On the Possible Impact of Robotic Childcare on Children's Brain Development and the Relevance of Social Structures

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1. Introduction: How and why robots are used in childcare

For the sake of the present analysis, we define social robots as types of robots capable of performing tasks that generate responses in people who use them (Breazeal 2003; de Graaf, Allouch, and van Dijk 2016; David, Thérouanne, and Milhabet 2022). Importantly, social robots exhibit communicative skills, either linguistic or nonlinguistic, which facilitate their social interaction with users (Naneva et al. 2020). The acceptability of social robots depends on different factors, including the physical safety of using the robots (De Santis et al. 2008) and their psychological comfort for the user (Zanchettin, Bascetta, and Rocco 2013). To increase their acceptability, social robots may be designed with a humanoid appearance (Eyssel, Kuchenbrandt, and Bobinger 2011). Overall, data tend to show a tendency toward accepting the use of social robots in a number of contexts (Sarda Gou, Webb, and Prescott 2021; David, Thérouanne, and Milhabet 2022; Dosso, Bandari, Malhotra, Guerra, et al. 2022; Dosso, Bandari, Malhotra, Hoey, et al. 2022).

Childcare robots are robotic devices specifically designed to assist parents and caregivers in taking care of children. These robots can be equipped with various features such as telepresence and other remote monitoring capabilities, functions for entertainment and play, educational content, and basic caregiving functions such as feeding or changing diapers. Jieon Lee, Daeho Lee, and Jae-Gil Lee (2022) provide an extensive overview of proposed child-robot connections, describing ways in which robotic devices can be used in childcare. For example, in relation to babies and toddlers (Abe et al. 2018), robots can potentially promote effective learning in classroom environments (Fridin and Belokopytov 2013; Li

2015; Belpaeme et al. 2018), enhance the persuasive quality of conveyed messages (for better or for worse) (Bainbridge et al. 2010; Jo, Lee, and Lee 2014), reduce stress, provide emotional relief for children, and even act as their friends and help them build social bonds (Belpaeme et al. 2013), going beyond mere educational purposes and functioning as effective tools for helping children to develop their personalities. Robots can also support parent-child communication (Oonaka 2013), provide entertainment (Kahn et al. 2012; Mwangi et al. 2017; Venture et al. 2017), help with the maintenance of children's behavioral records (Shiomi and Hagita 2017), and be used for mental health interventions (Cabibihan et al. 2013; Clabaugh et al. 2018; Kabacinska, Prescott, and Robillard 2021). The authors argue that, in view of these possible benefits, social robots can play important roles in child development, combining both the acquisition of specific notions (i.e., educational/intellectual development) and the capacity for mature social and relational skills (i.e., wide sociocultural development).

Different reasons may justify the use of robots in childcare, including technical (e.g., the robots' reliability and functional efficiency), social (e.g., limited time for childcare in some families), and moral (e.g., the robots may avoid or minimize risks of misconduct such as harassment or verbal violence) reasons. On the other hand, objections to their use can be similarly construed: the robots may be technically unreliable and functionally inefficient, create an incentive for parents to spend even less time with and caring for the children, or make parents less sensitive to the importance of physically interacting with their children. The use of robots may also reduce the tenderness of personal contact, physical or verbal. An application area of special interest focuses on supporting parenting in dual-income home environments, where both parents work and have limited time to be with their children and perform parenting tasks. This is especially relevant in societies that do not offer easy and affordable access to high-quality childcare. These parents may be concerned that their limitations in this regard might hinder the children's intellectual and emotional development

(Henrich 2014; Hsin and Felfe 2014), and consequently may be more prone to use social robots designed to bridge this gap in nurturing (Kwak et al. 2008; Arroyo et al. 2017), in addition to, or instead of, other alternative forms of childcare.

The question arises how this partial replacement of human care by machine actions might affect the infant or child. As mentioned above, childcare robots can be equipped with systems for telepresence, offering parents the possibility to compensate for their physical distance, but the fact remains that robots physically replace human caretakers. Since the human physicality (the presence of a human body) of parental relationships may arguably be considered as crucial for their effectiveness (e.g., to fulfill a number of children's needs [see below]), its virtualization through childcare robots raises issues analogous to its complete replacement. That is to say, to the extent that children need body contact with their caretakers, the virtualization and the complete absence of the relationship with them have similar, if not the same, negative ethical valence.

Assuming, for the sake of the discussion, that the machines are technically safe (that they will not put the baby in the oven instead of the chicken, or put the diapers over the infant's face, for example), is this technical and social development positive from the child's point of view? For instance, does the use of childcare robots lead to the enrichment of psychological and social skills, or may it instead prevent or hinder them? Can we anticipate any significant societal benefits or drawbacks?

We shall address this kind of question from psychological, neuroscientific, ethical, cultural, and sociopolitical perspectives. Acknowledging that the use of robots to complement or replace human caregivers may have great value for caretakers (whether parents or significant others), not least in liberating women who presently carry most of the burden for childcare globally, our analyses will focus primarily on the needs of children. However, in the course of the discussion, broader sociopolitical implications of introducing human-machine replacements in childcare will also briefly be mentioned.

2. The infant brain

In order properly to evaluate the possible benefits and risks of introducing robots into childcare, there are several specific needs of infants and children that are important to consider in terms of infant brain development. The extent to which these needs are or can be met by robots is crucial to the relevance and value of using robots in childcare. There are several academic disciplines studying this, notably psychology and neuroscience. We shall describe some relevant neuroscientific data and theories that are well established and not subject to notable controversy.

Human brain maturation, including the formation of synapses, is both prenatal and postnatal; it is far from complete at birth. In the course of growing up, the infant develops a capacity to focus its attention. It learns to distinguish between and recognize objects in its environment, such as faces, and becomes aware of itself as standing in various relations to these objects. Conscious processing develops into auto-distinction (when "this-here" is distinguished from "that-there"). Further developed, the individual becomes aware of itself as a subject of experience and ascribes mental states to itself: auto-distinction evolves into self-awareness (when "this-here" becomes "I"), normally at around one and a half years of age (Lagercrantz 2005), and possibly even earlier (Falck-Ytter et al. 2006). From the age of six to twelve months, the child typically sees a "sociable playmate" in the mirror's reflection. Self-admiring and embarrassment usually begin at twelve months, and at fourteen to twenty months most children demonstrate avoidance behaviors. Finally, at eighteen months, half of the children recognize the reflection in the mirror as their own, and by twenty to twenty-four months, 65 percent of the children had developed a conception and a memory of their own reflection, revealed for instance by them trying to evince marks on their own nose, taking advantage, in all these instances, of their episodic memory abilities (see Tulving 1983).

Evolutionary and developmental data indicate the following levels of consciousness (Lou, Changeux, and Rosenstand 2017):

- *Minimal consciousness*, "characterized by the capacity to display spontaneous motor activity and to create representations, for instance, from visual and auditory experience, to store them in long-term memory and use them, for instance, for approach and avoidance behaviour and for what is referred to as exploratory behaviour" (Changeux 2006, 2240). According to Marco Bartocci et al. (2006) and Lagercrantz & Changeux (2009), the twenty-five-to-thirty-week preterm fetus shows signs of minimal consciousness.
- *Recursive consciousness*, characterized "by functional use of objects and by proto-declarative pointing; … elaborate social interactions, imitation, social referencing and joint attention; … the capacity to hold several mental representations in memory simultaneously, and … to evaluate relations of self; … elementary forms of recursivity in the handling of representations, yet without mutual understanding" (Changeux 2006, 2240). The newborn infant exhibits sensory awareness, the ability to express emotions and processes mental representations (i.e., of a pacifier), and the ability to differentiate between self- and non-self-touch (Rochat 2003).
- *Explicit self-consciousness*, "characterized by self-recognition in mirror tests and by the use of single arbitrary rules with self-other distinction" (Changeux 2006, 2240). This level of consciousness develops at the end of the second year, together with working and episodic memory and some basic aspects of language (Posner and Rothbart 2007; Lou, Changeux, and Rosenstand 2017).

- *Reflective consciousness*, which entails “theory of mind and full conscious experience, with first person ontology and reportability” (Changeux 2006, 2240). This level of consciousness fully develops three to five years after birth.

The postnatal development of the human brain lasts considerably longer than in any other animal and, of particular relevance to our present discussion, social contacts and activities are crucial for this development to take place in an efficient and healthy manner. The most intense development occurs during the first two years, but it continues after puberty, and the highest executive functions that are determined by the frontal lobe are not fully mature until the age of around twenty-five, or even later (Lagercrantz 2005, 145-48). The environment is important for this process to be efficient. If neural networks are not active, they vanish: *Use it or lose it!* as the mantra goes (Lagercrantz 2005, 59). “In the absence of adequate stimulation, the cerebral network suffers irreversible injury” (Changeux 2004, 194). In fact, synapses are literally pruned on the basis of how much they are used.

Torsten Wiesel and David Hubel (1963) have, for example, demonstrated the irreversibility of lesions caused by experimental manipulation of the visual environment. By suturing the eyelid of a newborn monkey during its first six weeks of life, thus narrowing the columns corresponding to the closed eye (resulting in decreased vision or blindness), they established the existence of a sensitive period during which a reduction of sensory stimulation causes irreversible damage to cortical connectivity. Carla Shatz and her colleagues have subsequently shown through experiments with weasels that stimulation is necessary before the eye is even opened in order for synapses to develop adequate connectivity (Katz and Shatz 1996). It has been argued (e.g., by Eric Kandel) that early stimulation of children influences the formation of synapses; conversely, that lack of stimulation, poor nourishment, insecurity or absence of tender physical contact can give rise to serious brain damage (detectable, e.g., by fMRI [Lagercrantz 2005]) – damage that can be irreversible.

There are a number of needs that must be satisfied in order for the infant brain to develop in a healthy and harmonious manner, including:

- Tactile stimulation (touch, cuddles, holding, feeling caregivers' skin and heartbeat, notably when being breast- or bottle-fed) (Hertenstein 2011). This is important because the infant is still unable to articulate and communicate its needs linguistically, as well as cognitively to process information from others. In other words, the emotionally salient body contact with caretakers is crucial for them to experience being part of an interactive relationship of care.
- Smell. Among the emotionally salient interactions with caretakers, smell is particularly relevant, since it elicits strong emotional experiences, including the development of valenced memory (Cameron 2018; Ingebretsen Kucirkova and Stray Gausel 2023).
- Eye contact. Another relevant channel for emotionally salient interactions between infants and caretakers is eye contact, which plays an important role for the development of a number of infants' capacities, including empathy and self-other distinction (Çetinçelik, Rowland, and Snijders 2021; Khaluyan et al. 2021; Wever et al. 2022).
- Facial expressions. Human infants mimic a lot and learn to consistently connect emotions and behavior through observing parents, which is important for their development (Nelson and Modloch 2018; Garcia and Tully 2020). In fact, infants learn through imitation (Wang, Williamson, and Weltzoff 2015; Altinok, Over, and Carpenter 2023).
- Emotional responses. These include the capacity to learn the most appropriate emotions for the different experiences, as well as the distinction between a private (i.e., emotional) and public (i.e., behavioral) sphere. Again, the infants learn the

alphabet of emotions and how to connect them to reality through imitation (Donohue, Williamson, and Tully 2020).

The question here arises: to what extent can these needs be met by a machine?

3. A three-dimensional approach to the assessment of robotic childcare

For a childcare robot to be effective and its use positive for the child's development, we suggest that it should be able to, at least partly, meet the needs listed above and, in any case, not form an obstacle to their satisfaction. Some of them relate to the constitution (or physical nature) of both infants and caretakers, while others relate to their operational/functional capabilities. While robots can in principle replace humans for the latter, their use for fulfilling the first kind of needs is more challenging, at least to date.

The idea here is that, whereas robots may satisfy some infants' needs that depend only on executing some relevant functions (e.g., singing a lullaby) or for which the emulation of human features (e.g., facial expressions) is sufficient, they may be insufficient/unable to satisfy needs that are more deeply "physical" in both their origin and satisfaction (e.g., emotional bonding mediated by physical touch with a warm-blooded body). We should note that we are here referring to contemporary robots that do not have, for example, heartbeats or a warm-blooded body. If future technical developments alter this, the corresponding human-machine comparisons will have to be adapted.

This line of thought introduces three distinct perspectives that need to be considered: type, context, and extent. The evaluation of using robots in childcare will depend on the type of care it is intended for – and in what context – as well as the extent to which it is supposed to be used. We propose this three-dimensional evaluation as a useful approach to the assessment of childcare robots. Are we, for example, speaking about complementing or replacing human caregivers? And in which context? Relevant factors to consider are: the age of the child, the type of robot-child interaction, the type of family or parent (age, education, socioeconomic status, etc.), the broader social and human environment beyond the family, and the cultural and sociopolitical structures in which the child develops.

Against the background of the epigenetic development of the infant brain (by which we mean the cultural-social influence over the developing brain's architecture) and of the socioeconomic factors impacting the acceptability and effectiveness of using childcare robots, many questions arise about potential risks and benefits of using childcare robots. Before introducing some illustrative issues, we want to highlight the need to avoid an anthropocentric bias against the use of robots – that is, the idea that robotic childcare is intrinsically defective and worse than the direct human involvement in childcare. We propose a more balanced view, for instance, by not depicting human parenting as essentially idyllic while at the same time trying to identify what (if any) only humans can give to children, and examining whether the related limitation of robots is intrinsic to them or rather dependent on the level of presently available technology. We also avoid describing the "family" as a parent-child nuclear family, since in the contemporary world, numerous children grow up in other social formations – for example, with one parent (usually the mother) and an extended family of significant others (other relatives, friends, neighbors, etc.).

In what follows we shall argue specifically for the relevance of 1) the nature of the physical body of the child's caretaker, including the presence versus absence of a mind that notably permits (or not) mutual psychological relationships; and 2) the effects that the introduction of robotic childcare may have on the broader cultural, economic, and sociopolitical context.

3.1 The importance of bodies, minds, and the capacity for mutuality

We identified above a number of infants' needs that are connected to the epigenetic development of their brains. These include the need for tactile stimulation, smell, eye contact, facial expressions, and emotional responses, among others. As mentioned above, the satisfaction of some of these needs (i.e., tactile stimulation, smell, eye contact) requires the kind of physical (i.e., bodily) constitution that is presently typical of humans. With this we are not endorsing any form of biological chauvinism or essentialism, but merely point to certain features that human bodies presently have and that robots presently lack. Also, robots have a body, but that body is (so far) devoid of some features (e.g., warm blood, emotionality, value-based empathy capacity) that appear to be crucial for fulfilling some of the needs of infants in their development. As we said above, this may change in the future.

Importantly, the human body allows a form of mutuality. In fact, mutuality requires that behaviors are not simply the execution of functions but real manifestation of deliberate choices accompanied by subjectively salient experiences. For instance, happy facial expressions or joyful emotions may be displayed by robots while they are actually unable to really experience joy. This may be considered an ethically negative limitation of robots, which goes against their use in childcare, especially in situations where emotional responses are required. It may be objected that this depends on whether "perceived" mutuality is what really counts: in fact, robots may to some extent (and in the future may perfectly) imitate emotions, and this imitation may arguably be sufficient for the appropriate experience of mutuality by the child. Yet the question remains open whether this form of gaming emotionality can replace genuine human emotionality; and, if not, if it is of lesser value from the child's point of view, and if this then is ethically acceptable. As a general criterion, we have previously suggested that the use of AI (including robotics) is ethically problematic in contexts where features and capabilities that are (at least to date) specific to humans are required (Farisco, Evers, and Salles 2020).

That said, we note that human caregivers may engage in various forms of "emotional labor," expressing certain positive attitudes even though they do not feel them, due to fatigue, etc. Moreover, any capacity and characteristic of parents (and human caretakers more broadly) can have negative versions: emotional responses can be negative, and aggressive behavior, including violent educational practices, can cause great damage to children. In these cases, the use of neutral childcare robots would arguably be preferable to (such) human caretakers. While this conclusion may be valid in some cases, we should also note that children can learn the sensitivity to diverse relational/emotional experiences through their parents and/or other human caretakers. While these experiences may be positive or negative, parenthood and other forms of human caretaking help children to avoid becoming "emotionally blind" (i.e., unable to experience, detect, and express emotions, either positive or negative). Moreover, a child who is mostly used to robot company and is not accustomed to the varied, and sometimes intense and rapid, human emotional expressions and reactions, may become less able or even unable to deal with them when they occur (for example, the child may find the human emotionality scary and withdraw). This may then hamper that child's social development and future social capacities to engage maturely in human contexts. Importantly, reliance on social robotics for children (versus developed adults) has a potential for harm in social development that is more substantial at an earlier age and (perhaps) more likely to produce longer-term problems than a similar (social) technology used by adults. Even if social robots develop to the point where they seem to be able to replicate an adult caregiver, their introduction will also be somewhat experimental at key moments of a child's development, and we might imagine that placing tighter restrictions on this use than among adults (e.g., companion robots for adults or elderly individuals) is ethically recommendable. It is relevant to note here the recent recommendation (2024) issued by COMETS (the ethics committee of the Centre National de la Recherche Scientifique [CNRS]) calling for further research and vigilance regarding the effects that the use of so-called “social” robots have or may have on humans and human relations (Pelachaud et al. 2024).

This point also highlights the relevance of considering the dimension of extent. We have little doubt that both families and children could benefit from using some robotic devices. For example, a cute robot could be a sophisticated and fun toy, sing soothing lullabies, help ensure safety around the house, help children with special needs (e.g., autism), and so on. Such uses would hardly constitute any hindrance for the child’s development in any obvious way but can on the contrary support it. Concerns arise when the robotic complement begins to approach an increasingly large and perhaps almost complete *replacement* of human caregivers in contexts where human aspects of care are more crucial, some of which we outline above.

Another ethically salient dimension of using childcare robots is the use of misleading terms that result from an anthropomorphic view of the robots. This is the case, for instance, when the term “interaction” is applied to the child-robot relation or the term “collaboration” applied to the human caretaker-robot relation. In both cases, the question arises whether a real relationship of reciprocity between two agents is in place, or rather the interaction originates from only one of the two involved terms (e.g., from children only, while the robots only more or less automatically react to their inputs). These are not only linguistic details, but ethically salient linguistic choices that impact the way we perceive, accept, or refuse (in a word: evaluate) technology.

3.2 Cultural, political, and socioeconomic perspectives on robotic childcare

The social context is highly relevant when assessing robotic childcare. Although our aim in this paper is not primarily focused on the possible societal impacts of this technological development, we still find it useful briefly to draw attention to the relevance of sociopolitical factors for analyzing the use of childcare robots and to some important issues that may arise from such use.

Different societies have very different structures regarding childcare, in part due to deep cultural divergences in how infants/children, parenting, education, gender equity, and families are conceived (Georgas 2003; Bornstein 2012; Lansford 2022; Ria Novianti-Nur 2023). In some societies, a system of high-quality human-staffed nurseries is well developed. In Sweden, for example, they are widely accessible, with 86 percent of children age one to five enrolled in 2022 (see Skolverket 2024). In France, the attendance of children in nurseries (free of charge) is obligatory from the age of three (see Ministère de l'Éducation nationale 2024). These nurseries offer children social activities and help with their upbringing and social development whether or not they come from dual-income families. The underlying ideology includes (among other things) the idea that children benefit from contact with other children in organized settings from an early age (see, e.g., Wilford et al. 2013), and the idea that women and men share equal responsibility for childcare and should have equal opportunities to pursue their respective education, career, and so on. In these societies, robotic childcare would probably not be considered necessary, although they could still be considered useful. Moreover, if children have already spent their day away from the parents or primary caregivers, replacing them with robots to care for the children in the evening/night as well may be considered too extensive from the point of view of the child's well-being and sound development, assuming that spending time with human caregivers is better for a child than not spending time with them; and, in particular, assuming that a specific child's family is a good environment for its well-being and development.

In societies with an advanced system of nurseries and politics of parental equity (e.g., assuring paid parental leave for each gender), the introduction of robotic childcare could possibly even be seen as a threat to the system. If, say, robotic childcare would be less expensive for the state than nurseries, one can easily envisage a political push to replace nurseries (no matter how well they function) with home-robots, to save money for the state.

In other countries, such as Italy, where the dominant ideology is more conservative, there are far less developed nursery-systems, and the responsibility for childcare is placed directly on the parents, above all the mother, who receives very little state-funded assistance for the task (notwithstanding some recent attempts by the government to financially support the use of nurseries). The latest available statistics (from 2021) indicate that national nurseries can host a maximum of 28 percent of children, against the target of 45 percent set by the European Council in 2022 (Instituto Nazionale di Statistica 2023). The situation is even worse if we take territorial differences into account, with a large difference between northern and southern regions, where the numbers are much lower (around 10 percent). Overall, 33.4 percent of children under three years old attend nurseries in Italy (compared to the European average of 37.9 percent).

The potential value of robotic help increases in such contexts, at least from the caregivers' (especially mothers') point of view. Home robots could revolutionize the lives of primary caregivers (typically women) to whom robotic assistance could offer valuable time to pursue activities other than caregiving, such as work or education. Robots could "lift the burden of women's care work" (Parks 2010), although this would not necessarily be a value from a conservative government's point of view, if, or to the extent that, it endorses an ideology aiming to keep women socially subordinate, notably in education and professional life. Another socioeconomic consideration is whether this assistance would be available only for those who can afford it. Or is it also possible to offer assistance to families of modest economic means (who cannot afford expensive daycare or private human assistance)? It is beyond the scope of the present paper to analyze more deeply this type of sociopolitical and economic issues, but even so, it is important to consider socioeconomic factors in addressing the use of childcare robots and to the need to assess the (positive or negative) impact that the introduction of robotic childcare may have upon society.

4. Conclusion

We have here proposed a three-dimensional evaluation as a useful approach to assess childcare robots, with three factors that need to be considered: type, context, and extent. The evaluation of using robots in childcare will depend on the type of care it is intended for, in what context, and the extent to which it is used.

Focusing primarily on the child's perspective, in particular on requirements for healthy brain development in infants and children, we have argued for the relevance of the nature of the physical body of the child's caretaker, including the presence versus absence of a mind that notably permits (or not) mutual psychological relationships. We suggested that the satisfaction of some infants' needs (i.e., tactile stimulation, smell, eye contact) requires the kind of physical (i.e., bodily) constitution that is presently typical of humans. Robots may satisfy some infants' needs that depend only on executing some relevant functions (e.g., singing a lullaby), or for which the emulation of human features (e.g., facial expressions) is sufficient. In contrast, they are less able (if at all) to satisfy needs that are more deeply "physical," more precisely biological, in both their origin and satisfaction (e.g., emotional bonding mediated by physical touch with a warm-blooded body). It seems likely that both families and children could benefit from using some robotic devices, but if or when the robotic complement begins to approach an increasingly large and perhaps almost complete replacement of human caregivers in contexts where (presently specific) human aspects of care are more crucial, concerns arise. Relevant factors to consider are: the age of the child; the type of robot-child connection; the type of family, parent, or caregiver (age, education, socioeconomic status, etc.); the broader social and human environment beyond the family;

and the cultural and sociopolitical structures in which the child develops. Technological and social inventions such as childcare robots do not occur in a political void but can have strong sociopolitical and economic impact, differently depending on which social context we are analyzing. A fuller assessment of the pros and cons of introducing robots in childcare will need to be interdisciplinary and involve psychological, social, and political sciences, including gender studies, in addition to the technical and scientific expertise.[1]

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