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Interaction Design for an Enjoyable Play Interaction with a Small Humanoid Robot

Martin D. Cooney[1, 2], Takayuki Kanda[1], Aris Alissandrakis[3], Hiroshi Ishiguro[1, 2]

[1]ATR Laboratories
2-2-2 Hikaridai Keihanna
Kyoto 610-0228 Japan

[2]Osaka University
1-3 Machikaneyama, Toyonaka
Osaka 560-8531 Japan

[3]Adaptive Sys. Research Group
University of Hertfordshire, UK
Hatfield, AL10 9AB, U.K

{mcooney, kanda, ishiguro}@atr.jp, a.alissandrakis@herts.ac.uk

***Abstract*—Robots designed to act as companions are expected to be able to interact with people in an enjoyable fashion. In particular, our aim is to enable small companion robots to respond in a pleasant way when people pick them up and play with them. To this end, we developed a gesture recognition system capable of recognizing play gestures which involve a person moving a small humanoid robot's full body ("full-body gestures"). However, such recognition by itself is not enough to provide a nice interaction. We find that interactions with an initial, naïve version of our system frequently fail. The question then becomes: what more is required? I.e., what sort of design is required in order to create successful interactions? To answer this question, we analyze typical failures which occur and compile a list of guidelines. Then, we implement this model in our robot, proposing strategies for how a robot can provide "reward" and suggest goals for the interaction. As a consequence, we conduct a validation experiment. We find that our interaction design with "persisting intentions" can be used to establish an enjoyable play interaction.**

Keywords-components: interaction design, enjoyment, playful human-robot interaction, small humanoid robot

I. Introduction

Enjoyment has been shown to be a key constituent of functionality and work [2, 22], and to play an important role in technological artifacts gaining social acceptance [28, 31], a finding which has been replicated in the field of Human-Robot Interaction (HRI) [8]. Therefore, we would like to know how to design robots also capable of providing enjoyment during interactions. To this end, we propose a way in which a companion robot can provide enjoyment through the act of play.

A "companion robot" need not be only the object of play but can act proactively, as a play partner, based on its own intentions; entertainment need not be its primary function (we do not assume people will not limit play behavior to such robots); and it need not always play (e.g., when its current task is serious or urgent for the user [7]). "Enjoyment", the goal for this study, is a "pleasant experiential state . . . at the heart of entertainment" [29] and an important optimization criterion [16] related to "satisfaction" and usability (ISO 9241-11); it is often accompanied by a feeling of reward, clear goals, the matching of task challenge with a user's skill level, and perception of control [3, 4]. Lastly, "play" is a typical behavior which is "free" and absorbing [9], and which people of all ages engage in and enjoy for its own sake [5].

Fig. 1. How can a robot provide enjoyment through its behavior during a playful interaction?

Motion plays an intrinsic role in play with artifacts: people move toys such as dolls or teddy bears, puzzle pieces, or construction set blocks; some toys such as balls, swings, teeter-totters, hula hoops or jump ropes furthermore provide immediate and fine feedback through their own motion when moved. In HRI as well many robots are also designed to interact non-verbally via motion, e.g. [12, 14, 19, 20]. To investigate this important scenario, we set up a robotic platform capable of engaging in such non-verbal, motion-based play, Sponge Robot [1]. When picked up during play, Sponge Robot uses an inertial sensor to recognize how its body is moved: e.g., if a person is shaking the robot's body up and down, or if a person is making it dance from side to side. However, such recognition capability can only be useful if a robot has some mechanism for acting upon its knowledge. A person playing with a companion robot will not feel enjoyment if the robot does not move at all, moves randomly, or moves in an otherwise poor way. The question of how a robot can behave such that people feel good and enjoy an interaction (shown graphically in Fig. 1) constitutes the focus of the current work.

The rest of this paper is structured as follows. Section II discusses related work and Section III introduces our platform. Section IV motivates our desire for an interaction design and proposes guidelines, which are completed by conducting an

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experiment in Section V. Section VI provides discussion, and Section VII summarizes this paper's contributions.

II. Related Work

Many robots have been designed for play and enjoyment, e.g. [8, 12, 14, 15, 17, 19, 20, 23, 25, 26]; some of these had recognition capability [12, 19, 20, 23], and were small and humanoid [23]. However, these studies did not clearly indicate design principles which can be used to realize enjoyable play interactions for a small humanoid robot.

Possible design principles have been indicated outside of robotics in the field of psychology. Csíkszentmihályi identified general factors associated with enjoyment: reward, clear goals, the matching of task challenge with skill level, and perception of control [3, 4]. However, it is not clear how to apply these factors in designing an interaction.

The most relevant work we found with regard to our topic was one in HRI which aimed to provide therapy to children with disabilities [18]. The similarity of this work with the current study is that the authors described an approach for gathering requirements for playful interactions, in their case, using an expert panel. However, these requirements were then used to select a best robot for a particular interaction. In contrast, our focus is to show how to design enjoyable playful interactions for any small humanoid robot.

The new contribution of this work is that we identify typical pitfalls to avoid, and then propose and demonstrate a design for providing enjoyment during a playful interaction with a robot. With this knowledge and the recognition capability from [1], we can create robots capable of engaging in enjoyable play interactions.

III. Sponge Robot

The platform used in this study to engage in playful interactions, Sponge Robot (shown in Fig. 1 and described in detail in [1]), is a small humanoid robot, which is also soft and light to invite people to hold and play with the robot. In our previous work, we found people playing with a small humanoid robot performed ten or so typical gestures involving moving the robot's full body (such as hugging the robot or making it walk or dance) and described this type of robot as being like a "baby" or a "machine". These observations were in line with previous findings that some are more predisposed than others to perceive human-like traits in robots [27].

Internally, system architecture comprises sensor, gesture recognition, control (the focus of this study), and physical output (motions/sounds) components. During play, data from the robot's inertial sensor is sent wirelessly to an external laptop, which detects typical gestures people perform with an accuracy of 77%. Detected gestures are used to decide the robot's behavior: e.g., "responding" to a human's action, "suggesting" a way to play through proactive motion, or changing the robot's internal state (its intention or desire to play in a certain way). Finally, commands to play motions or sounds are relayed back to Sponge Robot, which seeks to provide enjoyment by moving using a typical number of degrees of freedom for a small humanoid robot (13, with 2 in each arm, 4 in each leg, and 1 in its head) and playing sounds using a speaker located in its abdomen.

IV. Designing an Enjoyable Interaction

Do we really require an interaction design to provide enjoyable interactions? And, if so, how can we come up with such a design? To find the answer to these questions, we prepared a simple initial version of our robot to hand to users.

A. *Simple Initial Design*

Sponge Robot's initial design was motivated by two requirements—enjoyable content and simplicity—and informed by observing existing (toy) robots[12345] [25, 26, 30].

For enjoyment, we provided Sponge Robot with walking and dancing motions often used by toy robots[1235], among other motions, as well as laughter and crying sounds, which can have an enjoyable effect[4][25, 26]. Lifelikeness, a characteristic of some robots [5][30], was implemented by making motions smooth, moderate (not overly large), and infant-like, as well as by setting the robot to idle if a user did not interact (to appear as if it had a life of its own).

For simplicity, sounds were limited to one positive and negative signal each. For logic, the robot was set to behave in a simple, turn-based way: suggesting and responding through its motions when the user does a gesture, laughing if a user complies with its suggestion, and crying otherwise. The robot also was designed to simply suggest the most recent gesture the user performed, which could positively reinforce the user's behavior and create an enjoyable mood. As well, instructions before playing with the robot were kept simple to avoid boring participants or telling them how to play: e.g., "play freely with the robot", or "the robot can perceive when its body is moved".

First Interactions with Participants

When we gave the robot to actual participants to play with one-on-one, we were surprised at what we observed: interactions were volatile and unstable, and often failed.

Fig. 2 shows several specific examples of failures. A user depicted in (a) turns Sponge Robot slightly, looking bored, and does not seem to notice the robot's suggestion motions or sounds as the robot flails away. Sponge Robot strikes a grimacing participant on the wrist in (b) in response to being rotated; this participant had started the interaction with a bright smile but no longer seemed enthusiastic at the end. (c) shows a participant who feels ignored tapping Sponge Robot, trying to stop the robot from idling and get some reaction—any reaction—from the robot. In (d), a user lunges to save the robot from suddenly falling.

Thus, the initial design failed to provide enjoyment, suggesting that a more appropriate interaction design was required. However, participants' general comments on how to improve the system did not clarify how to achieve such a design and often contradicted (e.g., the robot should be more

1 RoboSapien (http://www.wowwee.com)
2 E.M.A. (http://www.sega.com)
3 Jingle Bell Rock Santa (Christmas Fantasy, Ltd.)
4 Tickle Me Elmo (www.fisher-price.com)
5 Pleo (http://www.pleoworld.com)

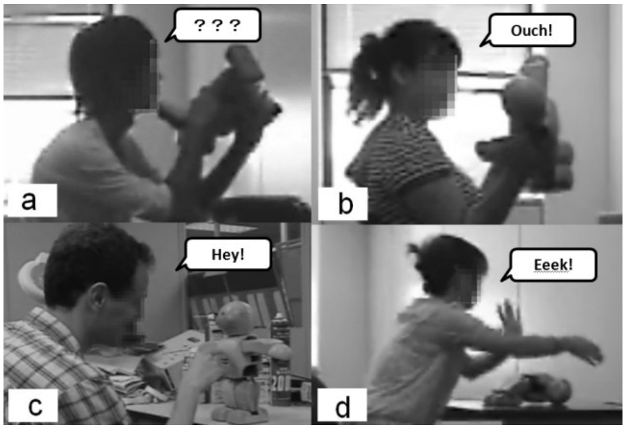

Fig. 2. Some scenes showing failures in initial interactions

docile, or wilder) or involved extra modalities such as vision or speech. On the other hand, it was clear when interactions failed, and feedback could be obtained regarding possible causes. Therefore, we decided to identify typical failure "patterns" from observation, find causes by interviewing participants, and then propose a model to avoid failures. The usefulness of a similar pattern-finding methodology for HRI has been expounded in [10], and applied in [21].

B. *Identifying Typical Failure Patterns*

A bottom-up approach was adopted toward identifying typical failures. First, failing points in initial interactions were identified by the experimenter; failures which occurred in a similar form for more than one user were grouped into typical patterns. Then, patterns were related to identify top-level logic. Failure patterns showed similarities; e.g., not knowing how to play is the primary reason not just for "No interaction" but also for "Just moving the robot" and "Robot ignores me". We found two basic top-level failure categories: failure in the robot's input (did users act on the robot in the intended way?), and failure in the robot's output (did users see and understand what the robot is doing?). Fig. 3 depicts failure patterns and their relation to one another using the metaphor of a trouble-shooting chart.

To avoid failures, knowledge of underlying causes is required; therefore, users' comments were analyzed. Typical failure patterns are shown on the right-hand side of Fig. 3 and reasons derived from users' feedback are described below.

No interaction

(*Description*) We were surprised to see some participants hardly interact at all: e.g. only picking up the robot and putting it back down on the desk. (*Reason*) The cause was complete failure of the robot's motions (responses and suggestions) and the instructions. Participants did not derive more reward from the robot's responses than its idling motions (e.g. flexing its arm, or leaning contrapposto), suggestions did not entice them to move the robot, and explicit explanation was required for what the robot *cannot* sense, as some participants eschewed the prescribed modality in favor of seeking to communicate via touch, sound, or vision.[1]

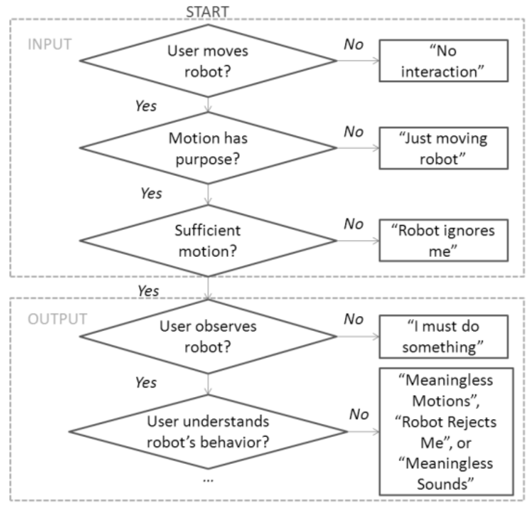

Fig. 3. Interaction "troubleshooting chart": diamonds on the left indicate reasons for failure, and rectangles on the right indicate failure patterns

Just moving the robot

(*Description*) Users who did interact often moved the robot without a clear purpose and in an incomplete way, sometimes pausing with the robot partially turned. (*Reason*) The robot's suggestions and instructions failed. Users reported that they did not how they could play with the robot.

Robot ignores me

(*Description*) Some users did seem to have an idea what they would like to do, but moved the robot too slightly or slowly to trigger a reaction, and avoided large gestures such as laying the robot down on the table. (*Reason*) Gesture recognition (lack of anticipation that users might behave in a reserved manner in a laboratory setting with an autonomous moving robot) and instructions led to this failure. Some participants were afraid that they could break the robot or injure themselves; the robot's (sometimes sudden) motions contributed to this feeling.

I must do something

(*Description*) Other users moved the robot continuously—not giving the robot a "turn" to act—and mostly ignored the robot's suggestion and response motions. (*Reason*) The instructions and general motion strategy failed. Such participants understood the modality (the user should move the robot's body) but did not understand the pattern of interaction (turn-based, and playing "with" the robot).

Meaningless ("Bug") Motions

(*Description*) Users who did seek to observe the robot's motions often did not respond to them as intended. Some said that the robot seemed inconsistent or like a bug in its own world, ignoring them and simply doing its own motions. Such users lost interest in playing, started to ignore the robot or tried to stop the robot from moving. (*Reason*) Participants reported not understanding the meaning of the robot's motions. The extent of this problem surprised us. We asked one user to just watch and describe the robot's motions, and found he was correct only 25% of the time; e.g., a dancing motion was

1 Wrong expectations may have resulted from the robot's appearance, as participants who thought the robot could see waved their hands in front of its eyes and forehead, where a person's eyes would be; previous studies also corroborate the importance of a robot's appearance toward shaping people's perceptions, e.g. [24].

interpreted as emphatic speaking using beat gestures, a walking motion was seen as a request for assistance, and hugging motions were seen as the robot wanting to shake hands or lie down (because the robot used its arms or leaned forward). Users also said they could not distinguish between motions intended to be reactions and proactive suggestion motions.

Robot Rejected Me

(*Description*) Some users saw meaning in the robot's motions, but interpreted them in a negative way: e.g., "When I tried to hug the robot, it pushed me away". This led to some very poor impressions of the robot and the play experience. (*Reason*) Motion design (sudden motions such as kicking which could be seen as negative responses) along with imperfect gesture recognition (e.g., not recognizing a user's hugging gesture in the example above) contributed to this problem.

Meaningless ("Cat") Sounds

(*Description*) Users often did not respond as intended to the robot's sounds, commenting in the interviews that sounds were one-pattern or irritating, or that the sounds seemed meaningless and faded into the background. Some people surprisingly mentioned that sounds seemed like "cat" sounds, even though they had been obtained from videos of real babies on YouTube. Likewise, we found that people often could not tell when the robot was supposed to be laughing or crying. (*Reason*) The meaning of sounds was difficult to understand when the robot emitted only a single call or cry, or when sounds were not accompanied by motion.

Comparison was made with another HRI study which identified four failure patterns for a large wheeled robot approaching a human [21]. We found close analogies for three of these patterns[1], but did not find a match for "rejected", a case in which a person did not want to interact, probably because we ask participants to play with the robot. This close correlation indicates that the identified failing points may be applicable to other contexts and other robots (e.g., those mentioned in Section II: Related Work). Therefore, the typical failures identified should be dealt with.

C. Design Guidelines

To design resolution strategies, individual reasons for failures were grouped into categories. Then, guidelines were assembled for each category to avoid failures, based on our own ideas and participants' feedback.

The categorization of reasons for failures is depicted in Fig. 4: (1) motions ((a) responses (b) suggestions), (2) sounds, (3) anticipation (application of context knowledge), and (4) instructions. Crosses (X) indicate the correspondence between reason categories and failure patterns (justification for this logic is given above in Section V.B). The guidelines drawn up based on these categories are described below. Guidelines comprise both components- development and *systems-related items* (the latter are in italics). As well, guidelines relate to the system architecture as follows: Guidelines 1, 1a, 1b, and 2 relate to motion creation and planning (control logic).

	1 Motion Design	a Responses	b Suggestions	2 Sounds	3 Anticipation	4 Instructions
No Interaction	X	X	X			X
Just Moving Robot			X			X
Robot ignores me					X	X
I must do something	X					X
Bug motions	X					
Robot rejected me	X				X	
Cat sounds	X			X		

Fig. 4. Correspondence between guidelines and typical failures

Guideline 3 applies to recognition. Guideline 4 is implemented alongside motion creation, and used before an interaction begins. In terms of novelty, guidelines span various levels. Some are largely obvious but important (e.g., timely motions). Others make sense, but may easily be overlooked (e.g., providing opportunities for an unskilled user to move all of a robot's degrees of freedom). Some are not at all obvious (strategies for offering reward or goals for the interaction) and must be tested and clarified (undertaken in the next section).

Guideline 1. Motion design: motions should be tested by naïve users, incorporate sounds when necessary to convey meaning, should involve all of the robot's main degrees of freedom; *should be quick to trigger and should not repeat indefinitely*

To design meaningful motions, we suggest feedback from naïve users while developing motion instances (adapting, pruning and branching potential motions, of course with consideration of the robot's nature and the context). Sounds should be played for motions which are typically accompanied by sound in the real world, such as yawning or snoring. Additionally, the set of motions designed should incorporate noticeable movements of all the robot's major appendages, as some users expressed frustration when they could not "make" the robot's arms or head move enough during an interaction. On the systems-level, to avoid the case where users do not pause long enough to see a robot's reactions or suggestions, a robot's motions should have little delay before starting. Also, motions should be "broken up" to avoid repeating the same pattern too many times.

For our case, motions were implemented for 7 full-body gestures[2] which seemed to be clearly understood (participants were able to say with an accuracy of 90% what the robot was doing).

Guideline 1a. Responses: large, positive

A robot should "reward" the user for interacting. Large, fast responses to a user's actions can be used to this end; these say to the user, "What you did really affected me!" As well, users who experienced positive moments in the interaction (e.g. a suggestion to hug from the robot, then a positive reaction after doing so) expressed high opinions of the robot, indicating that positive motions can also provide reward. What is not clear is if responses should always be large, fast, and positive: previous work indicated two possible strategies. Robotic toys like Tickle

1 Corresponding failure patterns: "Unreachable" and "No interaction", "Unaware" and "I must do something", "Unsure", in which a person tries to interact but receives no reaction, and "Robot ignores me".

2 *Up-Down*, *Lay Down, Stand*, *Dance, Walk, Hug*, *Upside-down* (N.B., these gestures and the method in which they are recognized are described in [1].)

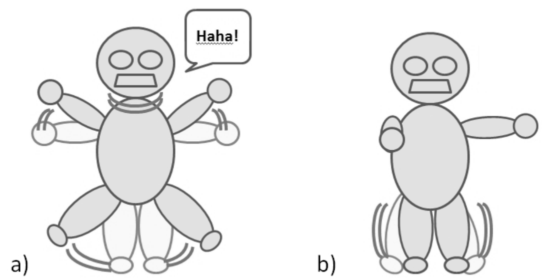

Fig. 5. Examples of (a) a large, positive response and (b) a suggestion ("Shall We Dance?")

Me Elmo tend to always show large, loud, "maximum" responses which are exciting and which can provide much enjoyment for short-term interactions. On the other hand, robots intended for longer-term, caring interactions like Paro [30] typically have some capability for "progressive" actions which are adapted based on the user's behavior. Therefore, we implemented two designs:

Responses 1. Maximum Reactions: The robot gives its largest and most positive reactions when the user does what the robot wants. (In our case, the robot moves its arms, legs, and head while using the loudest portion of its laughter stream.)

Responses 2. Progressive Reactions: The robot provides progressively larger and more positive reactions when the user does what the robot wants. (I.e., the robot first moves only its arms or legs, then its arms and legs, and finally its arms, legs and head, while laughing quietly at first, then with greater volume. The last reaction is the Maximum Reaction above.)

A large, positive reaction is shown in Fig. 5a: the robot flaps its arms, legs, and head, while emitting laughter.

Guideline 1b. Suggestions: to convey capabilities, goals; limited-reward; *continuous, cancellable, easy-first*

Suggestions, proactive motions performed by a robot, can be used to reduce confusion by indicating goals for the interaction ("Let's do this!") and capabilities ("I can play like this"). Suggestions should offer less reward than responses to be distinguishable and to encourage interaction. On the systems-level, suggestions should not be performed only once or they will not be noticed. Also, they should be quickly cancelled and the robot's first suggestions should be easy to understand and respond to (corresponding to gestures which can be recognized with few false positives or negatives).

However, it is not clear in the literature how a robot can communicate its desires and capabilities. The approach we chose was to take insight from how humans might suggest a way of playing (in the same way as we chose human-like motions to convey meaning). When humans suggest a way to play, they can try to propose various different options; or, they can insist on a specific desire:

Suggestions 1. Scrollable Suggestions: The robot "scrolls" (randomly) through various suggestions, indicating how a user can play with the robot.

Suggestions 2. Persisting Intentions: The robot does not show all of its suggestions immediately, but performs the same suggestion for a while; suggestions are shown in a predefined "easiest-first" order (Up-Down, Lay-Down, Dance, Walk, Hug). The robot requests a handshake to indicate when its intention changes, and intentions change if a certain maximum time has gone by (2 minutes), if the user has responded to the robot's suggestions and completely explored its responses, or if the user turns the robot upside-down for a significant time.

For both designs, we used codebook vectors and activity thresholds to determine when the robot was standing and not being interacted with (i.e., when the robot should suggest).

Guideline 2. Sounds: *non-isolated, accompanied with clear motions, timely*

To seem meaningful, sounds should be implemented as streams—avoiding isolated calls or cries—and start on time accompanied by clear motions. For Sponge Robot, we implemented energetic, "happy-seeming" motions and wild flailing motions to accompany laughter and crying. Volumes were adjusted based on feedback that loud sounds were "scary" and quieter sounds were difficult to hear. Finally, we confirmed that naïve users found the robot's laughter to be enjoyable.

Guideline 3. Anticipation: to improve gesture recognition

Knowledge of context should be applied to improve recognition performance. E.g., if some users act slowly when a robot is moving, the system should compensate. Or, if a user is expected to do a certain gesture, the system should predispose its likelihood to recognize this gesture to improve overall performance. To create such a situation, the system can proactively lead a user to respond in a certain way, rather than just waiting for users to perform *any* gesture. Such an approach has been advocated in [11] and is common for robots which use scripts to guide users' responses [6, 13].

For our system, anticipation was applied to improve recognition capability as follows. Very slow or fast variants of some gestures such as Lay Down and Upside-down were made detectable by checking the robot's current and past orientations compared with codebook vectors. As well, accuracies for Up-Down, Dance and Hug were increased for the case in which the user is expected to respond to the robot's desire. For Up-Down, our original system could only detect repeated up-down motion; this was rectified using a simple threshold on the z accelerometer axis, in conjunction with checking that the robot had not suddenly been stood and knocked against the table (which also results in suddenly elevated z axis values).

Guideline 4. Instructions: users should be prepared

Future robots will no doubt have greater recognition and expressive capabilities, and people will also have more experience interacting with them; in the meantime, particularly for novel ways of interacting it is vital that some information is conveyed through instructions: e.g., which modalities a robot can sense, what can be done to the robot without breaking it, and that the robot can respond and suggest.

V. EXPERIMENT

One option for an experiment would be to simply compare the original system with one using our design. However, this result alone would not be very informative: it can be expected that better design of motions and sounds, along with improved recognition and useful instructions, will lead to better results. Moreover, we still do not know precisely how to implement our design (as described in Section IV). Therefore, we conducted an experiment with two goals: the first, to verify that our model is useful for providing an enjoyable interaction; the second, to find a good strategy for a robot's responses and suggestions.

A. Participants

20 paid Japanese participants who had never played with our robot before (9 females and 11 males; average age 20.3 years, SD=2.1 years) participated in the experiment[1].

B. Conditions

We used a 2x2 within-participants factorial design with two factors: the robot's reward and intentions.

Reward factor

Maximum reward condition: the robot moves its arms, legs, and head while using the loudest portion of its laughter stream when a user does what the robot wants

Progressive reward condition: the robot moves its arms or legs, then arms and legs, then arms, legs, and head, laughing with increasing volume when a user does what the robot wants.

Intentions factor

Scrollable suggestions condition: the robot "scrolls" through various suggestions, when standing on the desk.

Persisting Intentions condition: The robot does not show all of its suggestions immediately, but repeats a single suggestion for a while, when standing on the desk.

These four conditions (described in more detail in Section IV) were combined to construct four different robot designs for participants to play with:

- Maximum Reward and Scrolling Suggestions
- Maximum Reward and Persisting Intentions
- Progressive Reward and Scrolling Suggestions
- Progressive Reward and Persisting Intentions

In all cases, the gestures the robot could recognize were the same. Each participant experienced all four conditions. The order of the conditions was counterbalanced.

C. Procedure

Participants sat at a desk in a partitioned-off space and played four times, each time with a different version of the robot. During the experiment, participants could hold the robot, put it down on the desk, place it on their laps, play with it on the floor, or hold it while standing or moving around the room. The robot performed suggestions when placed upright on the desk or responded if the participants did something to the robot. Participants informed the experimenter when they would like to stop playing. Average play time with one robot was 6.4 minutes (SD=2.7, min.=1.6, max.=10.4).

Before the first session, participants were given instructions, including a handout with contents similar to what might be found on a toy package: e.g., "The robot recognizes when its body is moved!", "If you put the robot on the table, the robot will suggest something??", and "Please don't throw the robot or set fire to it". Participants were also shown a short video clip of the robot's legs shaking and told this was a hardware bug. However, we did not indicate the gestures the robot could recognize or how participants should play.

After each session, participants filled out a questionnaire. After the fourth session, a short interview was conducted.

D. Measures

We observed when failures occurred, and obtained subjective measurements for perceived enjoyment, as well as factors we thought might contribute to enjoyment, using a questionnaire. Participants answered the following questions using a scale from 1 to 7:

- **How to Play** – Did you understand/not understand how to play with the robot?
- **Robot's Repertory** – How rich/not rich in variety were the robot's responses to your actions?
- **Robot's Intentions** – Did you understand/not understand what the robot was trying to do?
- **Control** – Did you feel/not feel a sense of control (like you were controlling the flow and contents of the play the way you wanted to)?
- **Enjoyment** – Was playing with the robot enjoyable/not enjoyable?

E. Hypothesis and Predictions

Our hypothesis was that failures would be less common; that more variety (expressive feedback) would be desirable, as robots' motions tend to be limited; and that clarity would be important for naïve users, from our observations in Section IV. Therefore, predictions were as follows:

Prediction 1: Fewer typical failures will be observed.

Prediction 2: Users would perceive most richness of variety and most enjoyment using the progressive reward condition.

Prediction 3: Participants would best understand how to play and the robot's intentions, and perceive the most enjoyment with the persisting intentions condition.

F. Results

Prediction 1 was supported: we were pleased to observe far less failures in interactions than for our initial naïve design; all participants interacted, watched the robot's suggestions and responses, and triggered "correct" gestures more than once. I.e., "No interaction" and "I must do something" were prevented,

1 These were not the same participants whose feedback was used to develop the design in Section IV.

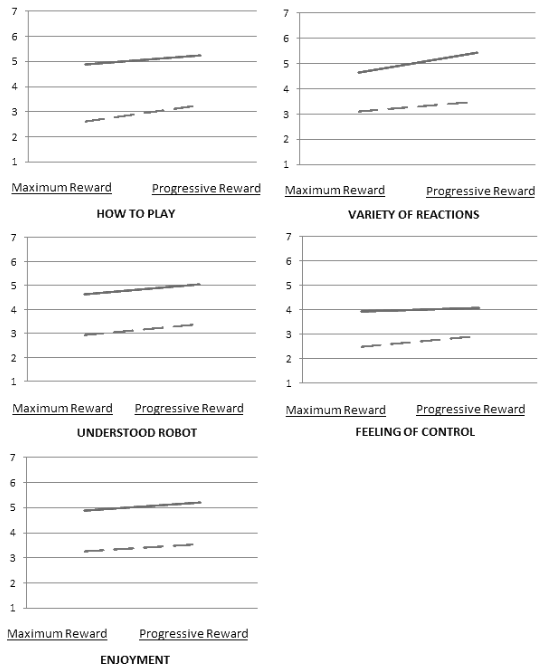

Fig. 6. Averaged scores for each questionnaire item and design condition (solid line: persisting intentions, dashed: scrolling)

"I don't know what to do" and "Robot ignores me" were rarer (although some users did small gestures for Walk and Dance suggestions), cases of rejection were fewer (e.g., due to better recognition for Hug from anticipation), and users tended to respond "correctly" to many of the robot's motions and sounds.

Questionnaire results for the experiment are shown in Fig. 6. We conducted a two-way repeated measures ANOVA test with two within-subject factors: the robot's reward and intentions. We found that progressive reward significantly increased perceived variety ($F=6.0$, $p=.024$), and its effect was nearly significant for how to play ($F=4.0$, $p=.059$). However, it did not significantly contribute to perceived enjoyment. Our second prediction was only partially supported.

For the robot's intentions, participants rated the persisting intentions condition significantly higher for all 5 measured items than the scrolling suggestions condition (how to play: $F=37.3$, $p<.001$; variety: $F=45.2$, $p<.001$; understood robot: $F=19.0$, $p<.001$; control: $F=10.2$, $p=.005$; enjoyment: $F=71.1$, $p<.001$). Our third prediction was supported.

G. *Interviews*

All participants were interviewed after playing with the robot. With regard to perceived reward, participants who often triggered the robot's responses mentioned observing variation in the progressive case. However, many participants spent much time trying to find out which gestures the robot could recognize and did not mention noticing variation. We think if participants played more than once with the robots or for a longer time that they would trigger the robot's desired responses more often and experience less enjoyment from seeing the same response in the maximum reward condition.

Regarding intentions, participants mentioned that they did not understand why the robot sometimes laughed and that the robot seemed less responsive in the scrolling suggestions condition. We think the fast pace and less anticipation confused: participants mentioned that it sometimes took time to understand the robot's suggestions. Therefore, we think when the robot's intentions persisted for some time, participants were able to try the same gesture several times and confirm that their actions did elicit a contingent response from the robot. This better understanding of the pattern of interaction helped participants know how to play, allowed them to see more of the robot's repertoire of motions, supported better communication, gave more of a feeling of control, and by doing so, provided participants with enjoyment.

VI. DISCUSSION

A. *Reasons for Enjoyment*

14 participants indicated specific moments they enjoyed most. Of the first moments reported, 4 participants enjoyed raising the robot high, 4 liked the robot's stand suggestions (the robot doing push-ups, sit-ups or trying to get up on its own), 4 mentioned the robot's dancing, 1 indicated the robot's unhappy struggling for Upside-down, and 1 said they liked the robot's response for Lay Down. Another thing participants mentioned was that they themselves felt happy when the robot seemed happy and that they associated the robot's happiness with their actions (they perceived contingency in the robot's actions).

B. *Limitations*

The goal of this study is to propose a design mechanism which can be used to enable enjoyable play interactions with a robot. However, the study was conducted using a very specific context (short non-verbal interactions using inertial gesture recognition), a specific robot (Sponge Robot), and targeted a specific audience (young adult Japanese). We did have the opportunity to also observe interactions of one version of the robot with groups of elderly people visiting our lab, and we did observe differences (participants treated the robot gently, much like an infant, and did not try to make the robot walk or dance). We believe that it will be useful in the future to investigate the performance of our design within other contexts, e.g. with other target groups, for long-term interactions and playful interactions involving speech (not just non-verbal behavior but also simple words), as well as extending the system to work across other modalities (such as touch).

VII. CONCLUSION

Our initial assumption—that we could simply hook up some motions to the robot's gesture recognition output in order to create an enjoyable interaction—was incorrect. Users did not understand the meaning of the robot's motions or sounds, grew confused and frustrated, interacted minimally or wildly and without pause, feared they would break the robot, and sometimes did not even interact at all. Toward avoiding these failures, we proposed an interaction design comprising four guidelines shown in Table 1. Furthermore, we proposed two

TABLE I. INTERACTION DESIGN

No.	Guidelines
1	Motions: meaningful (tested with naïve users), accompanied by sounds, using major DOFs; timely, non-repetitive
1a	Responses: large, positive; **progressive or maximum**
1b	Suggestions: conveying capabilities and goals, "limited reward"; continuous, cancellable, "easy-first", **persisting**
2	Sounds: non-isolated and with clear motions, timely
3	Anticipation: to improve gesture recognition
4	Instructions: users should be prepared

strategies each for a robot's responses and suggestions: progressive versus maximum reward, and scrolling versus persisting intentions. As a consequence, we conducted an experiment and found that persisting intentions have a significant positive effect on understanding of the robot and the interaction, perception of variation in the robot's actions and control over the interaction, and enjoyment; and that progressive reward increases perceived variety, which is important for long-term interactions. In conclusion, we showed that our interaction design with persisting intentions can be used to provide an enjoyable play experience with a reduced incidence of observed failures in interactions.

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