“Baby Robot”: Improving the Motor Skills of Toddlers

Eric Canas¹, Alba M. G. Garcia¹, Anaís Garrell² and Cecilio Angulo²,³

Abstract—This article introduces “Baby Robot”, a robot aiming to improve motor skills of babies and toddlers. Authors developed a car-like toy that moves autonomously using reinforcement learning and computer vision techniques. The robot behaviour is to escape from a target baby that has been previously recognised, or at least detected, while avoiding obstacles, so that the security of the baby is not compromised. A myriad of commercial toys with a similar mobility improvement purpose are into the market; however, there is no one that bets for an intelligent autonomous movement, as they perform simple yet repetitive trajectories in the best of the cases. Two crawling toys—one in representation of “Baby Robot”—were tested in a real environment with respect to regular toys in order to check how they improved the toddlers mobility. These real-life experiments were conducted with our proposed robot in a kindergarten, where a group of children interacted with the toys. Significant improvement in the motion skills of participants were detected.

I. INTRODUCTION

Crawling is a key step in the locomotion evolution for most of the babies, which concludes when the infant is able to walk. For approximately 50% of the babies [1], crawling behaviour usually starts at the age of 8 months, but it can also be later or never happening. It is an issue of interest for paediatric professionals and parents as it is a common concern about children mobility development. The current state of the art about the development of crawling in babies enumerate three key factors that ease its appearance:

• Smaller, slimmer, more maturely proportioned infants tend to crawl at earlier ages than larger, chubbier infants [2]. Hence, babies with a favourable ratio of muscle to body fat have a clear advantage when mobility is an issue.

• Babies that spend more time lying on their stomachs when they are awake tend to crawl earlier [3]. These sessions, commonly known as “tummy time”, help babies to strengthen and control better key muscles for crawling, such as the ones in their neck and shoulders, among others [4]. Additionally, early promotion of “tummy time” has been shown to be effective in improving feeding practices in infants between 1 and 12 months [5], as well as reducing the motor delay in young infants with Down syndrome [6].

• And, finally, positioning a certain toy out of the reach of babies encourages them to move towards it [7]. When this process is iterated several times, that is, the toy position is changed again when the infant is getting closer to it, longer training sessions are obtained. Additionally, it is important to let babies play with the toy after several trials in order to avoid frustration.

The latter key point has been exploited by a number of toy companies for years—even though any toy is suitable for this purpose as far as the baby is interested in it—, developing what it is known as “crawling toys”: toys that help parents, educators and paediatric professionals in the task of guiding children in developing motor skills to achieve crawling by motivating them (see Fig. 1).

In this study, we aim to investigate how the autonomous movement of these “crawling toys” affect to the engagement of babies with crawling. Our main hypothesis is that toddlers are more engaged to crawl when the toy presents intelligent and autonomous movements, rather than when their movements are neither intelligent nor autonomous. That is, we advocate for physical agents not implementing iterative movements, but robot motion behaviour taking children feedback into consideration. For this reason, we introduce “Baby Robot”, a robot aiming to improve crawling mobility of babies and toddlers. Authors developed a car-like toy that moves autonomously using reinforcement learning and computer vision techniques. The robot behaviour is to escape from a target baby that has been previously recognised, or at least detected, while avoiding obstacles, so that the security of the baby is not compromised. A myriad of commercial toys with a similar mobility improvement purpose are into the market; however, there is no one that bets for an intelligent autonomous movement, as they perform simple yet repetitive trajectories in the best of the cases. Two crawling toys—one in representation of “Baby Robot”—were tested in a real environment with respect to regular toys in order to check how they improved the toddlers mobility. These real-life experiments were conducted with our proposed robot in a kindergarten, where a group of children interacted with the toys. Significant improvement in the motion skills of participants were detected.

*This work was not supported by any organization

¹Eric Canas and Alba M. G. Garcia are with the Universitat Politècnica de Catalunya, UPC-BarcelonaTech, Barcelona, Spain \{eric.canas, alba.marla.garcia\}@estudiantat.upc.edu

²Anaís Garrel and Cecilio Angulo are with the Institut de Robòtica i Informàtica Industrial (CSIC-UPC). Llorens Artigas 4-6, 08028, Barcelona, Spain. \{agarrel, cangulo\}@iri.upc.edu

³Cecilio Angulo is with the Intelligent Data Science and Artificial Intelligence Research Centre (IDEAI-UPC). Jordi Girona 29, 08034, Barcelona, Spain. cecilio.angulo@upc.edu

Fig. 1: Toddlers from a kindergarten interacting with the “crawling toys” used for the control condition (top) and the “Baby Robot” condition (bottom).
from a target baby that has been previously recognised, or at least detected, while avoiding obstacles, so that the security of the baby is not compromised.

The rest of the paper is organised as follows: First, we will briefly summarise how the crawling problem have been faced by both, the research field and the industry. Moreover, we describe the state of the art in Section II. Then, we will introduce “Baby Robot”, describing its main purpose, behaviour and skills. Once the context of “Baby Robot” is defined, we will detail how the experimentation have been performed, in order to accept or refuse our hypothesis. Hence, in Section III, we introduce the methodology of the current work. Section IV presents the evaluation and the obtained results from the experimentation. Finally, Section V and VI describe the results and the discussion about the results yielded, respectively.

II. RELATED WORK

We work in this section in the current state of the art of our research topic by introducing robots capable of interact with children. Firstly, some commercial robots are introduced, without the aim to be an exhaustive list. Next, some specific robots developed for research purposes aiming to encourage children to move are also presented.

A. Commercial Toys

Taking a look at the current available proposals for crawling toys, common features can be observed among them:

- They are deeply focused on the aesthetics rather than the functionality itself. This concern includes bright colours, soft materials—mainly plastic, but sometimes fabric—to make more pleasant the interaction by touch and in the most sophisticated toys, happy melodies or sounds and lights. Moreover, they tend to have a pet-like shape such as cute dogs or cats. This is an important feature because aesthetics is key to catch the attention of babies [8] and motivate them to chase the toy, the final purpose for the toy.
- Regarding the mobility of these toys, great differences can be found among them: some of them can reproduce mechanical movements such as spin or wobble; other require manual interaction that lead to linear trajectories for a short period of time, i.e. “Crawl-After Cat on a Vac” [9], and the most sophisticated ones are able to move on their own but always performing simple trajectories, i.e. “Follow-Bee Crawl Toy” [10] and “Rock & Glow Unicorn” [11]. In Table I a brief summary of the usual common points between these toys is presented.

All the presented toys are autonomous; nevertheless, neither user’s feedback nor intelligent movements are related to them, thus their behaviour is completely independent from the baby actions. In contrast, our robot is endowed with skills which allow it to perceive the surrounding environment and act in consequence.

| Picture | Follow-Bee Crawl Toy [10] | Crawl-After Cat on a Vac [9] | Rock & Glow Unicorn [11] |
|---------|--------------------------|-----------------------------|---------------------------|
| Based on | Bee                      | Cat                         | Unicorn                   |
| Material | Plastic                  | Plastic                     | Plastic                   |
| Sounds | YES                      | YES                         | YES                       |
| Trajectory | Circular                | Linear                      | Linear                    |
| Other | Obstacle sensor / 3 modes | 3 ways to get the cat move  | 2 modes: static / movement |

TABLE I: Summary of the characteristics of the most advanced crawling toys available to date.

B. Research Toys/Robots

The research field in crawling mobility using robotics devices has been specially focused in the development of exoskeletons or assistance robots for promoting the early crawling of babies at risk of neurological diseases, such as Cerebral Palsy (CP) [12].

Cerebral Palsy is a physically disabling condition for children specially researched in the United States and Europe. It is a lifelong physical disability caused by damage of the developing brain and it affects muscle function, postural control and coordination of skilled movements. Researchers demonstrated that the effects of CP are apparent within the first year of life [13], [14]. Inability to crawl has implications beyond locomotion, as it is associated with other important skills of child development that are crucial for learning.

The present work introduces a new way to encourage children to move, using a small mobile robot that interacts with toddlers. Improving the engagement of babies in the crawling activity, as part of its playtime, is an area of research that has been more exploited by commercial toys than by research robots. However, none of them have faced the problem through intelligent and autonomous reactions, based on the babies’ actions.

III. METHODOLOGY

This section introduces the description of our research, the purpose, the target actors and the development of the behaviour of the robot.

A. Purpose

The purpose of “Baby Robot” is the same as any other “crawling toy”, which is to motivate babies to crawl—either for those that have not started yet and for those that are still practising—by placing the toys or robots out of the reach of the baby so that it catches their curiosity and the infant tries to chase it. It is worth noting that, contrarily to other available toys, “Baby Robot” is able to stay away from the baby for a longer period of time—until the responsible adult switches it off—, making the playing sessions virtually longer, thus increasing the time the baby is moving.
B. Target Actors

“Baby Robot” aims to be a “crawling toy”, so it is expected to be used in scenarios where the upbringing of babies at the earlier stages happen, such as their homes or kindergarten. It is recommended that these spaces comply with some characteristics to make the crawling sessions safer and better: they should be closed in order to control better the behaviour of the infant so as to avoid any possible risk. Additionally, they should also be clear, in order to provide the baby with a large enough space to play. To sum up, we expect that the responsible of the baby places “Baby Robot” where the baby can move freely without any major worry about their safety and under the supervision of the aforementioned responsible(s). Therefore, we can identify three clear roles that appear during this interaction:

- “Baby Robot”, whose purpose is to motivate the baby to crawl by following it.
- The baby, who gets interested in the robot and tries to chase it.
- The adult responsible of the baby at the time, who supervises the interaction and intervene when the baby is at risk or needs help, when the robot is not functioning as expected or when they switch the robot off to let the baby play with it or to end the session.

C. Behaviour of the robot

The ultimate goal of the behaviour of “Baby Robot” is to escape from the target baby, who is expected to follow the robot, while maintaining a constant distance of separation with them and avoiding any possible obstacle. This goal is achieved by means of the movement that allow the two wheels –with their corresponding electrical motors– and the idler wheel the robot has equipped along with the camera and the ultrasonic sensors placed at the front and at the back of the robot, respectively. A simplified scheme of the robot structure can be observed in Fig. 2.

“Baby Robot” can move in a total amount of twelve directions: forward, backwards, left, right, the four classic diagonals that are separated from the previous directions by a 45° angle and four extra orientations that are close to the forward and backwards directions forming a little angle to their left and their right. We added the latter as we found that the robot used to move forwards and backwards most of the times in order to escape from the target baby and that this little angle could help it to achieve a softer trajectory. Of course, it can also decide not to move, as well as to make different movements in place for catching the attention of the toddler when it is temporally lost. A diagram of the “Baby Robot” behavior is shown in Fig. 3.

The decision about which movement should be executed at each time-step is decided exclusively according to the distance and horizontal deviation to the target baby and distance to the closer obstacle. When the baby is not detected, “Baby Robot” uses the prior information about its latest position in order to rapidly locate the baby again.

D. Cognitive skills of the robot

“Baby Robot” interacts with their target users by means of its movement exclusively. Its objective is to escape from a baby that has been identified at the beginning of the session as target or not (in case there is just one baby in the room). The way our robot is able to decide which action must perform comes from two different sources that summarize its cognitive skills:

- The ability to recognise human bodies and faces, to identify faces and to compute the distance and horizontal deviation to these detection by means of the camera placed in front of the robot.
- The ability to compute the distance with respect to the closest obstacles by means of its front and back ultrasonic sensors.

IV. Evaluation

This section is devoted to the experimentation performed over the implemented robot, “Baby Robot”. First, we specify all the test performed as well as the data obtained from them. Next, we analyse these data in order to accept or reject our initial hypothesis: *A fully-autonomous and intelligent toy improves the engagement of babies with the crawling activity.*
when compared to toys that do not take baby feedback into consideration.

A. Toys implied

As “Baby Robot” is a prototype, it would be unsafe for babies to carry out the experimentation with it due to its accessible wires and batteries. Therefore, we have substituted it with a car-like toy by ToyTown that can be teleoperated in order to simulate “Baby Robot” behaviour (see Fig. 4 (left)). For the control condition, we have used a car-like press-and-go toy by TaviToys (see Fig. 4 (right)). This toy has been selected because it is, functionally and aesthetically, the closest option to the one used for the “Baby Robot” condition, but lacking of the autonomous and intelligent movement capabilities. It is important to remark that both toys have been selected aiming to isolate the “movement variable”, thus avoiding the influence of lights, sounds or aesthetics during the experimentation.

B. Test

Our experimentation was performed over a set of toddlers from a kindergarten, aged between 7 and 16 months. Their abilities ranged from those just taking their first crawling steps up to those who were already able to walk, but that still crawled frequently. Half of these toddlers were selected for the control condition and the other half for the “Baby Robot” condition. For both conditions, they played with their respective toys during five sessions of ten minutes, distributed along consecutive days. All the sessions were performed in a familiar environment for the toddlers, that were always accompanied by their caregiver—an adult they trust. For the control condition, the caregiver showed to them how the “Press & Go” toy works, and let the baby continue playing with it. For the “Baby Robot” condition, the caregiver put the toy near to the baby and used the remote control for simulating that the car autonomously escaped from the toddler. For both conditions we measured the following variables:

1) Percentage of time that the toddler is in movement during the session.
2) Distance travelled by the toddler during the session.

We must take into consideration the following clarifications:
- To prevent our presence from causing any disturbance in the toddler behaviour, the unique other person inside the room was always their usual—and trusted—caregiver. We always observed the sessions through a webcam placed in the corner of the room.
- Time that the toddler is rotating over itself, is considered as movement time.
- Distances travelled are estimated from a set of discrete landmarks placed in the room and distanced at one meter each one. Nevertheless, trajectory measurements could present approximation errors always lower than this distance.

A simplified scheme of the proposed experimental setup is presented in Fig. 5.

V. RESULTS

Fig. 6 represents the percentage of the session that the toddler was in movement according to both conditions: “Baby Robot” condition and control condition. Strong conclusions can be drawn from results depicted in Fig. 6. In “Baby Robot” sessions, toddlers were in movement during the 82.26 ± 5.6% of the session, while toddlers of the control condition were only in movement during the 26.55±8.9% of it. Therefore, in terms of training, “Baby Robot” produced a 3.1× improvement in the efficiency of the session. From the point of view of the distance travelled by the toddler during the session (see Fig. 7), conclusions are even stronger: In “Baby Robot” sessions, toddlers travelled in average 164.37±31.7 meters, while toddlers in the control condition only travelled 37.6 ± 11.9 meters in the same amount of time. It enhances the efficiency of the play session in a 4.4× factor.

In qualitative terms, caregivers in charge of controlling both toys reported the following key conclusions:
- Toddlers were clearly more engaged with the activity in the “Baby Robot” condition.
- They moved faster and made longer trajectories in the “Baby Robot” condition.

Fig. 4: Teleoperated toy in substitution of “Baby Robot” (left) and Press & Go toy selected for the control condition (right).

Fig. 5: Experimental environment setup.
Fig. 6: Percentage of the session that the toddlers were in movement for each condition.

![Percentage of the Session that the Toddler was in Movement](image)

**Fig. 7: Average distance (in meters) that the toddlers travelled in each session.**

![Distance Travelled by the Toddler During the Session](image)

- Although the disengagement process was slowed down in “Baby Robot” condition, in both cases the engagement with the activity decreased as the session progressed.

From a statistical perspective, these results also draw strong conclusions: we ran a t-test over them obtaining \( p < 0.0001 \), thus indicating that they have an extremely statistical significance. For this reason, we must reject the null hypothesis, accepting that: **Toddlers are more engaged to crawl when the toy presents intelligent and autonomous movements, rather than when their movements are neither intelligent nor autonomous.**

**VI. DISCUSSION**

In this study we investigated how toys with intelligent and autonomous movements that take into account the feedback of the toddler affect to their engagement with the crawling activity. We found strong evidences that supported our initial hypothesis. This opens a line of research for improving the engagement, and therefore the efficiency of children in their first steps apprenticeship. We hope that further research on these toy/robots will help parents around the world to promote the early and healthy development of their children movement abilities, providing them with all the benefits that these practices present for their correct growth.

**A. Limitations**

Although conclusions drawn from this study are strong, we acknowledge that our results could be slightly noised by some uncontrollable factors that limited the isolation of the “autonomous/intelligent movement” variable. These factors are, for example, the unavoidable aesthetic differences between both toys implied in the study, the lack of toddlers with special mobility conditions, or any difference in the behaviour or attitude of the caregiver that could be perceived by the toddler. Despite of these considerations, we believe that these results are strong enough to maintain the validity of the proposed hypothesis in a wide range of cases.

**B. Future Work**

Future research in this field shall continue to investigate how sounds, lights, colours and aesthetics affect the engagement that this kind of robots produce in children. Although this is one of the key points that the industry has faced when developing toys, there are no studies on how these factors affect to the stimulation of the toddler when playing with “crawling toys”. We consider that these lights, sounds, colours and cute aesthetics would play a key role in the study of how to keep the attention of the toddler for longer periods of time, thus increasing even more the effectiveness of the training sessions. Additionally, it would be necessary to expand the generality of the conclusions extracted from this study by researching in more diverse groups, including children with very diverse cultural backgrounds and different mobility conditions, as well as toddlers in all the stages of their early childhood. Finally, it should be studied how toys like “Baby Robot” could accelerate the transitions between different mobility stages, it is, the transition from “tummy time” to the crawling stage or from crawling to walking.

**ACKNOWLEDGEMENT**

Although we prefer to keep their anonymity in order to not compromise the identity of any child, we would like to thank the psycho-pedagogue of the kindergarten were our experimentation was developed, as well as all the caregivers that kindly accepted to prepare the setup and run the required tests. Without them, it would have been very difficult to develop this study.

**REFERENCES**

[1] K. E. Adolph, S. E. Berger and A. J. Leo. Developmental continuity? Crawling, cruising, and walking. Developmental science. vol. 14, pp. 306-18. 2011.

[2] K. E. Adolph, J. Rachwani and J. E. Hoch. Motor and physical development: Locomotion (Book Style). The Curated Reference Collection in Neuroscience and Biobehavioral Psychology. pp. 359-373, January, 2018.

[3] M. A. Lobo and J. C. Galloway. Enhanced handling and positioning in early infancy advances development throughout the first year. Child Dev. vol. 83, no. 4, pp. 1290-320, 2012.

[4] L. Hewitt, E. Kerr, R. M. Stanley and A. D. Okely. Tummy Time and Infant Health Outcomes: A Systematic Review. Pediatrics. vol. 145, no. 6, June, 2020.
[5] L. W. Ming, L. A. Baur, J. M. Simpson, C. Rissel and V. Flood. Effectiveness of an Early Intervention on Infant Feeding Practices and “Tummy Time”, A Randomized Controlled Trial. Archives of Pediatrics & Adolescent Medicine. vol. 165, no. 8, pp. 701-707, August, 2012.

[6] E. E. Wentz. Importance of Initiating a “Tummy Time” Intervention Early in Infants With Down Syndrome. Pediatric Physical Therapy. vol. 29, no. 1, pp. 68-75, January, 2017.

[7] K. Butcher. Why Crawl?. Michigan State University Extension, Ashley VandenBerg and Terra Dodds, 2013.

[8] K. Danko-McGhee. The Aesthetic Preferences of Infants: Pictures of Faces That Captivate Their Interest. Contemporary Issues in Early Childhood. vol. 11, no. 4, pp. 365-387, January, 2010.

[9] Fisher-Price, Laugh & Learn Crawl-after Cat on a Vac, 2021. [Online]. Available: https://www.fisher-price.com/en-us/product/laugh-learn-crawl-after-cat-on-a-vac-gjw35. [Accessed: 04- Apr- 2021]

[10] SkipHop, Explore & More Follow-Bee Crawl Toy, 2021. [Online]. Available: https://www.skiphop.com/skiphop-playtime-toys/V_303108.html. [Accessed: 04- Apr- 2021]

[11] ToysRUs, Bright Starts Rock & Glow Unicorn Toy, 2021. [Online]. Available: https://www.toysrus.com/bright-starts-rock-and-glow-unicorn-toy-B01C5L5EHU.html. [Accessed: 04- Apr- 2021]

[12] D. Miller, A. H. Fagg, L. Ding, H. A. Kolobe and M. Ghazi, M.Robotic. Crawling Assistance for Infants with Cerebral Palsy, Proceedings of the AAAI Workshop on Assistive Technologies Emerging from Artificial Intelligence Applied to Smart Environments, January, 2015.

[13] V.M. Barbosa, S.K. Campbell, E. Smith and M. Berbaum. Comparison of test of infant motor performance (TIMP) item responses among children with cerebral palsy, developmental delay, and typical development. Am. J. Occup. Therapy vol. 59, no. 4, pp. 446–456, 2005.

[14] T.H. Kolobe, M. Bulanda, L. Susman. Predicting motor outcome at preschool age for infants tested at 7, 30, 60, and 90 days after term age using the test of infant motor performance. Phys. Therapy. vol. 84, no. 12, pp. 1144–1156, 2004.