets out of conversational difficulties by making jokes or by dancing to distract children. This is very rudimentary compared to what is available in the rapidly advancing areas of computational natural language processing and speech recognition. Such developments could lead to care robots being able to converse with young children in a superficially convincing way within the next 5 to 10 years.

Face recognition is another important factor in developing relationships (Takayuka *et al*, 2004). Some care robots are already able to store and recognise a limited number of faces, allowing them to distinguish between children and call them by name. The RUBI robot system has built-in face detection that enables it to autonomously find and gaze at a face. This is a very useful way to engage a child and convince them that the robot has “intent”. Spurred on by their importance in security applications, face recognition methods are improving rapidly. Childcare robots of the future will adopt this technology to provide rapid face recognition of a wide range of people.

An even more compelling way to create the illusion of a robot having mental states and intention, is to give it the ability to recognise the emotion conveyed by a child’s facial expression. The RUBI project team has been working on expression recognition for about 15 years with their computer expression recognition toolbox (CERT) (Bartlett et al, 2008). This uses Ekman’s facial action units (Ekman and Friesen, 1978) which were developed to classify all human expressions. The latest development uses CERT in combination with a sophisticated robot head to mimic people’s emotional expressions.

The head, by David Hanson, resembles Albert Einstein and is made of a polymer material called Flubber that makes it resemble human skin and provides flexibility of movement. Javier Movellan, the team leader said that, “We got the Einstein robot head and did a first pass at driving it with our expression recognition system. In particular we had Einstein looking at himself in a mirror and learning how to make expressions using feedback from our expression recognition. This is a trivial machine learning problem.”, (personal communication, February 27, 2009). The head can mimic up to 5,000 different expressions. This is still at an early stage of development but will eventually, “assist with the development of cognitive, social and emotional skills of your children” (*ibid*).

Robots can be programmed to react politely to us, to imitate us, and to behave acceptably in the presence of humans (Fong et al, 2003). As the evidence presented earlier suggests, we have reached a point where it is possible to make children believe that robots can understand them at least some of the time. Advances in language processing, touch and expression recognition will act to strengthen the illusion. Although such developments are impressive, they are not without ethical concerns.

An infant entertaining a relationship with a robot may not be in a position to distinguish this from a relationship with a socially and emotionally competent being. As Sparrow pointed out about relationships with robot pets, "[they] are predicated on mistaking, at a conscious or unconscious level, the robot for a real animal. For an individual to benefit significantly from ownership of a robot pet they must systematically delude themselves regarding the real nature of their relation with the animal. It requires sentimentality of a morally deplorable sort. Indulging in such sentimentality violates a (weak) duty that we have to ourselves to apprehend the world accurately. The design and manufacture of these robots is unethical in so far as it presupposes or encourages this" (Sparrow, 2002).

Sparrow was talking about the vulnerable elderly but the evidence presented in this section suggests that young children are also highly susceptible to the belief that they are forming a genuine relationship with a robot. We could say in absolute terms that it is ethically unacceptable to create a robot that appears to have mental states and emotional understanding. However, if it is the child's natural anthropomorphism that is deceiving her, then it could be argued that there are no moral concerns for the roboticist or manufacturer. After all, there are many similar illusions that appear perfectly acceptable to our society. As in our earlier example, when we take a child to a puppet show, the puppeteer creates the illusion that the puppets are interacting with each other and the audience. The 'pretend' attitude of the puppeteer may be supported by the parents to 'deceive' very young children into thinking that the puppets have mental states. But this minor 'deception' might better be called 'pretence' and is not harmful in itself as long as it is not exploited for unethical purposes.

It is difficult to take a absolutist ethical approach to questions about robots and deception. Surely the moral correctness comes down to the intended application of an illusion and its consequences. Drawing an illusion on a piece of paper to fool our senses is an entertainment, but drawing it on the road to fool drivers into crashing is morally unjustifiable. Similarly, if the illusion of a robot with mental states is created for a movie or a funfair or even to motivate and inspire children at school there is no harm.

The moral issue arises and the illusion becomes a harmful deceit both when it is used to lure a child into a false relationship with a robot and when it leads parents to overestimate the capabilities of a robot. If such an illusory relationship is used in combination with near-exclusive exposure to robot care, it could possibly damage a child emotionally and psychologically, as we now discuss.

4. Psychological risks of robot childcare

It is possible that exclusive or near exclusive care of a child by a robot could result in cognitive and linguistic impairments. We only touch on these issues in this section as our main focus here is on the ways in which a child's relationship with a robot carer could affect the child's emotional and social development and potentially lead to pathological states. The experimental research on robot-child interaction to date has been short term with limited daily exposure to robots and mostly under adult supervision. It would be unethical to conduct experiments on long term care of children by robots. What we can do though, is make a 'smash and grab raid' on the developmental psychology literature to extract pointers to what a child needs for a successful relationship with a carer.

A fruitful place to start is with the considerable body of experimental research on the theory of attachment (Ainsworth et al 1978, Bowlby, 1969, 1980, 1998). This work grew out of concerns about young children raised in contexts of less-than-adequate caregiving, who had later difficulties in social relatedness (Zeanah et al, 2000). Although the term ‘attachment’ has some definitional difficulties, Hofer (2006) has noted that it has “found a new usefulness as a general descriptive term for the processes that maintain and regulate sustained social relationships, much the same way that *appetite* refers to a cluster of behavioral and physiological processes that regulate food intake” (p. 84).

A fairly standard definition that suits our purposes here is that “Infant attachment is the deep emotional connection that an infant forms with his or her primary caregiver, often the mother. It is a tie that binds them together, endures over time, and leads the infant to experience pleasure, joy, safety, and comfort in the caregiver's company. The baby feels distress when that person is absent. Soothing, comforting, and providing pleasure are primary elements of the relationship. Attachment theory holds that a consistent primary caregiver is necessary for a child's optimal development.” (Swartout-Corbeil, 2006). Criticising such definitions, Mercer (in press) acknowledges that while it is true that attachment has a strong emotional component, cognitive and behavioural factors are also present.

There is always controversy within developmental psychology about the detailed aspects of attachment. Our aim is not to present a novel approach to attachment theory but to use the more established findings to warn about the possibility of harmful outcomes from robot care of children. Here we take a broad brush stroke approach to the psychological data. Given the paucity of research on childcare robots we have not been age specific, but our concerns are predominantly with the lower age groups – babies to preschoolers up to five years old – that appear to be the target group of the manufacturers.

One well established finding is that becoming well adjusted and socially attuned requires a carer with sufficient maternal sensitivity to perceive and understand an infant’s cues and to respond to them promptly and appropriately (Ainsworth et al, 1974). It is this that promotes the development of *secure attachment* in infants and allows them to explore their environment and develop socially. But insecure forms of attachment can develop even when the primary carer is human. Extrapolating from the developmental literature, we will argue below that a child left with a robot in the belief that she has formed a relationship with it, would at best, form an insecure attachment to the robot but is more likely to suffer from a pathological attachment disorder.

Responding appropriately to an infant’s cues requires a sensitive and subtle understanding of the infant’s needs. We have already discussed a number of ways in which the relationship between a child and a robot can be enhanced when the robot responds contingently to the child’s actions with touch, speech or emotional expressions. When the responses are not contingent, pre-school children quickly lose interest as Tanaka et al (2007) found when they programmed a robot to perform a set dance routine. However, there is a significant difference between responding contingently and responding appropriately to subtle cues and signals. We humans understand and empathise with a child’s tears when she falls because we have experienced similar injuries when we were children, and we know what comforted us.

There is more to the meaning of emotional signals than simply analysing and classifying expressions. Our ability to understand the behaviour of others is thought to be facilitated by our mirror neurons (Rizzolatti et al, 2000; Caggiano et al., 2009). Gallese (2001) argues that a mirror matching system underlies our ability to perceive the sensations and emotions of others. For instance, it is possible to show that the same neurons become active when a person feels pain, or observes another feeling pain (Hutchinson et al, 1999).

Responding appropriately to the emotions of others is a contextually sensitive ability that humans are particularly skilled at from a very young age. Even newborns can locate human faces and imitate their facial gestures (Meltzoff and Moore, 1977). By 12 months, infants are able to interpret actions in context (Woodward and Somerville, 2000). By 18 months, they can understand what another person intends to do with an instrument, and they will complete a goal-directed behaviour that someone else fails to complete (Meltzoff, 1995, Herrmann et al, 2007).

No matter how good a machine is at classifying expressions or even responding with matching expressions, children require an understanding of the reasons for their emotional signals. A good carer's response is based on grasping the cause of emotions rather than simply acting on the emotions displayed. We should respond differently to a child crying because she has lost her toy than because she has been abused. A child may over-react to a small event and a caring human may realise that there is something else going on in the child's life like the parents having a row the night before. Appropriate responses require human common sense reasoning over a very large, possibly infinite, number of circumstances to ascertain what may have caused an unhappy expression. "Come on now, cheer up", might not always be the best response to a sad face.

A human carer may not get a full and complete understanding of the context of an emotion every time but they will make good guess with a high hit rate and can then recalculate based on the child's subsequent responses.

Advances in natural language processing using statistical methods to search databases containing millions of words could lead to superficially convincing conversations between robots and children in the near-future. However we should not mistake such interactions as being meaningful in the same way as caring adult-child interactions. It is one thing for a machine to give a convincing conversational response to a remark or question and a completely different thing to provide appropriate guidance or well founded answers to puzzling cultural questions. There are many cues that an adult human uses to understand what answer the child requires and at what level.

Language interactions between very young children and adults are transactional in nature – both participants change over time. Adults change register according to the child's abilities and understanding. They continuously assess the child's comprehension abilities through both language and non-verbal cues and push the child's understanding along. This is required both for language development and cognitive development in general. It would be extremely difficult to find specifiable rules that a robot could apply for transactional communication to adequately replace a carer's intuitions about appropriate guidance.

The consequence for children of contingent but inappropriate responses could be an *insecure* attachment called 'anxious avoidant attachment'. Typically, mothers with insecurely attached children are, "less able to read their infant's behaviour, leading them to try to socialise with the baby when he is hungry, play with him when he is tired, and feed him when he is trying to initiate social interaction" (Ainsworth et al, 1974 p 129). Babies with withdrawn or depressed mothers are more likely to suffer aberrant forms of attachment: avoidant, or disorganised attachment (Martins and Gaffan, 2000).

'Maternal sensitivity'[1] provides a detailed understanding of an infant's emotional state. Responses need to be tailor made for each child's particular personality. A timid child will need a different response from an outgoing one, and a tired child needs different treatment from a bored one. Off-the-shelf responses, however benign, will not create secure attachment for a child: "If he's bored he needs a distraction. If he's hungry he needs food. If he has caught his foot in a blanket, it needs releasing. Each situation requires its own tailor made response, suitable for the personality of a particular baby. Clearly, it isn't much use being given a rattle when you are hungry, nor being rocked in your basket if your foot is uncomfortably stuck" (Gerhardt, 2004 pp 197).

Another important aspect of maternal sensitivity is the role played by "mind-mindedness", or the tendency of a mother to "treat her infant as an individual with a mind rather than merely as a creature with needs that must be satisfied" (Meins et al, 2001). Mind-mindedness has also been shown to be a predictor of the security of attachment between the infant and mother. It comes from the human ability to form a theory of mind based on knowledge of one's own mind and the experience of others. It allows predictions about what an infant may be thinking or intending by its actions, expressions and body language. A machine without a full blown theory of mind (or a mind) could not easily demonstrate mind-mindedness.

Other types of insecure attachment are caused by not paying close enough attention to a child's needs. If the primary carer responds unpredictably, it can lead to an ambivalent attachment where the child tends to overly cling to her caregiver and to others. More recently, a fourth attachment category, disorganised attachment, has been identified (Solomon and George, 1999; Schore, 2001). It tends to result from parents who are overtly hostile and frightening to their children, or who are so frightened themselves that they cannot attend to their children's needs. Children with disorganised attachment have no consistent attachment behaviour patterns.

While it seems unlikely that a robot could show a sufficient level of sensitivity to engender secure attachment, it could be argued that the robot is only be standing in for the mother in the same way as a human nanny stands in. But a poor nanny can also cause emotional or psychological damage to a child. Children and babies are resilient but there is clear evidence that children do better when placed with childminders who are highly responsive to them. Elicker et al (1999) found that the security of attachment of children (aged 12 to 19 months) to their childcare providers varied depending on the quality of their interactions. Dettling et al (2000) studied children aged between 3 and 5 years old in home-based day care. They found that when they were looked after by a focused and responsive carer, their stress levels, as measured by swabbing them for cortisol, were similar to those of children cared for at home by their mother. In contrast, cortisol testing of children cared for in group settings with less focused attention, indicated increased levels of stress. Belsky et al (2007) found that children between 4.5 and 12 years old were more likely to have problems, as reported by

[1] Maternal sensitivity is a term used even when the primary carer is not the "mother".

teachers, if they had spent more time in childcare centres. At the same time they found that an effect of higher quality care showed up in higher vocabulary scores.

Thus even regular part-time care by a robot may cause some stress and minor behavioural problems for children. But we are not suggesting that occasional use will be harmful, especially if the child is securely attached to their primary carer; it may be no more harmful than watching television for a few hours. However, it is difficult at present, without the proper research, to compare the impact of passive entertainment to a potentially damaging relationship with an interactive artefact. The impact will depend on a number of factors such as the age of the child, the type of robot and the tasks that the robot performs.

In our earlier discussion of robot-child interaction research, we noted claims that children had formed bonds and friendships with robots. However, in such research, the terms ‘attachment’, ‘bonding’ and ‘relationship’ are often used in a more informal or different way than in developmental psychology. This makes it difficult to join them at the seams. Attachment theorists are not just concerned with the types of attachment but also with their consequences. As Fonagy (2003) pointed out, attachment is not an end in itself, although secure attachment is associated with better development of a wide range of abilities and competencies. Secure attachment provides the opportunity “to generate a higher order regulatory mechanism: the mechanism for appraisal and reorganisation of mental contents” (Fonagy, 2003 pp 230).

A securely attached child develops the ability to take another’s perspective. When the mother, or carer, imitates or reflects their baby’s emotional distress in their facial expression, it helps the baby to form a representation of their own emotions. This social biofeedback leads to the development of a second order symbolic representation of the infant’s own emotional state (Fonagy, 2003; Gergely and Watson, 1996, 1999), and facilitates the development of the ability to empathise, and understand the emotions and intentions of others. These are not skills that any near-future robot is likely to have.

When a young child encounters unfamiliar, or ambiguous circumstances, they will, if securely attached, look to their caregiver for clues about how to behave. This behaviour is termed “social referencing” (Feinman 1982). The mother or carer provides clues about the dangers, or otherwise of the world, particularly by means of their facial expressions. For example, Hornik et al (1987) found that securely attached infants, played more with toys that their mothers made positive emotional expressions about, and less with those that received negative expressions. A more convincing example of the powerful effect of social referencing is provided by research using a Gibson visual cliff. The apparatus, frequently used in depth-perception studies, gives the child an illusion of a sheer drop onto the floor (the drop is actually made safe by being covered with a clear plexiglass panel). Ten month olds will look at their mother’s face, and continue to crawl over the apparent perilous edge towards an attractive toy if their mothers smile and nod. They back away if their mothers look fearful or doubtful (Scorce et al, 1985).

It would certainly be possible to create a robot that provided facial indications of approval or disapproval of certain actions for the child. But before a robot can approve or disapprove, it needs to be able to predict and recognise what action the child is intending. And even if it could predict accurately, it would need to have a sense of what is or is not a sensible action for a given child in a particular circumstance. With such a wide range and large number of possible actions that a child could intend, it seems unlikely that we could devise a robot system to make appropriate decisions. As noted from the studies cited above, it is important that responses are individually tailored, sensitive to the child's needs, consistent and predictable.

4.1 Is robot care better than minimal care?

Despite the drawbacks of robot care, it could be argued that it would be preferable and less harmful than leaving a child with minimal human contact. Studies of the shocking conditions in Romanian orphanages show the effects of extreme neglect. Nelson et al (2007) compared the cognitive development of young children reared in Romanian institutions to that of those moved to foster care with families. Children were randomly assigned to be either fostered, or to remain in institutional care. The results showed that children reared in institutions manifested greatly diminished intellectual performance (borderline mental retardation) compared to children reared in their original families. Chugani et al (2001) found that Romanian orphans who had experienced virtually no mothering, differed from children of comparable ages in their brain development – and had less active orbitofrontal cortex, hippocampus, amygdala and temporal areas.

But would a robot do a better job than scant human contact? We have no explicit evidence but we can get some clues from animal research in the 1950s when they were less concerned about ethical treatment. Harlow (1959) compared the effect on baby monkeys of being raised in isolation with two different types of artificial "mother": a wire-covered, or a soft terry-cloth covered wire frame surrogate "mother". Those raised with the soft mother substitute became attached to it, and spent more time with it than with the wire covered surrogate even when the wire surrogate provided them with their food. Their attachment to the surrogate was demonstrated by their increased confidence when it was present – they would return and cling to it for reassurance, and would be braver – venturing to explore a new room and unfamiliar toys, instead of cowering in a corner. The babies fed quickly from the wire surrogate and then returned to cuddle and cling to the terry cloth one.

This suggests that human infants might do better with a robot carer than with no carer at all. But the news is not all good. Even though the baby monkeys became attached to their cloth covered surrogates, and obtained comfort and reassurance from them, they did not develop normally. They exhibited odd behaviours and "displayed the characteristic syndrome of the socially-deprived macaque: they clutched themselves, engaged in non-nutritive sucking, developed stereotyped body-rocking and other abnormal motor acts, and showed aberrant social responses" (Mason and Berkson, 1975).

Although Harlow's monkeys clearly formed attachments to inanimate surrogate mothers, the surrogates left them seriously lacking in the skills needed to reach successful maturity. Of course, a robot nanny could be more responsive than the cuddly surrogate statues. In fact when the surrogate terry-cloth mother was hung from the ceiling so that the baby monkeys had to work harder to hug it as it swung, they developed more normally that when the surrogate was stationary (Mason and Berkson, 1975). But these were not ideal substitutes for living mothers. The monkeys did even better when they were raised in the company of dogs which were not mother substitutes at all.

We could conclude that robots would be better than nothing in horrific situations like the Romanian orphanages. But they would really need to be a last resort. Without systematic experimental work we cannot tell whether or not exclusive care by a robot would be pathogenic. It is even possible that the severe deprivation exclusive care might engender could lead to the type of impaired development pattern found in Reactive Attachment Disorder (RAD) (Zeanah et al, 2000). RAD was first introduced in DSM-III (American Psychiatric Association, 1980). The term is used in both the World Health Organization's International Statistical Classification of Diseases and Related Health Problems (ICD-10) and in the DSM-IV-TR, (American Psychiatric Association, 1994).

Reactive Attachment Disorder is defined by inappropriate social relatedness, as manifest either in (i) failure to appropriately initiate or respond to social encounters, or (2) indiscriminate sociability or diffuse attachment. Although Rushton and Mayes (1997) warn against the overuse of the diagnosis of RAD it is still possible that the inappropriate and exclusive care of a child by a robot could lead to behaviour indicative of RAD.

Another worry is that a “robots are better than nothing” argument could lead to a more widespread use of the technology in situations where there is a shortage of funding, and where what is actually needed is more staff and better regulation. It is a different matter to use a teleoperated robot as a parental stand in for children who are in hospitals, perhaps quarantined or whose parent needs to be far away. Robots under development like the MIT Huggable (Stiehl *et al*. 2005; 2006) or the Probo (Goris *et al*. 2008; 2009) fulfil that role and allow carers to communicate and hug their children remotely. Such robots do not give rise to the same ethical concerns as exclusive or near exclusive care by autonomous robots.

Overall, the evidence presented in this section points to the kinds of emotional harm that robot carers might cause if infants and young children, lacking appropriate human attachment, were overexposed to them at critical periods in their development. We have reviewed evidence of the kinds of human skills and sensitivities required to create securely attached children and compared these with current robot functionality. While we have no direct experimental support as yet, it seems clear that the robots lack the necessary abilities to adequately replace human carers. Given the potential dangers, much more investigation needs to be carried out before robot nannies are freely available on the market.

5. Legal protections and accountability

The whole idea of robot childcare is a new one and has not had time to get into the statute books. There have been no legal test cases yet and there is little provision in the law. The various international nanny codes of ethics (e.g. FICE Bulletin 1998) do not deal with the robot nanny but require the human nanny to ensure that the child is socialised with other children and adults and that they are taught social responsibility and values. These requirements are not enforceable by the law.

There are a number of variations in the laws for child protection of different European countries, USA and other developed countries, but essentially legal cases against the overuse of robot care would have to be mounted on grounds of neglect, abuse or mistreatment and perhaps on grounds of retarding social and mental development. The National Society for the Prevention of Cruelty to Children (NSPCC) in the UK regards neglect as “the persistent lack of appropriate care of children, including love, stimulation, safety, nourishment, warmth, education and medical attention. It can have a serious effect on a child's physical, mental and emotional development. For babies and very young children, it can be life-threatening."

There are currently no international guidelines, codes of practice or legislation specifically dealing with a child being left in the care of a robot. There has been talk from the Japanese Ministry of Trade and Industry (Lewis, 2007), and the South Korean Ministry of Economy, Trade and Industry (Yoon-mi, 2007) about drawing up ethical and safety guidelines. The European Robotics Research Network also suggests a number of areas in robotics needing ethical guidelines (Verrogio, 2006) but no guidelines or codes have yet appeared from any of these sources. Some even argue that, "because different cultures may disagree on the most appropriate uses for robots, it is unrealistic and impractical to make an internationally unified code of ethics." (Guo and Zhang, 2009). There is certainly some substance to this argument as Guo and Zhang (2009) point out, "the value placed on the development of independence in infants and toddlers could lead to totally divergent views of the use of robots as caregivers for children." However, despite cultural differences, we believe that there are certain inviolable rights that should be afforded to all children regardless of culture, e.g. all children have a right not to be treated cruelly, neglected, abused or emotionally harmed

The United Nations Convention on the Rights of the Child gives 40 major rights to children and young persons under 18. The most pertinent of these is Article 19 which states that, Governments must do everything to protect children from all forms of violence, abuse, neglect and mistreatment. Article 27 requires that, "States Parties recognize the right of every child to a standard of living adequate for the child's physical, mental, spiritual, moral and social development". These articles could be seen to vaguely apply to the care of children by robots but it is certainly far from being clear.

In the USA, Federal legislation identifies a minimum set of acts or behaviors that define child abuse and neglect. The Federal Child Abuse Prevention and Treatment Act (CAPTA), (42 U.S.C.A. §5106g), as amended by the Keeping Children and Families Safe Act of 2003, defines child abuse and neglect as, at minimum:

- Any recent act or failure to act on the part of a parent or caretaker which results in death, serious physical or emotional harm, sexual abuse or exploitation; or
- An act or failure to act which presents an imminent risk of serious harm.

Under US federal law, neglect is divided into a number of different sections. The most appropriate for our purposes, and one that does not appear under UK or European law, is *emotional or psychological abuse*. Emotional or psychological abuse is defined as, "a pattern of behavior that impairs a child's emotional development or sense of self-worth." This may include constant criticism, threats, or rejection, as well as withholding love, support, or guidance. Emotional abuse is often difficult to prove and, therefore, child protective services may not be able to intervene without evidence of harm or mental injury to the child. Emotional abuse is almost always present when other forms are identified." (What is Child Abuse and Neglect Factsheet).

Although much of the research on child-robot interaction has been conducted in the USA, the main manufacturers and currently the main target audience is in Japan and South Korea. As in the other countries mentioned, the only legislation available to protect Japanese children from overextended care by robots is the Child Abuse

Prevention Law 2000. "The Law defines child abuse and neglect into four categories: (i) causing external injuries or other injuries by violence; (ii) committing acts of indecency on a child or forcing a child to commit indecent acts; (iii) neglecting a child's needs such as meals, leaving them for a long time, etc.; and (iv) speaking and behaving in a manner which causes mental distress for a child." (Nakamura, 2002).

In South Korea it may be harder to prevent the use of extended robot childcare. Hahm and Guterman (2001) point out that "South Korea has had a remarkably high incidence and prevalence rates of physical violence against children, yet the problem has received only limited public and professional attention until very recently" (p 169). The problem is that "South Koreans strongly resist interference in family lives by outsiders because family affairs, especially with regard to child-rearing practices are considered strictly the family's own business." The one place where it might be possible to secure a legal case against near-exclusive care by robots is in the recently revised Special Law for Family Violence Criminal Prohibition (1998). This includes the Child Abuse and Neglect Prevention Act which is similar to the laws of other civilised countries: "the new law recognises that child maltreatment may entail physical abuse, sexual abuse, emotional abuse or neglect".

In the UK, a case against robot care would have to be built on provisions in the Children and Young Persons Act (1933 with recent updates) for leaving a child unsupervised "in a manner likely to cause unnecessary suffering or injury to health". The law does not even specify at what age a person can be a baby sitter; it only states that when a baby-sitter is under the age of 16 years old, the parents of the child being "sat" are legally responsible to ensure that the child does not come to harm.

Under UK law, a child does not have to suffer actual harm for a case of neglect to be brought. It is sufficient to show that the child has been kept in, " a manner likely to cause him unnecessary suffering and injury to health", as in the case of R v Jasmin, L (2004) 1CR, App.R (s) 3. The Appellants had gone to work for periods of up to 3 hours leaving their 16 month old child alone in the home. This happened on approximately three separate occasions. The Appellants were both found guilty of offences relating to neglect contrary to S1(1) Children and Young Persons Act 1933 and were sentenced to concurrent terms of 2 years imprisonment. Summing up, Lord Justice Law said that, "… there was no evidence of any physical harm resulting from this neglect [but] …both parents had difficulty in accepting the idea that their child was in any danger".

The outcome would have been different if the parents had left the child alone in exactly the same way but had stayed at home in a different room. If they could have shown that they were monitoring the child with a baby monitor (and perhaps a CCTV camera), the case against them would have been weak and it is highly unlikely that they would have been prosecuted.

This case is relevant for the protection of children against robot care because near future-robots, as discussed earlier, could provide safety from physical harm and allow remote monitoring combined with autonomous alerting and a way for the parents to remotely communicate with their children. The mobile remote monitoring available on a robot would be significantly better than a static camera and baby monitor. If absent parents had such a robot system and could reach the child within a couple of minutes, it would be difficult to prove negligence. The time to get home is probably crucial. We could play the game of gradually moving the parents' place of work further and further away to get a threshold time of permissibility. It then becomes like the discussion of how many hairs do you have to remove from someone's head before they can be called bald. These are the kind of issues that will only be decided by legal precedence.

Another important question about robot care is, who would be responsible and accountable for psychological and emotional harm to the child? Under current legislations it would be the parents or primary carers. But it may not be fair to hold parents or primary carers entirely responsible. Assuming that the robot could demonstrably keep the child safe from physical harm, the parents may have been mislead by the nature of the product. For example, if a carer's anthropomorphism had been amplified as a result of some very clever robot-human interaction, then that carer may have falsely believed that the robot had mental states, and could form 'real' relationships.

This leads to problems in determining accountability beyond the primary carer. Allocating responsibility to the robot would be ridiculous. That would be like holding a knife responsible for a murder – we not are talking about hypothetical sentient robots here. But blaming others also has its difficulties. There is a potentially long chain of responsibility that may involve the carer, the manufacturer and a number of a third parties such as the programmers and the researchers who developed the kit. This is yet another of the many reasons why there is a need to examine the ethical issues before the technology is developed for the mass market. Codes of practice and even legislation are required to ensure that the advertising claims are realistic and that the product contains warnings about potential danger of overuse.

If a case of neglect is eventually brought to court because of robot care, a large corporation with commercial interests may put the finest legal teams to work. Their argument could be based on demonstrating that a robot could both keep a child safe from physical harm and alert a designated adult about imminent dangers in time for intervention. It would be more difficult to prove emotional harm because many children have emotional problems regardless of their upbringing. Pathological states can be genetic in origin or result from prenatal brain damage among other possible causes. Thus a legal case of neglect is most likely to be won if an infant or a baby is discovered at home alone with an unsafe robot.

6. Conclusions

We have discussed a trajectory for childcare robotics that appears to be moving towards sustained periods of care with the possibility of near-exclusive care. We examined how child care robots could be developed to keep children safe from physical harm. Then we looked at research that showed children forming relationships and friendships with robots and how they came to believe that the robots had mental states. After that, we examined the functionality of current child care robots and discussed how these could be extended in the near future to create more 'realistic' interactions between children and robots, and intensify the illusion of genuine relationships.

Our main focus throughout has been on the potential ethical risks that robot child care poses. The ethical problems discussed here could be among those that society will have to solve over the next 20 years. The main issues and questions we raised were:

- Privacy: every child has a right to privacy under Articles 16 and 40 of the UN Convention on Child Rights. How much would the use of robot nannies infringe these rights?
- Restraint: There are circumstances where a robot could keep a child from serious physical harm by restraining her. But how much autonomous decision authority should we give to a robot childminder?
- Deception: Is it ethically acceptable to create a robot that fools people into believing that it has mental states and emotional understanding? In many circumstances this can be considered to be natural anthropomorphism, illusion and fun pretence. Our concerns are twofold (i) it could lead parents to overestimate the capabilities of a robot carer and to imagine that it could meet the emotional needs of a child and (ii) it could lure a child into a false relationship that may possibly damage her emotionally and psychologically if the robot is overused for her care.
- Accountability: Who is morally responsible for leaving children in the care of robots? The law on neglect puts the duty of care on the primary carer. But should the primary carer shoulder the whole moral burden or should others, such as the manufacturers, take some share in the responsibility?
- Psychological damage: Is it ethically acceptable to use a robot as a nanny substitute or as a primary carer? This was the main question explored. If our analysis of the potentially devastating psychological and emotional harm that could result is correct, then the answer is a resounding 'no'.

In our exploration of the developmental difficulties that could be caused by robot care, we have assumed that it would be regular daily and possibly near exclusive care. We also discussed evidence that part-time outside care can cause children minor harm that they can later recover from. Realistically a couple of hours a day in the care of a robot are unlikely to be any more harmful than watching television - if we are careful about what we permit the robot to do. We just don't know if there is a continuum between the problems that could arise with exclusive care and those that may arise with regular short-time care.

In a brief overview of international laws, we found that the main legal protection that children have is under the laws of neglect. A major concern was that as the robots become safer and can protect children from physical harm and make sure that they are fed and watered, it will become harder to make a case for neglect. However, the quality of robot interaction we can expect, combined with the evidence from developmental studies on attachment, suggest that robots would at best be insensitive carers unable to respond with sufficient attention to the fine detailed needs of individual children.

As we stated at the outset, we are seeking discussion of these matters rather than attempting to offer answers or solutions. The robotics community needs to consider questions like the ones we have raised, and take them up, where possible, with their funders, the public and policy makers. Ultimately, it will be up to society, the legislature and professional bodies to provide codes of conduct to deal with future robot childcare.

References

Ainsworth, M., Blehar, M., Waters, E. and Wall, S. (1978) *Patterns of attachment: a psychological study of the strange situation.* Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Ainsworth, M. D. S., Bell, S. M., & Stayton, D. J. (1974). Infant-mother attachment and social development: Socialisation as a product of reciprocal responsiveness to signals. In M. P. M. Richards (Ed.), *The introduction of the child into a social world*. London: Cambridge University Press.

Bartlett, M.S., Littlewort-Ford, G.C., and Movellan, J.R. (2008). Computer Expression Recognition Toolbox. Demo: *8th Int'l IEEE Conference on Automatic Face and Gesture Recognition.* Amsterdam

Belsky, J., Vandell, D.L., Burchinal, M., Clarke-Stewart, K.A., McCartney, K., Owen, M.T. (2007) Are there long-term effects of early child care? *Child Development*, 78 (2), 681-701.

Blum, D. (2003) *Love at Goon Park: Harry Harlow and the Science of Affection*. John Wiley: Chichester, England.

Bowlby, J. (1969) *Attachment and Loss: Volume 1: Attachment*. London: Hogarth Press.

Bowlby, J. (1980) *Attachment and Loss: Volume 3: Loss*. London: Hogarth Press.

Bowby, J. (1998) (edition originally 1973) *Attachment and Loss: Volume 2: Separation, anger and anxiety*. London: Pimlico.
Caggiano, V., Fogassi, L., Rizzolatti, G., Thier, P., & Casile, A. (2009). Mirror neurons differentially encode peripersonal and extrapersonal space of monkeys. *Science*, Vol. 324, pp. 403- 406.

Cayton, H. (2006) From childhood to childhood? Autonomy and dependence through the ages of life. In Julian C. Hughes, Stephen J. Louw, Steven R. Sabat (Eds) *Dementia: mind, meaning, and the person*, Oxford, UK: Oxford University Press 277-286

Children and Young Persons Act 1933 UK Statute Law Database, Part 1 Prevention of cruelty and exposure to moral and physical danger: Offences: 12 *Failing to provide for safety of children at entertainments*. http://www.statutelaw.gov.uk/legResults.aspx?LegType=All+Legislation&searchEnacted=0&extentMatchOnly=0&confersPower=0&blanketAmendment=0&sortAlpha=0&PageNumber=0&NavFrom=0&activeTextDocId=1109288

Chugani, H., Behen, M., Muzik, O., Juhasz, C., Nagy, F and Chugani, D. (2001) Local brain functional activity following early deprivation: a study of post-institutionalised Romanian orphans. *Neuroimage,* 14: 1290-1301.

Cramer, H. S., Kemper, N. A., Amin, A., and Evers, V. (2009) The effects of robot touch and proactive behaviour on perceptions of human-robot interactions. In *Proceedings of the 4th ACM/IEEE international Conference on Human Robot interaction* (La Jolla, California, USA, March 09 - 13, 2009). HRI '09. ACM, New York, NY, 275-276.

Dautenhahn, K., Werry, I. (2004) Towards Interactive Robots in Autism Therapy: Background, Motivation and Challenges. *Pragmatics and Cognition* 12(1), pp. 1-35.

Dautenhahn, K. (2003) Roles and Functions of Robots in Human Society - Implications from Research in Autism Therapy. *Robotica* 21(4), pp. 443-452.

Dettling, A., Parker, S., Lane, S., Sebanc, A., & Gunnar, M. (2000). Quality of care determines whether cortisol levels rise over the day for children in full-day childcare. *Psychoneuroendocrinology*, 25, 819±836.

Ekman P. and Friesen, W. (1978) *Facial Action Coding System: A Technique for the Measurement of Facial Movement*, Consulting Psychologists Press, Palo Alto, CA

Elicker, J., Fortner-Wood, C., and Noppe, I.C. (1999) The context of infant attachment in family child care. *Journal of Applied Developmental Psychology,* 20, 2, 319-336

Feinman, S., Roberts, D., Hsieh, K. F., Sawyer, D. And Swanson, K. (1992), "A critical review of social referencing in infancy," in *Social Referencing and the Social Construction of Reality in Infancy*, S. Feinman, Ed. New York: Plenum Press.

Fice Bulletin (1998) *A Code of Ethics for People Working with Children and Young People.* http://www.ance.lu/index.php?option=com_content&view=article&id=69:a-code-of-ethics-for-people-working-with-children-and-young-people&catid=10:fice-declaration-2006&Itemid=29

Fonagy, P., (2003) The development of psychopathology from infancy to adulthood: The mysterious unfolding of disturbance in time. *Infant Mental Health Journal* Volume 24, Issue 3, Date: May/June 2003, Pages: 212-239

Fong. T., Nourbakhsh, I., and Dautenhahn, K. (2003) A Survey of Socially Interactive Robots, *Robotics and Autonomous Systems* 42(3-4), 143-166.

Gallese, V. (2001) The shared manifold hypothesis: From mirror neurons to empathy. *Journal of Consciousness Studies*, 8, 33-50.

Gergely, G., & Watson, J. (1996). The social biofeedback model of parental affect-mirroring. *International Journal of Psycho-Analysis* , **77**, 1181-1212.

Gergely, G., & Watson, J. (1999). Early social-emotional development: Contingency perception and the social biofeedback model. In P. Rochat (Ed.), *Early social cognition: Understanding others in the first months of life* (pp. 101-137). Hillsdale, NJ: Erlbaum.

Gerhardt, S. (2004) *Why love matters: how affection shapes a baby's brain*. Routledge Taylor and Francis Group, London and New York.

Goris, K., Saldien, J., Vanderniepen, I., and Lefeber, D. (2008) . The Huggable Robot Probo, a Multi-disciplinary Research Platform. *Proceedings of the EUROBOT Conference 2008*, Heidelberg, Germany, 22-24 May, 2008, pages 63-68..

Goris, K., Saldien, J., and Lefeber, D. 2009. Probo: a testbed for human robot interaction. In *Proceedings of the 4th ACM/IEEE international Conference on Human Robot interaction* (La Jolla, California, USA, March 09 - 13, 2009). HRI '09. ACM, New York, NY, 253-254.

Guo, S. and Zhang, G. (2009) Robot Rights, Letter to *Science*, 323, 876

Hello kitty web reference
http://www.dreamkitty.com/Merchant5/merchant.mvc?Screen=PROD&Store_Code=DK2000&Product_Code=K-EM070605&Category_Code=HKDL

Hermann, E., Call, J., Hare, B., and Tomasello, M. (2007) Human evolved specialized skills of social cognition: The cultural intelligence hypothesis. *Science*, 317(5843), 1360-1366.

Hertenstein, M.J. (2002) Touch: its communicative functions in infancy, *Human Development*, 45, 70-92.

Hertenstein, M.J., Verkamp, J.M., Kerestes, A.M., and Holmes, R.M. (2006) 'The communicative functions of touch in humans, nonhuman primates, and rats: A review and synthesis of the empirical research', *Genetic, Social & General Psychology Monographs*, 132(1), 5–94.

Hornik, R., Risenhoover, N., & Gunnar, M. (1987). The effects of maternal positive, neutral, and negative affective communications on infant responses to new toys. *Child Development, 58*, 937-944.

Hutchinson, W., Davis, K., Lozano, A., Tasker, R., and Dostrovsky, J. (1999) Pain-related neurons in the human cingulated cortex. *Nature Neuroscience*, 2, 403-5.

Kahn, P. H., Jr., Friedman, B., Perez-Granados, D., & Freier, N. G. (2006). Robotic pets in the lives of preschool children. *Interaction Studies, 7*(3), 405-436.

Kanda, T., Nishio, S., Ishiguro, H., and Hagita, N. (2009) Interactive Humanoid Robots and Androids in Children's Lives. *Children, Youth and Environments,* 19 (1), 12-33. Available from: www.colorado.edu/journals/cye.

Lewis, L. (2007) The robots are running riot! Quick, bring out the red tape, The Times Online, April 6th http://www.timesonline.co.uk/tol/news/world/asia/article1620558.ece

Liu, C., Conn, K., Sarkar, N., and Stone, W. (2008) Online affect detection and robot behaviour adaptation for intervention of children with autism. *IEEE Transactions on Robotics*, Vol. 24, Issue 4, pp. 883-896.

Lopes, M. M., Koenig, N. P., Chernova, S. H., Jones, C. V., and Jenkins, O. C. (2009). Mobile human-robot teaming with environmental tolerance. In *Proceedings of the 4th ACM/IEEE international Conference on Human Robot interaction* (La Jolla, California, USA, March 09 - 13, 2009). HRI '09. ACM, New York, NY, 157-164.

Marti, P., Palma, V., Pollini, A., Rullo, A. and Shibata, T. (2005) My Gym Robot, *Proceeding of the Symposium on Robot Companions: Hard Problems and Open Challenges in Robot-Human Interaction,* pp.64-73,

Martins, C. and Gaffan, E.A. (2000) Effects of early maternal depression on patterns of infant-mother attachment: A meta-analytic investigation, *Journal of Child Psychology and Psychiatry* 42, pp. 737–746.

Mason, W.A. and Berkson, G. (1975) Effects of Maternal Mobility on the Development of Rocking and Other Behaviors in Rhesus Monkeys: A Study with Artificial Mothers. *Developmental Psychobiology* 8, 3, 197-211.

Mason, W.A. (2002) The Natural History of Primate Behavioural Development: An Organismic Perspective. In Eds. D. Lewkowicz and R. Lickliter, *Conceptions of Development: Lessons from the Laboratory.* Psychology Press. 105-135.

Mavridis, N., Chandan, D., Emami, S., Tanoto, A., BenAbdelkader, C. and Rabie, T. (2009) FaceBots: Robots Utilizing and Publishing Social Information in Facebook. *HRI'09*, March 11–13, 2009, La Jolla, California, USA. ACM 978-1-60558-404-1/09/03.

Melson, G. F., Kahn, P. H., Jr., Beck, A. M., & Friedman, B. (in press a). Robotic pets in human lives: Implications for the human-animal bond and for human relationships with personified technologies. *Journal of Social Issues*.

Melson, G. F., Kahn, P. H., Jr., Beck, A. M., Friedman, B., Roberts, T., Garrett, E., & Gill, B. T. (in press b). Robots as dogs? - Children's interactions with the robotic dog AIBO and a live Australian shepherd. *Journal of Applied Developmental Psychology*

Mercer, J. (in press for 2010), Attachment theory, *Theory and Psychology*, Meins, E., Fernyhough, C., Fradley, E. and Tuckey, M. (2001) Rethinking maternal sensitivity: mothers' comments on infants' mental processes predict security of attachment at 12 months. *Journal of Child Psychology and Psychiatry* 42, pp 637-48.

Meltzoff, A.N. (1995) Understanding the intention of others: Re-enactment of intended acts by 18 month old children. *Developmental Psychology* 32, 838-850.

Meltzoff, A.N. and Moore, M.K. (1977) Imitation of facial and manual gestures by human neonates. *Science*, 198, 75-78.

Mitsunaga, N., Miyashita, T., Ishiguro, H., Kogure, K., and Hagita, N. (2006) Robovie-IV: A Communication Robot Interacting with People Daily in an Office, In *Proc of IROS*, 5066-5072

Nakamura, Y. (2002) Child abuse and neglect in Japan, *Pediatrics International*, 44, 580-581.

Nelson, C.A., Zeanah, C.H., Fox, N.A., Marshall, P.J., Smyke, A.T. and Guthrie, D. (2007) Cognitive recovery in socially deprived young children: The Bucharest early intervention project. *Science*, 318, no 5858, pp 1937-1940.

Orpwood, R., Adlam, T., Evans, N., Chadd, J. (2008) Evaluation of an assisted-living smart home for someone with dementia. *Journal of Assistive Techologies*, 2, 2, 13-21.

Rocks, C. L., Jenkins, S., Studley, M. and McGoran, D. (in press).'Heart Robot', a public engagement project. Robots in the Wild: Exploring Human-Robot Interaction in Naturalistic Environments. Special Issue of *Interaction Studies*

Rushton, A. and Mayes, D. 1997. Forming Fresh Attachments in Childhood: A Research Update. Child and Familiy Social Work 2(2):121-127.

Sharkey, N. (2008a**)** The Ethical Frontiers of Robotics, *Science*, 322. 1800-1801.

Sharkey, N (2008b) Cassandra or False Prophet of Doom: AI Robots and War, *IEEE Intelligent Systems,* vol. 23, no, 4, 14-17, July/August Issue

Sharkey, N. and Sharkey, A. (in press) Living with robots: ethical tradeoffs in eldercare, In Wilks, Y. *Artificial Companions in Society: scientific, economic, psychological and philosophical perspectives.* Amsterdam: John Benjamins

Sharkey, N., and Sharkey, A. (2006) Artificial Intelligence and Natural Magic, *Artificial Intelligence Review,* 25, 9-19.

Shibata, T., Mitsui, T., Wada, K., Touda, A., Kumasaka, T., Tagami, K. and Tanie, K. (2001) Mental Commit Robot and its Application to Therapy of Children, Proc. of 2001 *IEEE/ASME Int. Conf. on Advanced Intelligent Mechatronics*, pp.1053-1058.

Schore, A. (2001) The effects of early relational trauma on right brain development, affect regulation, and infant mental health. *Infant Mental Health Journal*, 22, 1-2, pp 201-69.

Scorce, J. F., Ernde, R. N., Campos, J., & Klinnert, M. D. (1985). Maternal emotional signaling: Its effect on the visual cliff behavior of 1-year-olds. *Developmental Psychology, 21*(1), 195-200.

Solomon, J. and George, C. (eds) (1999) *Attachment Disorganisation*, New York: Guilford Press.

Sparrow, R. (2002) 'The March of the Robot Dogs', *Ethics and Information Technology* , Vol. 4. No. 4, pp. 305-318

Stiehl, W. D., Lieberman, J., Breazeal, C., Basel, L., and Lalla, L. (2005). The Design of the Huggable: A Therapeutic Robotic Companion for Relational, Affective Touch. AAAI Fall Symposium on Caring Machines: AI in Eldercare, Washington, D.C.

Stiehl, W. D., Breazeal, C., Han, K., Lieberman, J., Lalla, L., Maymin, A., Salinas, J., Fuentes, D., Toscano, R., Tong, C. H., and Kishore, A. 2006. The huggable: a new type of therapeutic robotic companion. In *ACM SIGGRAPH 2006 Sketches* (Boston, Massachusetts, July 30 - August 03, 2006). SIGGRAPH '06. ACM, New York, NY, 14.

Swartout-Corbeil, D.M. (2006) Attachment between infant and caregiver, In *The Gale Encyclopedia of Children's Health: Infancy through Adolescence*, MI: The Gale Group

Takayuki, K., Takuyaki, H., Eaton, D. and Ishiguro, H. (2004) Interactive robots as social partners and peer tutors for children: a field trial, *Human Computer Interaction*, 19, 16-84

Tanaka F., Cicourel, A. and Movellan, J. R. (2007). Socialization Between Toddlers and Robots at an Early Childhood Education Center. *Proceedings of the National Academy of Science*. Vol 194, No 46, 17954 x17958.

Turkle, S., Taggart, W., Kidd, C.D., Dasté, O. (2006a) Relational Artifacts with Children and Elders: The Complexities of Cybercompanionship. *Connection Science*, 18, 4, pp 347-362.

Turkle, S., Breazeal, C., Dasté, O., and Scassellati, B., (2006b) “First Encounters with Kismet and Cog: Children Respond to Relational Artifacts”. In *Digital Media: Transformations in Human Communication*, Paul Messaris and Lee Humphreys (eds.). New York: Peter Lang Publishing

United Nations Convention on the Rights of the Child, http://www2.ohchr.org/english/law/crc.htm

Verrugio, G. (2006) The EURON robotethics roadmap, *6th IEEE-RAS International Conference on Humanoid Robots*, 612-617

What is Child Abuse and Neglect Factsheet, http://www.childwelfare.gov/pubs/factsheets/whatiscan.cfm

Woodward, A.L. and Sommerville, J.A. (2000) Twelve-month-old infants interpret action in context. *Psychological Science*, 11, 73-77.

Yohanan, S., and MacLean, K.E. (2008) The Haptic Creature Project: Social Human-Robot Interaction through Affective Touch. In *Proceedings of the AISB 2008 Symposium on the Reign of Catz & Dogs: The Second AISB Symposium on the Role of Virtual Creatures in a Computerised Society*, volume 1, pages 7-11, Aberdeen, Scotland, UK, April, 2008.

Yohanan, S., Chan, M., Hopkins, J., Sun, H., and MacLean, K. (2005) Hapticat: Exploration of Affective Touch. In ICMI '05: *Proceedings of the 7th International Conference on Multimodal Interfaces,* pages 222-229, Trento, Italy, 2005.

Yoon-mi, K. (2007) Korea drafts "Robot Ethics Charter", *The Korea Herald*, April 28,

Yoshiro, U., Shinichi, O., Yosuke, T., Junichi, F., Tooru, I., Toshihro, N., Tsuyoshi, S., Junichi, O, (2005) Childcare Robot PaPeRo is designed to play with and watch over children at nursery, kindergarten, school and at home. Development of Childcare Robot PaPeRo, Nippon Robotto #Gakkai Gakujutsu Koenkai Yokoshu, 1-11.

Zeanah, C.H., Boris, N.W. and Lieberman, A.F. (2000) Attachment disorders of Infancy In Arnold J. Sameroff, Michael Lewis, Suzanne Melanie Miller (Eds) *Handbook of developmental psychopathology*, Birkhäuser, 2nd Edition