Designing Sociable CULOT as a Playground Character

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Abstract. CULOT is designed as a playground character with the aim of grounding the playground language (verbal, non-verbal, playing-rules, etc) between children through play-routing while experiencing the pleasure of play. A robot establishes "persuasiveness" activities inside the playground, through the process of generating play rules/contexts and executive social interactions and engagement toward the intention of "attachment" of the children to the robot through interaction and activities. The behavior of the robot plays a significant role in executing the above playground activities (or interaction). As a primary study, our focus is to explore how robot behaviors (cues) are capable of generating the playground rules, social interaction and engagement in order to convey its intention to children and extract the potential dimensions in order to design CULOT behaviors as a playground character by considering the above factors.

Keywords: Playground language, persuasiveness, attachment.

1 Introduction

Playground is a space that enables child to expand their imagination, social intelligence, and language for their initial growth and development [5]. Through play routing, children can learn social and cultural rules, experience expressions of affective behaviors, language experiences, and utilize their own language

Fig. 1. Sketch of the playground activities with CULOT robots

C. Stephanidis and M. Antona (Eds.): UAHCI/HCII 2014, Part II, LNCS 8514, pp. 571–580, 2014.

through symbolic communication [8]. There is substantial research showing the clear connection between play and brain development, motor-skills, and social capabilities [2][1]. All learning, whether it be emotional, social, motor, or cognitive, is accelerated, facilitated, and fueled by the pleasure of play [14].

We can comprise a variety of playground environments to facilitate different patterns of playing structures, including free-play contexts and structured-play contexts. Structured-play (e.g., football, baseball, etc.) already includes established rules, number of players, and who the winner or loser will be; however, a free-play structure does not have any rules, restriction of players, etc., which therefore provides more opportunities for children to build up their own rules and procedures. In the context of a free-play structure, children are provided a greater environment to develop their social interaction, communication capabilities, leadership, etc., because they have to communicate interactively to establish the activities while playing harmoniously with other members in the playground [10].

A caregiver (parent, teacher, etc.) also plays a vital role on the playground in establishing interaction between children and also assisting their activities [9]. In this phase, the caregiver pretends to be a teacher, parent, or colleague to support the pleasure of play and also to enhance the social interaction and social intelligence of the children. Through considering the above role of the caregiver, researchers in field of social robotic have been motivated to develop a robotic platform for children in playing contexts [6][7]. These project motivations are directed toward a variety of goals; recently, Cynthia [12] developed a playground character which can be connected to a blended reality (connecting the physical world and virtual world) while establishing a variety of interactive scenarios. Muu [11] was designed to explore the effectiveness of the minimal design and meanwhile establish interaction between children as a social mediator. Aurora [15], IROMEC [4], and ROBOSKIN [13] all explore the usability of a robotic platform for children with autism to enhance their social interaction through game-playing scenarios.

Particular studies have contributed either to exploring a robot's cognitive development model or have attempted to explore how children respond to the robotics platform toward the aim of building social robots. Our attempt is to build up a spatiotemporal foundation toward constructing a playground language based on our social robot, CULOT. As such, the primary motivation of our study was to understand the essential dimensions when designing the CULOT as a playground character - especially in designing the robotic behaviors inside the playground for conducting the rules of play, social interaction, as well as to convey a robot's intention, including determining the characteristics (attributes of the communication channel) of the powerful cues (behaviors). In addition, we attempt to extract the potential dimensions as a roadmap in designing the robot's behaviors as a playground character.

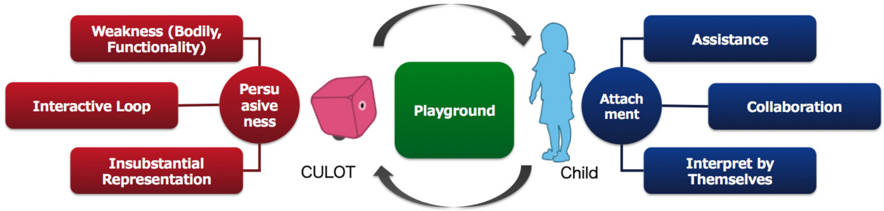

Fig. 2. Interactive process of the implementation

2 Sociable CULOT as a Playground Character

CULOT executes the "persuasiveness" interactions toward "attachment" children into the playground activities (Figure 2). Robot mainly grounds the persuasive interactions through its weakness and insubstantial representations [16]. A weakness of CULOT can be defined based on its body and functionality; CULOT does not have hands and legs, and it cannot grasp any other object. However, CULOT can execute minimal behaviors (e.g., move, push, and express non-verbal behaviors), and through these interactive behaviors the robot can express its intention. Due to the weakness of CULOT's behaviors, it is necessary to evoke children's assistance and collaboration via the insubstantial representation of the playground activities through the interactive loop. Children might anticipate (interpret by themselves) CULOT's interaction and playground activities through the process of insubstantial representation. With this proposed concept, a variety of activities and playground language (symbolic communication, vocal communication, etc.) might be grounded through the child-CULOT interactions.

3 Playground Activities

The robot has to be involved various activities on the playground in order to generate the play rules/contexts, to execute social interactions and engagement, and to convey its intention to the children. Accordingly, it can demonstrate the play rules/contexts while tracking the children's interests and motivation, social interaction, and engagement to establish interactive communication toward enhancing the pleasure of play, and CULOT can also determine how to convey its intention through the behaviors. CULOT can execute the above activities/ interaction through "direct asking (straightly convey robot intention (explicit behaviors))," "indirect asking (insubstantial representation about the intention (implicit behaviors))," "collaboration (working together)," and "encouragement (cheering to activities)." These behaviors can be generated through its inarticulate sounds and pushing/moving behaviors (non-verbal behaviors).

4 Design of CULOT

CULOT was designed by following the minimal standards to establish interaction with the user (Figure 3). Moreover, all of its external appearance (body) is made with soft material, and its eyes are designed with a web-camera. The robot is capable of generating a variety of gestures through the servo-motors - it can move back, forward, left and right. Also, the robot can acquire inarticulate sounds which vary according to the interactions. Several image processing algorithms were embedded to obtain the environmental conditions and changes.

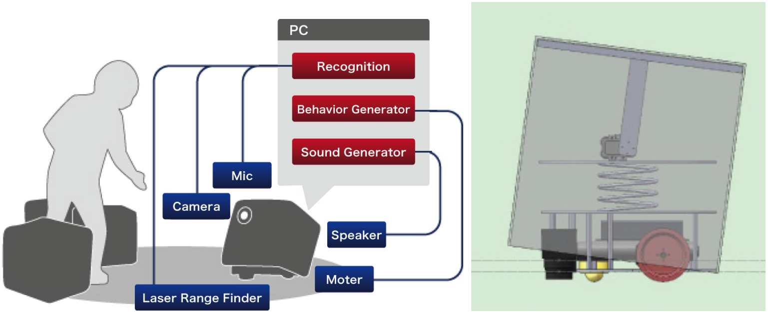

Fig. 3. Designing the architecture of the robot

5 Experimental Protocol

The primary objective of the study was to explore potential social cues for a robot to generate the playground rules, social interaction and engagement in order to convey its intention to the children. Several combinations of communication channels (inarticulate sound, moving behaviors, gestural interactions,

Table 1. Twelve videos created by representing "direct asking (explicit)," "indirect (implicit)," "encouragement," and "collaborative ."

Category	Code of the Videos	Descriptions of the Behaviors	Number of robots/Communication Channels
Direct	A1	One robot is pushing a block into outside	Body gestures
	A2	Two robots are conveying to push a block	Multi-robots, Eye-gaze, Vocal, and Nodding
	A3	One robot is conveying to push a block	Nodding, and Body Orientation
Indirect	B1	One robot is requesting to push a block	Body Movement, Eye-gaze, and Vocal
	B2	One robot is moving around a block	Body Movement
	B3	Multi-robots are establishing the inarticulate sound while looking at a block	Multi-robots, Eye-gaze, and Vocal
Encourage	C1	One robot is doing body interactions and vocalizing while an another robot is pushing a block	Multi-robots, Body Movement, and Vocal
	C2	One robot is moving between two blocks while another robot is nodding by synchronizing inarticulate sound	Multi-robots, Body Movement, and Vocal
	C3	One robot is nodding toward a block while another robot also turns toward a same-block	Multi-robots, Body Orientation, and Nodding
Collaborative	D1	Two robots are pushing two different blocks	Multi-robots, Body Movement
	D2	Two robots are pushing a block	Number of Robots, Body Movement
	D3	One robot is nodding toward two blocks (green and orange), and another robot is pushing an orange block	Multi-robots, Body Movement, and Nodding

etc.) have been considered in generating a robot's social cues, and to finally educe the optimum design dimensions (road-map) in order to design the CULOT behaviors as a playground character. As shown in Table 1, the study developed the "direct (straightly convey robot intention (explicit behaviors))," "indirect (insubstantial representation of the intention (implicit behaviors))," "encourage (cheering activities)," and "collaboration (working together)" behaviors by considering the inarticulate sounds, moving behaviors, gestural interactions, etc. (Figure 4). Twelve total numbers of behaviors were designed by preparing twelve videos with a real playground setup (Table 1) (context of block arrangement as shown in (Figure 1). To explore the above goals, the following two experiments were conducted.

Experiment 1: An initial experiment was conducted to explore what are the most powerful cues (behaviors) to generate the playground rules, social interaction and engagement, and to convey its intention by using the subjective rating of the participants. We used the above twelve videos to obtain the subjective ratings through the interface of LimeSurvey; we included a single video with nine questions (the questioner being depicted in Table 2) on a single page and each participant had to access twelve pages, with a total 108 (12 pages * 9 questions) ratings being obtained from each user. The questions were designed as follows: questions $(Q1, Q2, Q3)$ represents the evaluation of the behavioral capability to establish the playground rules; consequently $(Q4, Q5, Q6)$ evaluates the potentiality to establish social interaction & engagement, and to evaluate the capability to convey its intention from questions $(Q7, Q8, Q9)$ with the rating scale of $(1 - 5)$. The participants indicated their ratings through a website, with 32 people (19-27 years of age, 9 males and 23 females) participating in the experiment.

Experiment 2: The second experiment was directed to extract the optimum dimensions to design the robot's behaviors. We selected eight videos (direct (A1, A2), indirect (B2, B3), encouragement (C1, C3), and collaboration (D1, D2) according the higher subjective ratings of Experiment 1. Moreover, the highest mean value of the subjective rating for each behavior was considered for all of the

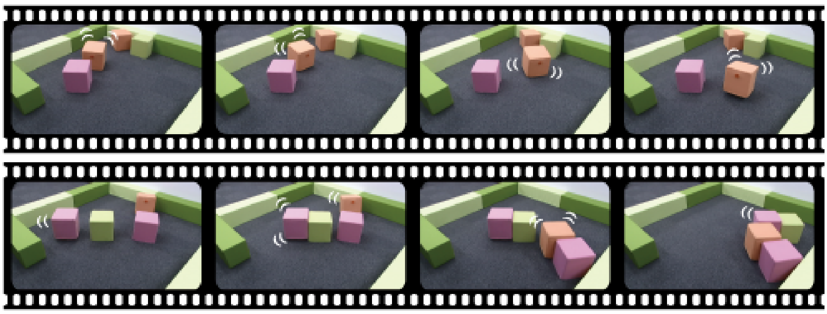

Fig. 4. Figures show a screen shot of the robot's behaviors of $A3$ and $D1$

questions in selecting the above eight behaviors. Our experimental procedure was as follows. We randomly arranged the two videos (suppose video1 and video2) with the following three questions on a single page using LimeSurvey: (1) video1 and video2 had a similar power to build "play ground rules," (2) video1 and video2 had a similar power to establish "social interaction and engagement," and (3) video1 and video2 had a similar power to convey "its intention to the participants." The participants rated the 28 comparisons, and the experiment was conducted with 28 participants between 19-27 years of age (8 male, 20 female).

6 Results

6.1 Results for Experiment 1

Figure 5 depicts the subjective ratings for the each of the videos with relevant questions ($Q1-Q9$) from the questionnaire. In addition, we applied an ANOVA to expose the significant differences of the subjective ratings of the twelve videos within the each question. The left-hand figure shows the subjective ratings for "capable to establish playground rules," with "capable to establish the social interaction & engagement" in the middle of the figure, and "potential to convey its intention" being also depicted on the right-hand figure. As shown in Table 2, we found significant differences within the all of the questions, which suggests that participants closely evaluated how each of the behaviors could potentially generate playground rules, social interaction & engagement, and convey the robot's intention, since all of the rated ($Q1-Q9$) questions were represented from the above categories.

Another motivation of this study was to extract the characteristics (or attributes) of higher rated behaviors in each category: playground rules, social interaction & engagement, and convey the robot's intention. We selected the highest and lowest mean values of behaviors in each question (represented in the above categories), as shown in Table 2. We applied independent t-tests to

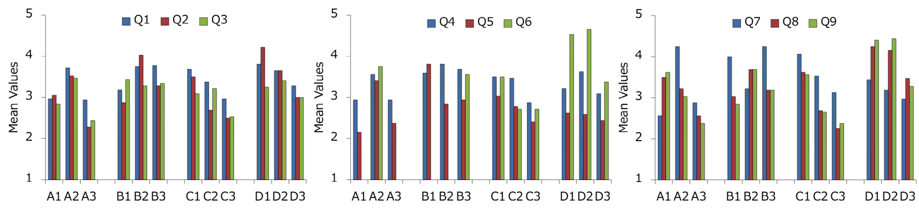

Fig. 5. The figures show the subjective rating for each video (behaviors) by considering each of the questions of the questioner. According to the questionnaire category, the left-hand figure shows the subjective ratings for "playground rules," with the middle of the figure showing the "social interaction & engagement," and "convey its intention" also being depicted in the right-hand figure. All Codes (e.g $A2$, $B2$. etc) were described in Table 1

determine the significant differences of the rating between the highest and lowest behavior ratings in each question. The significant difference between each question suggests that the subjective ratings had clear rating differences, which is important in examining the behaviors and understanding the attributes (characteristics) by synchronizing the robot activities.

If we consider the category of "playground rules," which represents questions $Q1$ to $Q3$, we obtained higher ratings for $D1, D2, A2$, and lower ratings for $A3, A3, A3$. When we look at the higher rated videos of $D1, D2, A2$, all of these behaviors have a common characteristic in that multiple robots were involved in the activities. However, only a single robot was involved in the lower-rated video. These results might suggest that the swarming behaviors of robots with explicit behaviors (directly indicating the activities) are more powerful in making the playground rules. We had higher ratings for $B2, B1, D2$ and lower ratings for $C3, A1, C2$ questions of $Q4$ to $Q6$, which represents the "social interaction & engagement." If we carefully look at these higher rated behaviors, all are defined as implicit (did not directly indicate the task) behaviors. Implicit behavior always evokes the curiosity of humans which intensifies their social interaction and engagement. This might indicate that the implicit behaviors are more positional in establishing the social interaction and engagement in a playground context. Inarticulate sounds and the robot's swarm behaviors were powerful in conveying the robot's intention when we look at the higher rated videos in $Q7$ to $Q9$.

6.2 Results for Experiment 2

In applying multidimensional scaling (MDS) [3], we separately considered the ratings for (1) video1 and video2 had a similar power in building the "play ground rules," (2) video1 and video2 have a similar power in establishing "social interaction and engagement," and (3) video1 and video2 had a similar power in conveying "its intention to the participants." MDS is useful to extract the structure or patterns of the rating (similarity and dissimilarity) through the distance of the visualizations. We can also derive new dimensions to represent the plotted variables by the underlying dissimilarity, since we can explore what are the patterns of the participants rating for each category and how we can acquire the road-map (dimensions) in order to design the robot's behaviors as a playground character.

Figure 6 depicts the results of the multidimensional scaling (MDS) for the subjective ratings of "playground rules", "social interaction and engagement", and "convey its intention to the participants." According to the distance of each plotted points (A1, A2, B2, B3, C3, D1, and D2), we created three boundaries by considering the distances between the points for each figure. Three clusters were extracted as follows: $(C3, B3)$, $(C1, D2, D1, A1)$, and $(A2, B2)$, which are common for the above three categories. The extracted clusters were clearly separated on the visualization, which indicates that a type of road-map appears in the design of the robot's behaviors on the playground. Through MDS, we could extract the optimum dimensions from the visualization, which can defined as follows: The $(C3, B3)$ cluster mainly represents the robot's eye gaze

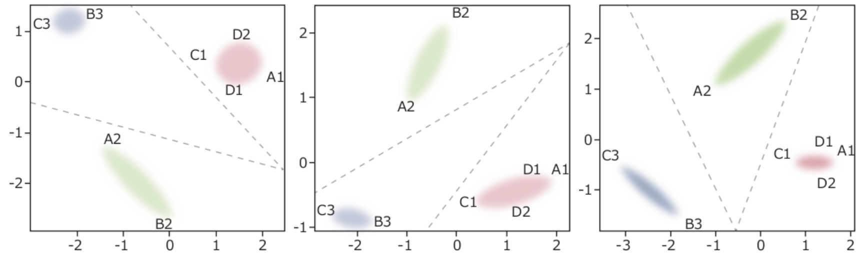

Fig. 6. Results of the MDS for the subjective ratings of "playground rules (left-hand side)," "social interaction and engagement (center)," and "convey its intention to participants (right-hand side)." All Codes (e.g $A2$, $B2$. etc) were described in Table 1.

Table 2. There were significant differences when we consider each question, and the higher and lower rated videos (behaviors) and the information of these significant differences were placed at the end of the table

Questions \ Behaviors	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	Significance	High & Low Mean Values
Q1: Robot can merged into playground.	2.97	3.72	2.94	3.19	3.75	3.78	3.69	3.38	2.97	3.81	3.66	3.28	F(31,341)= 9.87, p<0.001	high - D1 low - A3 t(31)=5.602 p<0.05
Q2: Robot can built the play rules.	3.06	3.53	2.28	2.88	4.03	3.28	3.50	2.69	2.50	4.22	3.66	3.00	F(31,341)= 18.47, p<0.001	high - D1 low - A3 t(31)=9.887 p<0.05
Q3: I wanted to play with robot(s).	2.84	3.47	2.44	3.44	3.28	3.34	3.09	3.22	2.53	3.25	3.41	3.00	F(31,341)= 8.40, p<0.001	high - A2 low - A3 t(31)=6.126 p<0.05
Q4: Robot(s) look like child.	2.94	3.56	2.94	3.59	3.81	3.69	3.50	3.47	2.88	3.22	3.63	3.09	F(31,341)= 7.08, p<0.001	high - B2 low - C3 t(31)=5.356 p<0.05
Q5: Robot(s) tried to interact with human.	2.16	3.41	2.38	3.81	2.84	2.94	3.03	2.78	2.41	2.63	2.59	2.44	F(31,341)= 11.11, p<0.001	high - B1 low - A1 t(31)=8.324 p<0.05
Q6: Robot can establish a collaboration.	-	3.75	-	-	-	3.56	3.50	2.72	2.72	4.53	4.66	3.38	F(7,217)= 18.91, p<0.001	high - D2 low - C2 t(31)=8.285 p<0.05
Q7: Robot(s) tried to tell something.	2.56	4.25	2.88	4.00	3.22	4.25	4.06	3.53	3.13	3.44	3.19	2.97	F(31,341)= 12.90, p<0.001	high - B3 low - A1 t(31)=7.552 p<0.05
Q8: I can understand robot's behavior.	3.50	3.22	2.56	3.03	3.69	3.19	3.63	2.69	2.25	4.25	4.16	3.47	F(31,341)= 13.64, p<0.001	high - D1 low - C3 t(31)=8.584 p<0.05
Q9: I can understand robot's intention.	3.63	3.03	2.38	2.84	3.69	3.19	3.56	2.66	2.38	4.41	4.44	3.28	F(31,341)= 15.71, p<0.001	high - D2 low - A3 t(31)=8.360 p<0.05

behaviors and bodily interactions, the explicit behaviors were extracted in the $(C1, D2, D1, A1)$ cluster, and the implicit behaviors were found in $(A2, B2)$. The above finding indicate that when we designed the robot's behaviors as playground characters, it was necessary to pay attention to three types of dimensions of behavioral design: (1) the category can be designed by considering the gaze and body interactions, (2) the category can be designed by considering the explicit behaviors (directly indicating the activities/goal), and

(3) the category can be designed by considering the implicit behaviors (do not directly indicate the activities/goal). It is important to consider the above categories in designing the robot's behaviors as a playground character, which are important in executing the variant behaviors by closely tracing the children's behaviors and feedback, for example, initially the robot can execute the implicit behaviors, and then if it does not succeed it can execute the explicit behaviors to fulfill its goal.

7 Discussion and Conclusion

The results of Experiment 1 revealed that an explicit behavior (directly indicating the activities) was more powerful in making playground rules, while implicit behavior was more powerful in establishing the social interaction & engagement (do not directly indicate the task); and for conveying a robot's intention, inarticulate sounds and bodily interactions were powerful. The second experiment of the study that depicted a roadmap and dimensions in designing the robot's behaviors were as follows: The behaviors of CULOT might be designed using three category types: (1) considering the gaze and body interactions, (2) explicit behaviors (directly indicating the activities/goal), and (3) implicit behaviors (do not directly indicate the activities/goal).

As a conclusion, we can combine the experimental results as follows. When we design the CULOT behaviors as playground characters, we should consider the above three dimensions (gaze and bodily interaction, implicit behaviors, and explicit behaviors). According to the activities (make playground rules, social interaction & engagement, and convey robot's intentions) on the playground, the robot could select the suitable behaviors to be executed according to the results of Experiment1, e.g., if the robot needs to establish social rules, then it can use explicit behavior (directly indicating the activities). In our future work, we will focus on utilizing the above higher-rating behaviors. Additionally, the extracted road-map will utilized to design playground activities toward the goal of exploring playground language through child-CULOT interactions.

Acknowledgement. This research has been supported by both Grant-in-Aid for scientific research of KIBAN-B (21300083) and Grant-in-Aid for scientific research for HOUGA (24650053) from the Japan Society for the Promotion of Science (JSPS).

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