TACTOPI: a Playful Approach to Promote Computational Thinking for Visually Impaired Children

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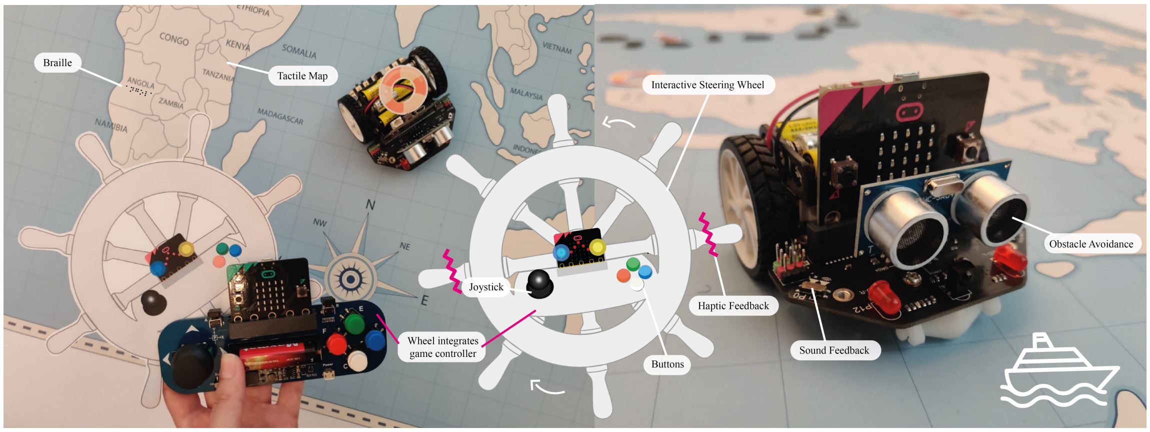

Fig. 1. TACTOPI, a playful environment designed from the ground up to be rich in both its story (a nautical game) and its mechanics (e.g., a physical robot-boat controlled with a 3D printed wheel), tailored to promote computational thinking at different levels (4 to 8 years old).

The usage of playful activities is common in introductory programming settings. There is normally a virtual character or a physical robot that has to collect items or reach a goal within a map. Visually, these activities tend to be exciting enough to maintain children engaged: there is constant feedback about the actions being performed, and the virtual environments tend to be stimulating and aesthetically pleasant. Conversely, in adaptations for visually impaired children, these environments tend to become poorer, damaging the story at the cost of the programming actions and its dull mechanics (e.g., place a arrow block to move the character forward). In this paper, we present TACTOPI, a playful environment designed from the ground up to be rich in both its story (a nautical game) and its mechanics (e.g., a physical robot-boat controlled with a 3D printed wheel), tailored to promote computational thinking at different levels (4 to 8 years old). This poster intends to provoke discussion and motivate accessibility researchers that are interested in computational thinking to make playfulness a priority.

CCS Concepts: • **Human-centered computing → Accessibility**.

Additional Key Words and Phrases: play, computational thinking, visually impaired children, robots

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1 INTRODUCTION

In the last few years, we have witnessed the democratization of introductory programming environments. The importance of computational thinking training is now widely accepted which made these environments more pervasive at home and part of school curricula. For children (4-8 years old), these tend to be playful and tactile-rich.

Most of these environments have been barred to visually impaired children. Either they are not accessible, or when accessible environments are procured, they tend to lose playfulness and to be highly cognitive demanding for children. As already happens in several other learning areas, visually impaired children have access to less enthusiastic and more demanding instruments to acquire the same concepts.

Recent studies explored the potential of tangible robotic environments with visually impaired children. Pires et al. [8] identified a set of qualities that programming environments should have to provide a layer of inclusion to visually impaired children. Children used tangible blocks to spatially move a robot in a map. Their exploratory results revealed the potential of this type of environments to foster spatial and computational thinking skills. Ousama et al. [7] explored the use of robots to engage children in inclusive play experiences using an accessible physical environment. This preliminary research highlighted the benefits of using robots to promote computational skills and inclusive play.

We present TACTOPI, its conceptual pillars and a first implementation using Micro:bit. TACTOPI is a playful and tangible environment designed from the ground up to promote computational thinking concepts while playing. In this approach, instead of fitting a game to a block or automata-based environment (the common approach), we first designed a tangible game where the player is controlling a ship through a map, and then designed levels to promote computational thinking concepts, accommodating different ages and learning levels.

This preliminary work prioritises playfulness and hopes to contribute with useful insights into the relationship between playfulness and sustained engagement. Also, by designing an environment to be accessible from the beginning, we hope to promote inclusion and set an example for the design of future playful and accessible computational training environments.

2 TACTOPI

This work explores the idea of an inclusive exploratory nautical game - TACTOPI - to engage children in a playful experience while acquiring computational thinking skills. A tactile physical interaction that can be fun for children, with mechanisms similar to real ones that can lead to a more immersive experience. The goal is to use a mobile robot as a ship remotely controlled by a helm (steering wheel).

2.1 Learning through Play and embodiment

In TACTOPI, we support the approach "Coding as a playground" [3] to engage children in learning to code through fun, play and creativity. Children can use a series of computational thinking processes - such as abstraction, algorithm and procedures, debbugging, data collection, problem decomposition and pattern recognition [2]- in a engaging and immersive way with TACTOPI. This environment presupposes a richness of multi-sensory elements such as an audio narrative and sound cues, sounds of the sea, wind and animals, akin to a video game. The textures on the map, beyond the graspable elements of navigation and collectable coins, will contribute to an immersive experience and the child's engagement and play.

The sensorimotor experiences that TACTOPI supports allow children to create direct associations between a concrete experience (e.g., move a wheel to the right) and an abstract concept (e.g., the robot ship moves to the right). Such embodied actions help in the representation of abstract concepts facilitating the learning process [5]. In addition, embodied actions with objects outsource thought processes improving or reshaping inner processes. Every object we couple with in a cognitive way becomes an opportunity for thought, control, and imagination[6].

TACTOPI also gives children a greater control and agency over the central element of the game, the ship, which creates a more personalised experience and responsiveness of a more direct and natural interface. Such approach contrasts with setups where the constant combination of tangible elements, for basic actions and the response time of the action can lead to the child's boredom.

2.2 Supporting Navigation Skills

Special needs educators frequently use activities with physically augmented maps to train geography, fine motor skills and navigation and orientation skills. In one visit to one inclusive visual ability mixed school - with which we regularly collaborate - we had the opportunity to observe how one blind child interacted with a physical map and a kingpin (used as a ship). The child had the goal to move the ship from point A to point B following some tactile reliefs and braille descriptions in the map. This simple setup has great implications in children's navigation skill; when a child navigates space they use mental representations of their own body and the environment. In TACTOPI, the child navigates a ship by controlling the ship's steering wheel, through natural movements of rotation. A set of buttons and a joystick, also embedded in the wheel, allows complementary actions and interaction with elements on the map, such as sound.

The prototype has two different Controller-Navigation modes that support computational thinking activities, namely Grid navigation and Free Navigation. The grid navigation mode presupposes a grid-based movement, i.e. the ship movements are restricted to move inside the cell units. Initially, they can use small arrows on the map to plan a set of instructions, to travel from point A to B, to fulfil a certain goal on the map. The challenges progressively increase, adding obstacles to avoid, or missions that challenge them to find strategies and plan sequences of instructions. The free navigation mode gives children freedom to move the ship in an exploratory way, by freely moving the wheel to command the ship. It also presupposes reaching from point A to B but in real time with constraints such as limited time or obstacles at the sea, such as continents, islands or pirate's ships. Through the attempted reading of obstacles by the ultrasonic sensors, incorporated in the ship, it emits audible warnings and haptic feedback, progressively more intense as it approaches obstacles in order to create a response/ reaction and avoid a collision.

3 TACTOPI'S PROTOTYPE

We envision the use of TACTOPI in educational or even domestic environments in which there is a need for educational and playful materials for accessibility and development of computational thinking skills. To this end, we are focused on creating reproducible low-cost materials.

3.1 The TACTOPI Steering Wheel

The wheel is a 3D printed model that contains the control board, a joystick and 6 buttons - augmented and customised using 3D printed graphical elements.The wheel provides haptic feedback, using vibration motors on both left and right sides in order to induce corrective actions. Another important functionality is to be able to save a sequence of instructions, using the four coloured buttons in the wheel, thus creating a pattern, such as drawing a square. The child can save the instructions as a pattern and then recall the patterns to create characters or a scenario, using accessible materials as Plasticine.

A device can be made intuitive to use by designing it so that its operation can be learned simply through its observation. This is possible through the appropriate use of deliberate clues in the product that trigger past experiences and prior knowledge. We are inspired by Diefenbach's perspective [4] on 'intuitiveness'; an attribute of a product that drives an automatic and unconscious use in individuals.

3.2 The TACTOPI Map

Maps are tangible but symbolic representations of space [1]. The possibility to manipulate and interact with the map affords the inner representation of spatial configurations and strengthens children's spatial mental models. TACTOPI's map is composed by 3D printed tactile elements with different textures so the child can differentiate the earth and water tiles. The oceans, continents and countries also include braille labels.

3.3 The TACTOPI Ship

The robot is based on *Maqueen*, a programming robot for STEM education, which inherits playability and integration with BBC micro:bit [https://microbit.org/] and a range of interesting features for an affordable price. The highlighted robot's features for the TACTOPI's concept are line following, small size and flexible movement, ultrassonic sensors for obstacle avoidance, ambient light, LED lights, buzzer, highly expandable both mechanically and with add-on components as voice control sensor and NFC module. This robot, the main character, will be encapsulated in a 3D printed small ship. This can then be customised with children's preferences of anthropomorphic or technical details.

3.4 The TACTOPI Auditory Feedback

TACTOPI affords multiple audio resources and feedback while children guide the ship, including the sound of waves, obstacles (whales, icebergs, pirates,etc.) and relative locations in the map (lighthouses). The controller integrated in the wheel also has its specific audio buttons. Depending on the activity, the four coloured buttons have different purposes. For example, to order elements on the map (the nearest lighthouse) there will be a "bip" sound as a clue for the child to target the ships relative location.

4 CONCLUSIONS AND FUTURE WORK

The process of "making something accessible" *a posteriori* regularly implicates the loss of qualities, turning access into the only priority. Although accessibility is increased, we need to question if it was so to the original system or to a different and limited one. In the area of inclusive education, adapted tools tend to be less engaging than the original ones. In introductory programming training, adaptations tend to lose the playful layers, becoming all about the blocks and the actions, which ultimately leads to less immersion and reduced engagement and motivation. With TACTOPI, we intend to provoke this *status quo* and prioritize playfulness. However, it was conceived with a richness of elements that accommodates the training of different concepts and at different levels. In future work, we plan to use TACTOPI as a co-design instrument with visually impaired children, their families and educators, to design a variety of activities that can sustain learning and engagement for longer periods of time for each individual child.

REFERENCES

[1] Alissa N. Antle. 2007. The CTI Framework: Informing the Design of Tangible Systems for Children. In *Proceedings of the 1st International Conference on Tangible and Embedded Interaction* (Baton Rouge, Louisiana) *(TEI '07)*. Association for Computing Machinery, New York, NY, USA, 195–202. https://doi.org/10.1145/1226969.1227010

[2] Valerie Barr and Chris Stephenson. 2011. Bringing Computational Thinking to K-12: What is Involved and What is the Role of the Computer Science Education Community? *ACM Inroads* 2, 1 (Feb. 2011), 48–54. https://doi.org/10.1145/1929887.1929905

[3] Marina U Bers. 2018. *Coding as a playground: Programming and computational thinking in the early childhood classroom.* New York: Routledge).

[4] S. Diefenbach and D. Ullrich. 2015. An Experience Perspective on Intuitive Interaction: Central Components and the Special Effect of Domain Transfer Distance. *Interacting with Computers* 27, 3 (2015), 210–234.

[5] Thea Ionescu and Dermina Vasc. 2014. Embodied Cognition: Challenges for Psychology and Education. *Procedia - Social and Behavioral Sciences* 128 (2014), 275 – 280. https://doi.org/10.1016/j.sbspro.2014.03.156 International Conference: EDUCATION AND PSYCHOLOGY CHALLENGES - TEACHERS FOR THE KNOWLEDGE SOCIETY – 2nd EDITION EPC – TKS 2013.

[6] David Kirsh. 2013. Embodied Cognition and the Magical Future of Interaction Design. *ACM Trans. Comput.-Hum. Interact.* 20, 1, Article 3 (April 2013), 30 pages. https://doi.org/10.1145/2442106.2442109

[7] Oussama Metatla, Sandra Bardot, Clare Cullen, Marcos Serrano, and Christophe Jouffrais. 2020. Robots for Inclusive Play: Co-Designing an Educational Game With Visually Impaired and Sighted Children. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3313831.3376270

[8] Ana Cristina Pires, Filipa Rocha, Antonio José de Barros Neto, Hugo Simão, Hugo Nicolau, and Tiago Guerreiro. 2020. Exploring Accessible Programming with Educators and Visually Impaired Children. In *Proceedings of the Interaction Design and Children Conference* (London, United Kingdom) *(IDC '20)*. Association for Computing Machinery, New York, NY, USA, 148–160. https://doi.org/10.1145/3392063.3394437