Gotta Hatch 'em All!: Robot-Supported Cooperation in Interactive Playgrounds

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Figure 1: Children play with the robot in our interactive playground.

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Abstract
In this paper, we present ongoing research combining two technologies to support children's cooperative interaction: interactive playgrounds and robots. We propose that interactive playgrounds are vehicles for playful cooperation when robots are integrated into the system as cooperative co-players. We developed the *Hatch 'em all* game, wherein children are encouraged to hatch eggs cooperatively with a robot, and tested the effect of the robot's cooperative behavior on the children. We found that when the robot played cooperatively, children cooperated and helped the robot more than when the robot played selfishly. Our findings suggest that the social affordances of the playground, together with the social interactions between the children and the robot, enabled instances of team cooperation and prosocial behavior. Our work contributes to the CSCW community by opening a novel avenue for supporting children's cooperation, which could serve as a future test-bed to investigate the role of robots in cooperative interaction.

Author Keywords
child-robot interaction; interactive playground; cooperative game; CSCW.

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous;H.5.3 Computer-supported cooperative work

Interactive playgrounds are installations that combine the immersion of digital games with the benefits of traditional play.

Elements of our system: (i) Sensors obtain information from the environment and the players therein. (ii) Actuators project the game into the playground and provide feedback to players. (iii) Gameplay encourages cooperative interactions. (iv) The robot reinforces the cooperative affordances of the game mechanics, stimulating team cooperation.

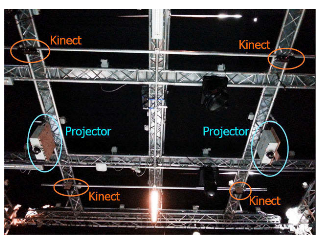

Figure 2: Sensors and actuators.

Introduction and related work

Technology nowadays is integrated into the fabric of children's daily life, but is often deemed to confine its young users to screen-based solitary interactions [8]. Thus, full-body and social interactions, both of paramount importance for children's development [7], are sometimes neglected.

To address this, technologies for children are increasingly moving away from screen-based interactions towards embodied interaction paradigms [1]. Interactive playgrounds (see Sidebar) revitalize full-body, social interactions incorporating embodied playful experiences in the Human-Computer Interaction (HCI) agenda [6]. Although interactive playgrounds are able to encourage children's cooperation and learning [4, 5], the social affordances provided by these playgrounds often have a limited influence on positive group dynamics. To overcome this limitation, researchers are exploring robots in interactive playgrounds, as characters controlled by players [9] or opponents in dyadic games [3]. Nonetheless, combining interactive playgrounds with robot co-players to support group cooperation *via social interaction* is still an untapped opportunity in the CSCW field. In our research, we explore, for the first time, how a robot's co-player behavior enables team cooperation and prosocial tendencies (i.e. help the robot in the game) in an interactive playground. This paper presents our system, the "*Hatch 'em all*" game, and the first empirical evaluation of how the robot (cooperative vs. uncooperative behavior) affects children behavior.

Robot-Supported Cooperation in an Interactive Playground

The overarching goals of our research are to provide opportunities for (i) children to discover the benefits of playing together, and (ii) social learning of cooperative behaviors in play. Therefore, we designed a game where players benefit from cooperation and we explore how a robot enables team play in this game. Instead of playing individually, the robot encourages players to explore and cooperate through the game mechanics provided by the interactive playground. Figures 1 and 2 show our prototype, and the sidebar details the elements of the system. We target children 7 to 10 years old, who typically show changes in the ability to collaborate effectively within this age range [7].

Hatch'em all game. The game was designed with the following principles in mind: (i) encourage team cooperation (ii) support embodied co-located interactions (iii) encourage player exploration of the game mechanics. The game is designed for two human players and one robot player. The goal of the game is to hatch bird's eggs as fast as possible. These eggs fall from a nest (i.e. appear) in random locations of the playground, one by one, every three seconds. The maximum number of eggs that can be in play simultaneously are four. If the eggs remain unhatched for too long, they may be snatched by a nasty cat that is prowling about (Figure 3). To hatch an egg, players need to stand on top of them for 10 seconds. To provide opportunities for cooperation between players, we designed a *team hatching* game mechanic. Once a player begins to hatch an egg, lines connecting this egg to two other eggs are drawn (Figure 4). If another player starts to hatch one of the connected eggs, the hatching speed is doubled. If the last player stands on the third connected egg, the three eggs start to emit red particles (Figure 5). Through *team hatching*, cooperation is encouraged, but never enforced, as eggs can be hatched on their own. We included an event in the game (inspired by a similar task in [7]) where players choose whether or not to help the robot hatch an egg whose connecting line is broken (Figure 6). We call this the *help event*. This event takes place twice: halfway through the game and at its end. The egg can be hatched normally by the robot, but to be

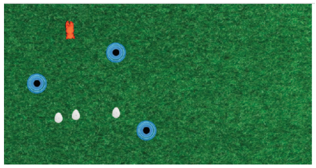

Figure 3: The initial state of the game: three players are tracked, eggs are falling and the nasty cat is coming.

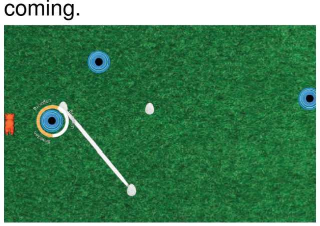

Figure 4: A line connecting two eggs has been drawn due to the *team hatching* game mechanic.

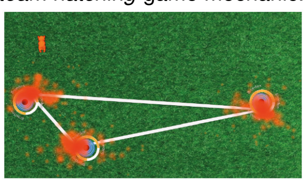

Figure 5: Three connected eggs are being hatched simultaneously.

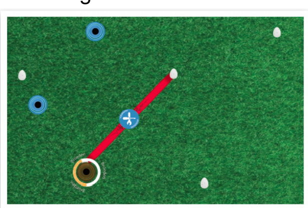

Figure 6: The broken line during the *help event*.

able to unlock *team hatching*, the broken line needs to be fixed by a human player by standing on the tool icon for a couple of seconds. The rationale behind this event is to (i) encourage group synergy by helping the robot to unlock *team hatching*, and (ii) test whether a cooperative robot can elicit prosocial behaviors, a metric often used to evaluate cooperative play [7, 10].

Robot and Cooperative Behavior. The role of the robot (a description in Figure 7) is to encourage *team hatching* and elicit help during the *help event*. We designed a simple behavioral repertoire based on motion (e.g. navigating towards a target egg, lateral motion if in need of help), and gibberish sounds used to provide positive or negative feedback (from a validated corpus [11]), to convey the robot's intentionality and goal-directness. The cooperative behaviors of the robot consist of moving fast towards a connected egg and hatching it to activate *team hatching*, emitting happy sounds when *team hatching* is successful, and emitting sad sounds when it is not. The robot was remotely controlled by a researcher who followed a script (WoZ method).

Evaluation of Robot-Supported Cooperation

The first step to evaluate the viability of our approach is to understand whether the cooperative behavior of the robot encourages (i) team cooperation and (ii) prosocial actions from the child towards the robot similar to the ones they share with cooperative peers [7].

Method and Participants We carried out a between subject play-test. We compared cooperative behaviors of the robot against uncooperative behaviors, i.e. robot playing selfishly. Therefore, we needed to add uncooperative behaviors to our repertoire. These behaviors were: not moving toward a connected egg, thereby not participating in *team hatching*, and emitting happy sounds when hatching independent eggs. As a result, the robot plays the game selfishly. The mechanics of the *Hatch 'em all* game remained the same. We used observational methods: two coders observed the activation rate of *team hatching* (i.e. number of times players engaged in *team hatching* divided by the total number of *team hatching* opportunities available) and counted the instances where players helped repair the robot's broken line during the *help event*. Our expectations are that when playing with the cooperative robot (i) the number of times *team hatching* occurs will be higher and (ii) players will repair the robot's broken line more often. We recruited 14 participants from a primary school in the Netherlands (7 females, 7 males, m age= 9.87 years sd= $.1$). Participants were randomly assigned either to the cooperative ($N = 8$) or uncooperative condition ($N = 6$).

Preliminary Results and Discussion An independent sample t-test showed that the rate of *team hatching* (see Sidebar in the next page) was significantly higher in the cooperative robot condition than in the uncooperative one. We infer from this that a robot that exhibits cooperative behaviors is able to impact the social behaviors of the children who, in return, cooperate more and play as a team. A chi-square test (see Sidebar in the next page) shows that participants helped the cooperative robot by fixing its broken line significantly more times when compared to the uncooperative robot. This result provides an early indication that a cooperative robot encouraging cooperation in the interactive playground enables social strategies like mutual help and reciprocity.

Conclusions and Future Work

Our preliminary findings suggest that interactive playgrounds are vehicles for playful cooperation when cooperative robots are integrated in the system. The social affordances of the playground in tandem with the robot's cooperative behavior

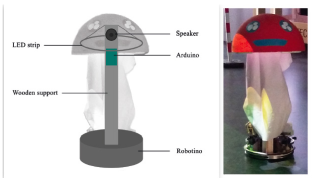

Figure 7: A description of the robot's components: mobile robotic base (Festo Robotino), wooden support, Arduino, speaker, led strip and a dummy Styrofoam and fabric shell.

Effect of robot-supported cooperation on team cooperation and on children's prosocial behavior towards the robot:

Team Cooperation Results An independent sample t-test showed that the rate of *team hatching* was significantly higher in the cooperative robot condition ($m = .74, sd = .30$) than in the uncooperative one (m= $.35$, sd= $.21$, $t(12)$ $p = .007$)

Help results Participants helped the cooperative robot by fixing its broken line significantly more times when compared to the uncooperative robot (85.7% vs. 21.4%,$\chi 2(1)$, $(N = 14)$ = 11.631, $p < 0.001$.)

are able to encourage players towards more cooperative and team behavior. Future work will focus on understanding how the robot behaviors influence children's cooperative behavior and on untangling children's perception of the robot.

Despite the limitations, we believe that our exploratory research contributes to CSCW by shedding light on a new avenue for supporting children's cooperation with robotic technology embedded in interactive playgrounds. We also indirectly address an underlying CSCW question [2] on how robots can participate in the collaborative process. We believe our system could become a test-bed to investigate the role of robots in cooperative interaction with children.

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