Using RoboChick to Identify the Behavioral Features Promoting Social Interactions

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***Abstract*—Studies of social behaviors in animals are faced with various methodological difficulties, which can be addressed by using controlled artificial social agents. Previous studies have shown that various animal species interact with passive replicas or interactive robots that mimic their conspecifics. In the case of chickens, filial attachment (imprinting) to robots is observed in young chicks. However, the features and functions of the robots that maximize the efficiency of chicken-robot attachment have not yet been identified. Therefore, we designed RoboChick, a simple robot that can be easily customized with different features. Further, we developed a protocol for assessing the attractiveness of each feature. In the current study, we tested the attractiveness of two RoboChick features during robot-chick interactions: the presence of flashing lights and vocalizations in response to chick interactions. Our proposed protocol proved suitable for assessing the efficacy of the features. RoboChick, which is open and modular, can be easily reproduced by other research groups and adapted to test different features in different experimental conditions.**

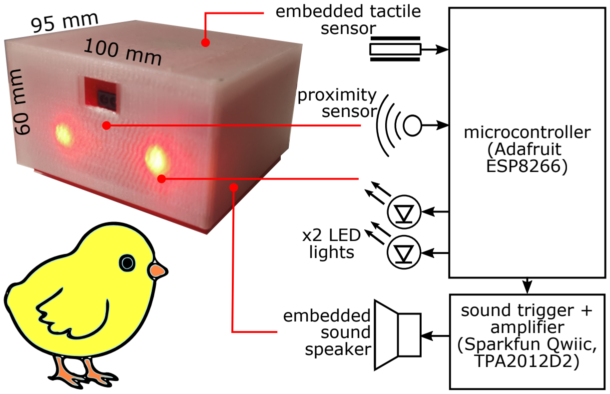

Fig. 1: The design and main components of RoboChick.

I. INTRODUCTION

Several types of interactive robots and animal replicas have been used in the study of social interactions. In experiments with animals, the interacting individuals are crucial elements of each other's environment, yet are nearly entirely out of experimental control. As a result, replicability is difficult to achieve, as repetition of the same experimental conditions within or across subjects is unlikely [1]. The use of robots not only enables good control over experimental conditions, but also allows us to study more complex interactions [2] than just a single stimulus-response scenario [3]. Furthermore, the use of artificial social agents allows to dissect the studied behavior by enabling the researcher to isolate features of the behavior to assess its impact on the overall interaction or to dissociate behaviors from environmental context in which they usually occur.

Previously it was shown that a number of species, such as guppy fish [4], rats [5], dogs [6], and chickens [7] interact with robots, exhibiting behaviors that are comparable to those observable in natural interactions. Knowledge of how the studied behavior is expressed in natural conditions is of crucial importance when assessing the suitability of robots for investigating the behavior. Due to the well-established phenomenon of filial imprinting (the social attraction developed for the first objects experience after hatching), the domestic chicken (*Gallus gallus*) is a suitable animal model for the study of social interactions [8]. Imprinting is a fast social learning mechanism through which hatchlings develop a strong preference for an adequate interaction partner, in the early days of their life [9]. While imprinting evolved to support attachment to a parent, chicks have been found to imprint on a range of conspicuous biological and artificial objects [8] [10]. Chicks exhibit affiliative responses towards the object they have imprinted on, such as staying in close proximity to the imprinting object, following it, and showing signs of distress when the object is removed [9]. These behaviors are characteristic markers of imprinting, thus allowing to recognize when imprinting has taken place, making it a suitable behavior to investigate with the use of robots [8].

Previous studies on chicken-robot interactions showed that chicks express a range of affiliative behaviours indicative of imprinting towards the robots, such as following [7] and distress upon separation [11]. Furthermore, mobile robots were shown to promote learning and development, as observed in a

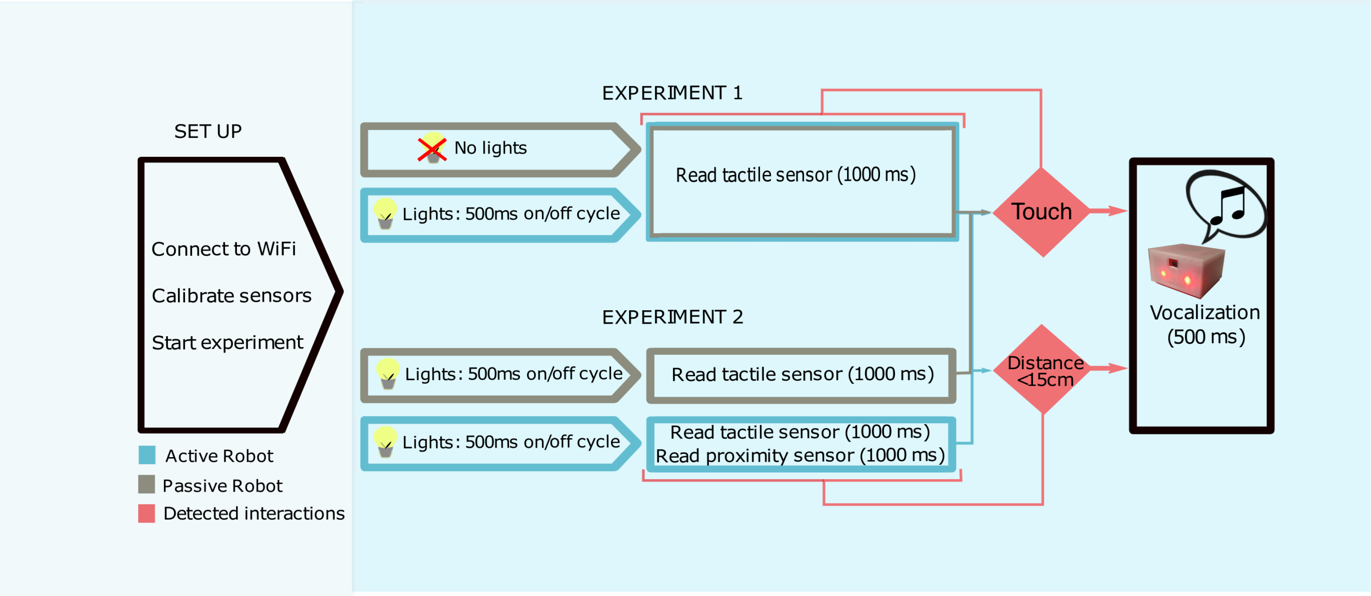

Fig. 2: RoboChick functionality and experiment summary. Following the set-up phase, the robots displayed their pre-programmed behaviors (flashing lights) and began reading the tactile (experiment 1 and 2) and proximity (experiment 2) sensors. When the sensors were triggered by interactions from the chick (touch or approach) the robots produced vocalizations.

study in which chicks were exposed either to a mobile robot or a stationary robot [11]. Nonetheless, none of the previously developed robots produced imprinting of comparable strength as that elicited by conspecifics. For this reason, we propose a protocol for identification of features promoting interactions and imprinting, in order to arrive at a combination of features that could make robots equally attractive to real animals. We have designed RoboChick, an interactive robot capable of not only detecting, but also responding to chick behaviors. We considered both long-range (tactile, proximity) and short-range (vocalizations, appearance) interactions in the design of the robot. To enable easy testing of various features and facilitate customization for other experiments, the robot is modular and amenable to modifications. Additionally, we propose a two-alternative choice experiment design for assessing the attractiveness of features of the robot in eliciting social interactions from chicks. We present preliminary results from two pilot experiments which employed the proposed protocol and RoboChick to examine the preference of visually-naïve chicks for a robot that a) produced flashing lights vs. a robot that did not (experiment 1); b) produced vocalizations upon detection of a chick's approach vs. one that did not (experiment 2).

1) Requirements: The minimum requirements for the robot to be practical in behavioral studies are that a) it is attractive to chicks; b) it can detect social behaviors performed by chicks; c) it can mimic social behaviors. To satisfy the first requirement, we implemented a number of features known to promote imprinting in the first instance of the prototype: salient color (red, [12]; flashing lights at the front of the robot [12]; having size similar to a chick [13]; and emitting vocalizations [14].

We aimed to enable the robot to detect touches and proximity of the chicks, as these are key aspects of filial behaviour. In terms of interactive features, in the initial design of the robot, we decided to enable acoustic stimuli, which are an important aspect in hen-chick interactions, as well as a feature that can contribute to effective imprinting [15].

2) Design: The control system of the robot was housed inside a 100 mm x 95 mm x 60 mm transparent, 3D-printed cube (outer shell), with a smaller red cube placed inside (inner shell) (fig. 1). The shells were custom designed in Fusion360 3D modelling software. Two LED lights were installed at the front of the cube.

Microcontroller The robot was controlled with a Wi-Fi enabled Adafruit Feather Huzzah ESP8266 microprocessor powered through a USB connection to a PC.

Sensory Outputs In order to enable the robot to produce sounds, a three-component audio system was installed, including an MP3 player (Sparkfun Qwiic Trigger MP3), a mini speaker (RS PRO 8 Ohms 1W Miniature Speaker 36mm) and a mini amplifier (TPA2012D2 StereoAmp) (fig. 1). Additionally, two LED lights (red) were installed at the front of the cube.

Sensors Tactile contacts were detected by a piezoelectric sensor placed between the outer an inner shell of the robot, such that it was the only surface of contact between them. With this placement, touches on any of the surfaces of the outer shell would cause displacement that would trigger the piezoelectric sensor. For detecting proximity, we used an infrared sensor (GP2Y0E03 IR Distance Sensor) placed at the front of the robot. This sensor can detect objects within 3-50 cm range in front of the robot.

Software RoboChick was controlled with software written in Arduino (www.arduino.cc) and ran on an Espressif ESP8266 microcontroller, via an Adafruit Feather Huzzah development board. The program read measurements from all sensors and forwarded them to a connected PC. The serial information was read and displayed using Processing IDE (www.processing.org), which also enabled to later save the readings collected during the experiment to files.

The microcontroller was used to run a webserver which provided the user interface that could be accessed from any Wi-Fi enabled device. The user interface was rendered as a simple webpage on the computer, that could be used to send configuration parameters to the robot.

The following settings of the sensors and actuators were pre-fixed: the rate of LED lights flashing (500 ms on/ 500 ms off cycle), minimum intervals at which the robot would detect individual events (1000 ms for all sensors) and sound duration (500 ms).

Full code and hardware specification required to assemble RoboChick are available online [1].

II. BEHAVIOURAL EXPERIMENTS

The behavioral experiments presented are small-sample pilot studies aimed at assessing the suitability of the robot and the experimental protocol for testing different robotic features. The experiments consisted of presenting a chick with two robots which differed in terms of a single tested feature. As such, the experiment was a double-choice task. Each chick's preference for a robot was assessed based on number of tactile contacts made with each robot and the amount of time spent in their proximity.

A. Chicks

Seven (4 female, 3 male) one-day old chicks (*Gallus gallus*) from the Ross 308 strain were tested in the experiments. The eggs were ordered from PD Hook Hatcheries Ltd. and were incubated for 21 days at Queen Mary University of London under standard controlled conditions (37.7C, 40% humidity). Three days prior to hatching, the eggs were transferred into a hatchery, where they were incubated until hatching in 37.7C and 60% humidity.

B. Setup and Procedure

The experiment was conducted in a 920 mm (L) x 600 mm (W) x 520 mm (H) arena lined with white plastic (fig. 3a). A food and water container were placed at the midline of the arena. The arena was lit up with an LED light strip placed directly above it to ensure even lightning. Two identical RoboChicks were placed on opposite sides of the arena. The experiments were recorded audio-visually with a camera and a microphone placed directly above the arena.

The current study comprised two experimental conditions and involved a comparison of the preference for one of the two robots. The experimental procedure was the same for both conditions: visually naïve chicks were placed in the middle of the arena, between two robots. Each session lasted 30 min, during which the chicks were allowed to freely explore the arena and the robots. The position of the active and the passive robots was randomized across experiments.

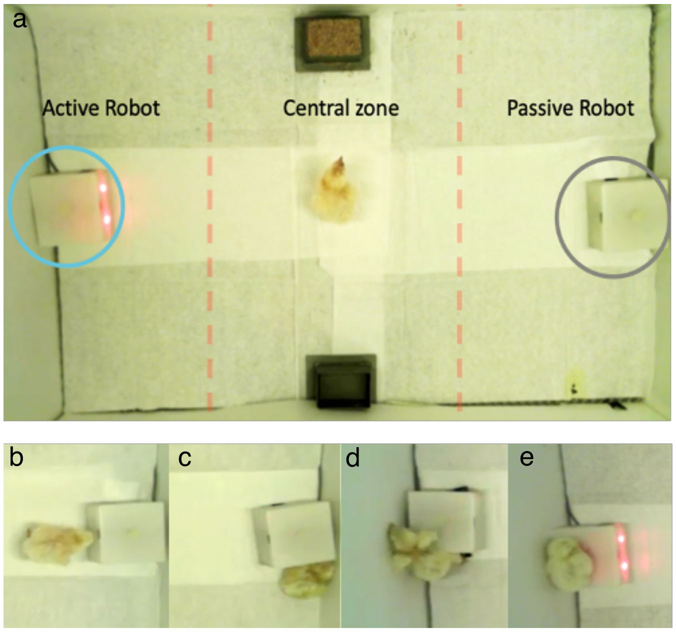

Fig. 3: a) Layout of the experimental arena. Robots were placed at the far ends of the arena, which was divided into 3 zones: (dashed line): central zone, active robot (marked in blue) zone and passive robot (marked in grey) zone. Interactions with the robot observed during the experiment: b) pecking; c) snuggling; d) climbing; e) standing on top.

1) Experiment 1: In this pilot experiment, one of the robots (”the active robot”) produced a flashing light stimulus, while the other one did not (”the passive robot”). Both robots emitted a pre-recorded chick vocalization upon detecting a tactile contact from the chick. Three chicks were tested in this condition.

2) Experiment 2: In this pilot experiment, chicks' (n=4) preference for a robot that emits sounds upon detecting an approaching chick versus a robot that does not was tested. One of the robots (”the active robot”) emitted a vocalization when a chick was detected in front of the robot within a 15 cm distance.

C. Data Analysis

Chicks' preference for the robots was assessed based on the data collected by the robot (time of active interaction with each robot) and by analyzing the videos recorded during the experiment. All data analysis was performed using Python.

Chicks' position within the arena was tracked automatically using DeepLabCut [16], an open-source deep-learning toolbox that extracted the position of the center of each chick's body in each frame of the recorded videos. The coordinates generated this way were used to plot spatial heatmaps, demonstrating the amount of time spent in each portion of the arena. To

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[1] https://github.com/ARQ-CRISP/RoboChick

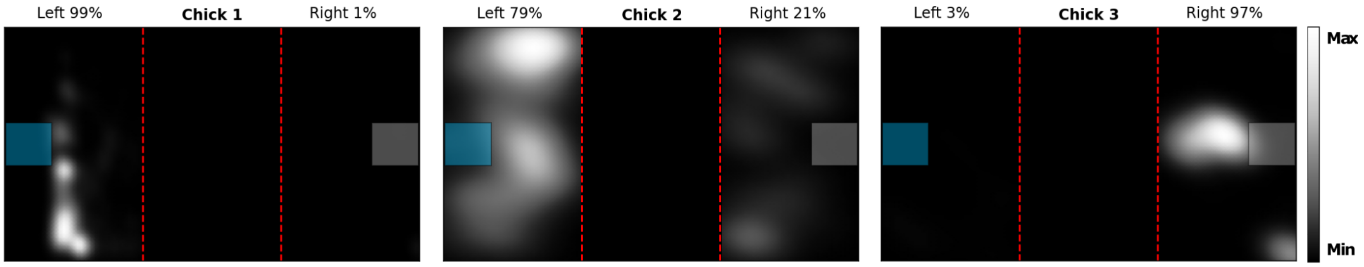

Fig. 4: Experiment 1 (active robot: flashing light): heatmaps showing the proportion of time chicks spent in each part of the arena. The arena is divided into 3 sections, the active robot (blue square) zone, central zone, and passive robot (grey square) zone. The active robot (blue square) is plotted on the left, regardless of its actual placement in the experiment, which was counterbalanced. Percentage score above the arena correspond to the proportion of time each chick spent in the right and left zone, with central zone excluded from that analysis.

assess chicks' preference for either of the robots, the arena was divided into 3 virtual regions: active robot and passive robot zones (35 cm x 60 cm), and central zone (22 cm x 60 cm) (fig. 2a). The preference was quantified as the proportion of time (T) spent outside the central zone and near the active robot (thus excluding the time chicks spent in the central zone):

$$\text{Preference} = \frac{T_{active\ robot}}{T_{active\ robot} + T_{passive\ robot}} \times 100 \qquad (1)$$

Using this formula, a score of 50 would indicate no preference for either robot, while scores above 50 would indicate preference for the active robot.

III. RESULTS

Data collected from the tactile sensors on the robots was used to calculate time of active physical interaction with each of the robots. The robots were programmed to detect whether the touch sensor was being triggered every 1000 ms. Therefore, multiple contacts detected in succession were considered to indicate a prolonged contact. The sum of contacts detected on each sensor represents the time of active interaction.

A. Behavioural Observations

To inform the design of future versions of the robot, we observed the behavior of chicks during the experiments to identify behaviors and types of interactions the robots should be responsive to. The chicks spent the first minutes of the experiment in the middle of the arena before they would start exploring. All chicks explored the arena, showing most interest in areas near the robots and corners and rarely showing interest in food or water. A long-range behaviour we observed frequently was that chicks often produced vocalizations while exploring the arena and prior to approaching the robots. Several types of short-range interactions with the robots, i.e., proximity and tactile interaction, were observed. We identified 4 main types of contacts made by the chicks (fig. 3b-d). When pecking (fig. 3b), chicks would make very brief contacts with the robot by hitting it with their beak. These often happened in sequences of several pecks performed at very short intervals. Snuggling (fig. 3c) occurred when chicks would rest by the side of the robot while maintaining contact with it. This was usually a prolonged interaction, whereby chicks would sometimes spend several minutes without moving from the snuggling position. Climbing (fig. 3d) occurred when chicks would press their bodies against the robot, but rather than doing so while being still and resting, they would move back and forth or up and down, thus making the contact with the robot intermittent. Sitting on top (fig. 3e) occurred when chicks climbed the robot and rested on top of it. This type of interaction could also last up to several minutes.

These interactions differed in the terms of pressure that the chicks applied to the robot (e.g., their full weight when climbing and sitting on top, very gentle touches when pecking, a range of intensities when snuggling), but also in terms of duration of the contacts. These differences have implications for the type of sensors that should be used, should the need to distinguish between different types of these interactions arise. In the current experiment we quantified the detected tactile contacts as "active time of interaction," but future experiments should aim to distinguish between different types/durations of individual interactions.

B. Experiment 1

In this experiment, we assessed the attractiveness of a robot with a flashing light. Since maintaining proximity to the imprinting object is an index of successful imprinting [8], we assessed the areas occupied by the chicks throughout the experiment. In order to do that, we generated heatmaps representing time spent in each zone of the arena (fig. 4). As can be seen, two of the chicks (chick 1 and 3) showed strong preference for one of the robots and spent the majority of the experiment in proximity to that robot. One of the chicks (chick 2) explored both robots during the experiment but spent the majority of time with one of them.

To analyze chicks' exploratory behavior, we plotted the proportion of time spent near the active robot in each 10 min interval of the experiment (fig. 5). Chick 1 and 3, showed strong preference for one of the robots in the first 10 minute interval of the experiment, which is a hallmark of imprinting

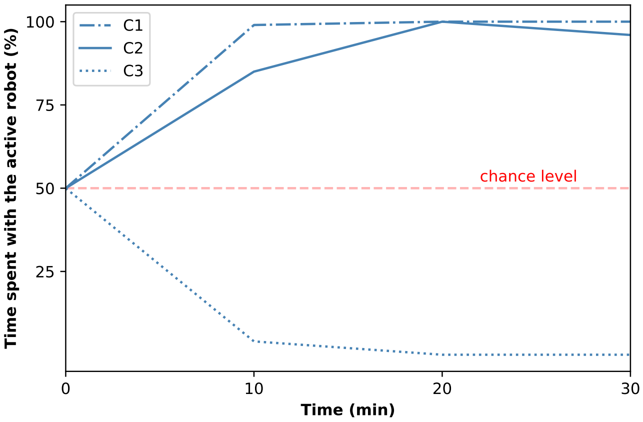

Fig. 5: Experiment 1 (active robot: flashing light): percentage of time chicks spent near the active robot in each 10-minute interval of the experiment. Chance level (red dashed line) indicates no difference in the time spent with either robot.

[9].Preference of chick 2 was not as defined during the first interval, however, it was evident in the following two intervals.

Finally, we quantified the data collected from the robots' sensors by calculating time of active interaction- the sum of all instances of the tactile sensor being activated, each counting as one second. The data is in fig. 6. All chicks interacted more with the active robot (mean time of active interaction= 264.67 s, σ = 135.72) than with the passive robot (mean time of active interaction= 119.33 s, σ = 97.53). Due to the small sample size in this pilot experiment, we cannot conclude whether this difference was significant.

These behavioral observations indicate that chicks showed no signs of fear of the flashing lights, thus making them an appropriate stimulus to be used in further experiments. The fact that all the tested chicks had tactile interactions with both of the robots indicate that they show interest in the robots and explore them readily. We also showed that 30 minutes are sufficient to engage chicks with RoboChick. These findings encourage use of the robot in further experiments.

C. Experiment 2

In this experiment, we were interested in assessing the attractiveness of a robot producing a chicken vocalization upon detecting the approach of a chick. A heatmap representing the proportion of time spent in each portion of the arena was constructed for each chick (fig. 7). All chicks explored both robots, although in some cases (chick 4 and chick 5) they spent a large portion of the experiment in proximity to one robot.

Fig. 8 shows the percentage of time within each 10-minute interval that the chicks spent next to the active robot. As can be seen, chicks 4 and 7 showed strong preference for one of the robots within the first interval of the experiment and remained there throughout the rest of the experiment. Chick 6 was the only one that did not show a stable preference for either of the robots at any point of the experiment spent similar portions of time in both zones.

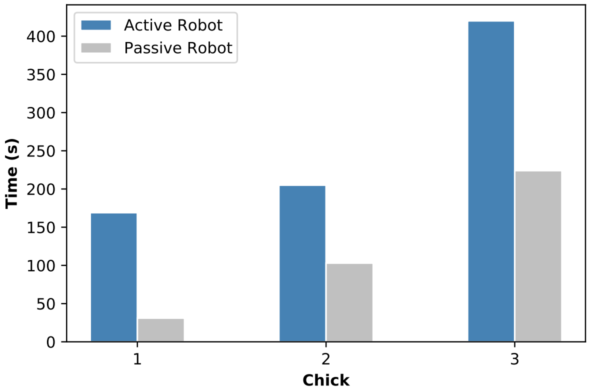

Fig. 6: Experiment 1 (active robot: flashing light): time of active interaction with each robot. Time was calculated as the sum of tactile interactions (detected every one second) detected by the sensor installed on the robot.

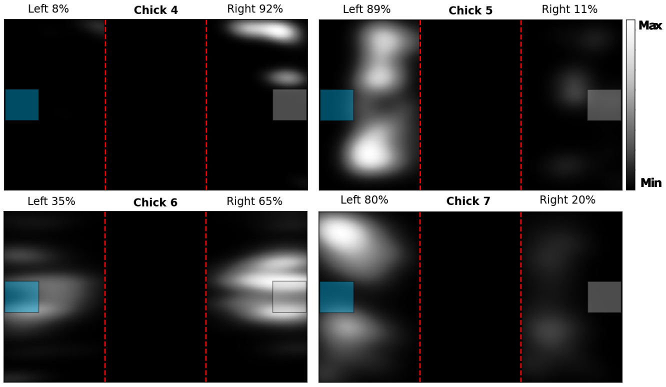

Fig. 7: Experiment 2 (active robot: vocalizations from a distance): heatmaps showing the proportion of time chicks spent in each part of the arena.

Due to software issues affecting data storage, we were unable to analyze the time of active interaction with the robots in this experiment.

IV. CONCLUSIONS

In this study, we have developed RoboChick, a robot aimed at providing a platform for identifying features that promote social interaction and filial imprinting in chicks. Focus on interaction, modularity and ease of modification distinguish RoboChick from previous designs of robotic agents for the study of social interactions in chickens(e.g. [7], [11]). The modular design, compactness and cost-effectiveness of manufacturing RoboChick make it easy to use by research groups without a strong background in robotics, thus making it an accessible tool for ethological research. RoboChick can be modified easily in accordance with the requirements of intended experiments, in a way that allows to test a variety of multimodal interactive features, e.g., vocalizations or tactile stimulation.

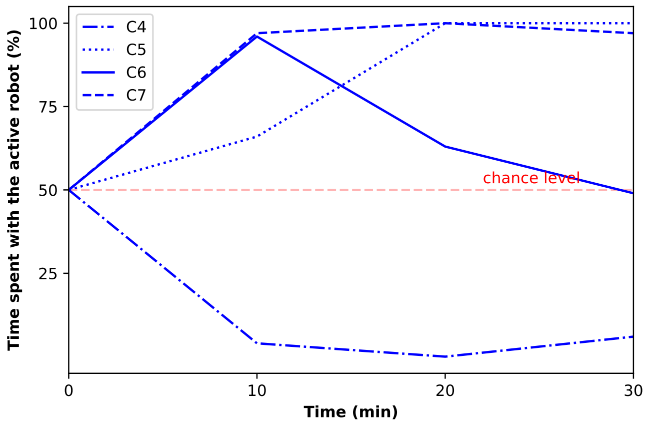

Fig. 8: Experiment 2 (active robot: vocalizations from a distance): time percentage of time chicks spent near the active robot in each 10-minute interval of the experiment. Chance level (red dashed line) indicates no difference in the time spent with the active and the inactive robot.

Furthermore, RoboChick opens the possibility of conducting closed-loop experiments, whereby the robotic agent's behaviors are dependent on the actions performed by the focal animal.

The behavioral work presented here tested a double-choice experimental protocol which can be used for assessing social preference for one of two robots, allowing for comparisons between robots that differ on one feature only. In our pilot experiments, we have shown that chicks readily interact with the robot in its current form. In both conditions that we have tested, chicks approached and explored the robots, interacted with them in a number of ways, and showed no signs of fear of them. Further experiments with larger sample sizes will be needed in order to determine which features are preferred. Once these are identified, the RoboChick's attractiveness to chicks can be compared with that of real hens. We have shown that RoboChick is suitable for conducting such tests, presenting the opportunity for more widespread use of robotic agents in studies of social interactions.

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