An Interactive Game with a Robot: Peoples' Perceptions of Robot Faces and a Gesture-Based User Interface

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***Abstract*—This paper presents findings from a HRI user-study which investigated participants' perceptions and experiences playing a simple version of the classic game, stone-paper-scissors with a humanoid robot. Participants experienced the robot displaying one of four different robot faces and interacted with the robots using a gesture-based interface. Findings from the study indicated that the effects of the different robot faces were inter-related with participants gender and ratings for overall enjoyment of the game experience. The usability and effectiveness of the gesture-based interface were overall rated positively by participants, though the use of a separate display for the game interface seems to have distracted participants attention from the robot's face.**

Keywords; HRI, Human-Robot-Interaction, Gesture-Based User Interface, Interactive Game Robot

I. INTRODUCTION

Recent research aims towards developing robots for use in domestic, office or other human-oriented environments. These robots will interact with humans in these environments as a matter of course and should exhibit behaviour that is not just safe and socially acceptable for humans in the vicinity, but should also facilitate and enhance the usability of the robots. Overall it has been found that people prefer consistency, in particular regarding robot appearance, capability and functionality [1][2]. The judgement of consistency of robot appearance, behaviour and function is subjective and it is likely that peoples' own idiosyncratic preferences and perceptions play a large role. However, some general characteristics regarding peoples preferences for robots have been discovered. Most people do not like robots to have realistic human appearances [3], but prefer some degree of human-likeness. A sizeable minority strongly prefer robots with non-human-like (i.e. machine-like) appearance [4][5]. It has been shown that people perceive human-likeness for robots as two main factors, physical-likeness and expressive-likeness, with the latter (i.e. communication and interaction abilities) generally more desirable than physical human-likeness (i.e. appearance) [6]. Most people would prefer to interact with a robot by means of speech [7][8] and many previous studies (e.g. [9][10][11]) have indicated that robot speech capabilities hold much promise with regards to Human Robot Interaction (HRI). However, speech recognition technology is not yet reliable enough to be used by non-experts in human-oriented unstructured and noisy environments. Therefore, current robots are typically controlled by users using traditional keyboards, mouse, or touch based Graphic User Interfaces (GUIs). With the recent cost effective availability of the Microsoft Kinect [12], the use of gesture based user-interfaces has become a feasible way for users to interact with robots in a relatively natural way; either as a supplement to existing modes of interaction or as the main mode of interaction and control [13][14].

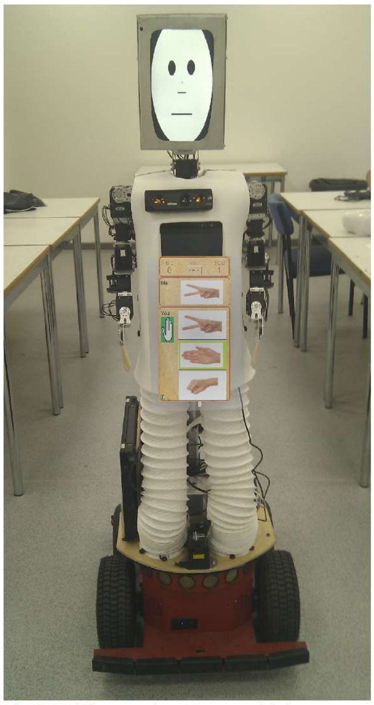

Figure 1. CHARLY (Companion Humanoid Autonomous Robot for Living with You) with 'retro robot' body covers and LCD face display showing a simple cartoon-like face.

CHARLY (Companion Humanoid Autonomous Robot for Living with You) is a humanoid robot developed by the Adaptive Systems research group at the University of Hertfordshire (see Figure 1). It is particularly aimed at investigating robot appearance and social behaviour and HRI. During 2010-11 it was shown in public venues in project demonstrations, dissemination and as part of an art exhibit, “My Familiar Companion” in collaboration with international artists, Anna Dumitriu and Alex May [15]. These venues were attended by relatively large numbers of people, which provided the opportunity to carry out survey-based research in conjunction with these events [6]. In the light of the findings, technical and procedural experience gained from these events, it was decided to carry out a new HRI study to investigate in more depth some of the issues that had arisen. The areas chosen for further investigation were: Peoples' perceptions and reactions to different face displays and to evaluate a newly developed Kinect gesture based user interface. This was to be achieved by playing a simple interactive game with the robot. The main research questions were:

1) *Does the appearance of the robot's face display have any effects on users' perceptions or preferences for interacting with the robot?*

2) *Is the Kinect based gestural interface a feasible way for users to interact and control a robot.*

Section II describes the robot and game system, Section III the user study method, Section IV presents the results and Section V the Discussion and Conclusions.

II. CHARLY SYSTEM DESCRIPTION

CHARLY has a simplified human-like appearance (humanoid) and scale, and was developed as part of the EU funded project LIREC (LIving with Robots and intEractive Companions). CHARLY is designed with easily replaceable head and body covers so that the robot's appearance may readily be changed to facilitate HRI research. CHARLY was developed using as many (low cost) standard parts as possible and the arms are primarily used for making expressive gestures. The body is mounted on two 'legs' and the robot can assume either a bending, crouching or sitting position. The robot body is mounted on a Pioneer 3AX mobile robot base [16].

1) *CHARLY Server and Control*

A dedicated Mini-PC implements a simple TC-IP based server which allows remote client programs to connect over a local (wired or wireless) LAN to control the robot. Remote clients can be written in any programming language that supports IP sockets. The underlying control software has obstacle detection and avoidance continuously active in normal use, so CHARLY has the capability to move safely in people orientated environments, either under direct control or autonomously.

2) *Morphing Face Display System*

A Face Morphing display system was developed when CHARLY was previously shown at the “My Familiar Companion” art exhibit [15]. This used a Microsoft Kinect camera mounted on the robot's chest to detect and isolate the faces of anyone coming within range. All the detected faces are combined into a single image such that faces closer to the Kinect have more influence over the resulting image than ones further away. The morphing face display program also acted as a client program for CHARLY and directly controlled the head and body movements for the “My Familiar Companion” exhibit.

3) *CHARLY Stone Scissors Paper Game*

For the current Study an Interactive Game program was developed which used the Kinect sensor to interpret users' gestures and implement a simple game based on Stone, Paper, Scissors. This program ran concurrently with the Face Morphing Program (only for one of the experimental conditions, see Section III) on CHARLY's laptop PC and allowed participants to interact with CHARLY using only gestures.

Initially it was planned to used CHARLY's hands to make appropriate gestures for Stone, paper or scissors, to use the Kinect to recognise hand gestures directly and to use speech to provide the main means of providing information to participants. However, though feasible in a quiet lab situation, it was found not robust enough in noisy and dynamic public areas. It was therefore decided to use a second body-mounted touch-pad to provide a dedicated display where the game progress and user interface was displayed (see Figure 3). Also, a method for controlling the game and robot with the human participants' whole arm gestures was found to be much more reliable in public environments. The program interfaced to the CHARLY Server and initiated simple pre-scripted body, head and arm movements, gestures and speech at appropriate points of the game.

4) *Game Interface and Description*

The game interface is shown in Figure 3. The topmost part displays the current game score. The robot score is labelled as “Me” and the user score is labelled as “You”. The middle area, also labelled as “Me”, displays an image of the robot's selection. During the game, this image changed randomly over time giving the user a clue as to which option the robot will choose. The bottom area has three buttons that allow the user to select rock, paper or scissors. This area is labelled as “You”. Each button has an image of the hand gesture for scissors, paper and rock as used in the real game. The user makes a choice by moving their (left or right) arm up and down (Figure 4) then pushing their hand forward when their desired choice icon is highlighted (Figure 5). When the user makes a selection, the image freezes to indicate the robot's choice. A complete game session consisted of three rounds, each of three individual games. The first player (robot or participant) to win two individual games in a round wins the round. The first to win two rounds wins the game. A complete game of three rounds typically lasted from 5 to 10 minutes. Depending on who won the game, the robot said “I won the game” or “You won the game” and either waved its arms in the air or adopted a head down posture respectively.

B. CHARLY Face Displays

The robot used four different face displays during the interactive game sessions. Each participant experienced only one face display from: *Simple static face* - A simple black and white, cartoon-like face constructed from ellipses and straight lines (Figure 6). *Morphing user face display* - The face display slowly changed to an image of the face of the the interacting person (see Figure 7 and section II.A.2 for more details). *A fixed image of a real robot face* - This robot face image was from a robot head we had used previously for live HRI studies [17][18] (Figure 8a). *Simple cartoon-like expressive face* - Three simple cartoon-like faces, constructed from ellipses and straight lines, formed simple 'expressions' which predicted the game intention of the robot (Figure 8b-c).

III. Experimental Set-up and Procedure

The study ran for 2 weeks in late November 2011 and was performed in the foyer area of the University of Hertfordshire Learning Resources Centre (LRC). The LRC is open to students and staff working at the University and provides open access to research, library, computing resources and social areas. A high level of casual and passing foot traffic occurs within the foyer area and this provided a potentially large number of participants for taking part in the Interactive Game Study (IGS). CHARLY was set-up at one end of the entrance foyer area, with the robot operator, control and support equipment partially obscured by screens (see Figure 2). A separate desktop computer ran a browser-based questionnaire to obtain participants' views on their IGS experience. Brief descriptions of the questions are provided in the following section IV along with the questionnaire results and analyses. The experimental procedure was as follows:

1. Any passers-by that showed interest in the robot and game, were asked if they wanted to play a game with the robot. If the answer was positive, they were then asked for consent to take part in the study. Note, if they only wanted to play the game, this was acceptable. If they consented to take part in the study, they were asked to sign a consent form to allow data and/or video recordings to be collected and used for subsequent research purposes.
2. The game was described and the gesture-based interface was shown to them. After a short practice, the game was restarted and up three rounds were played. Many participants did not complete a full three rounds, either because a winner was declared after two rounds, or the participant wanted to finish.
3. The participant was then directed to the questionnaire computer and left to complete the online questionnaire. An experimenter was on hand in case of any difficulties with using the software, but did not lead or direct their responses to the questions.

IV. Results

The questionnaire was divided into the following categories:

Demographic – Age, gender, occupation, handedness, robot computer and games experience, and Kinect (xbox) experience. The total number of participants was 80, 54 males (68%), 26 females (32%) and 7 (8%) were left handed. Their ages ranged from 17 to 60 (mean = 27), 40 (50%) were quite or very familiar with computer games but only 12 (15%) rated themselves as familiar with (toy or service) robots. 57 (71%) had not used a Kinect before.

Figure 2. A participant playing the interactive game with CHARLY in the University of Hertfordshire Learning Resources Centre

Figure 3. Stone-paper-scissors game interface when the user is being tracked and selecting paper

Game Experience – Enjoy overall, like playing with CHARLY, who won?, like winning/losing, play again, understand game, game difficulty, like CHARLY as game partner and like game interface.

CHARLY specific – Overall appearance, looking at, pleasing, comfort, distraction, difficulty focusing on game. Face; like, annoy, prefer another? Voice; like, like talking?

A. *Principal Component Analysis (PCA): Global Liking, Face Type and Demographics.*

In order to categorise the response data, a series of PCA analyses were run. Variables loading less than .5 on any given factor were removed as part of the analyses. The predictors of Global Evaluation were assessed using a stepwise multiple regression. The variables entered into the initial model were: Gender, Age, Familiarity with Robots, Familiarity with the Xbox Kinect, Familiarity with Computer Games, Familiarity with Rock, Paper, Scissors Game, Face type (Simple Static Face, Simple Expressive Face, User Face and Robot Face). The final analyses are reported here:

1) *Global Evaluation of the Experience*

The PCA on the variables intended to investigate a general (global) evaluation of the interaction as a whole found a unidimensional construct, formed of three factors

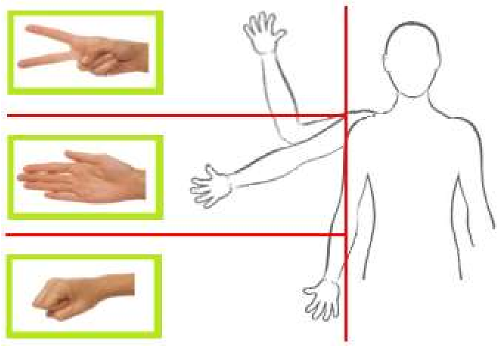

Figure 4. The three areas related to the user's body where a detected hand is associated with the selection of one of the three buttons of the game

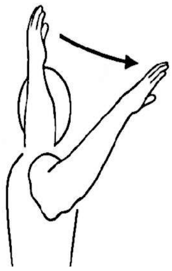

Figure 5. Schema of the movement necessary to press the scissors button

which had an eigenvalue of 2.22 and explained 73% of the variance. Table 1 provides the factor loadings and the variables are presented below:

Table 1: PCA of the Global Experience Evaluation Variables

Variable	Factor Loading
How was your experience of playing the game with CHARLY?	.87
Did you like playing with CHARLY?	.88
If you had the Opportunity, would you like to play with CHARLY again?	.83

2) *Game Usability*

Table 2: PCA of the Robot Evaluation variables

Variable	General	Voice	Distraction
Did you like CHARLY's General Appearance?	**.825**	.050	.083
Did you find it pleasing looking at CHARLY ?	**.839**	.284	.076
CHARLY distracted me from the game	.119	.029	**.828**
CHARLY made it difficult to focus	.010	.215	**.800**
Did you like CHARLY's face?	**.767**	.300	.116
I liked CHARLY's Voice	.015	**.853**	.057
Felt good talking with CHARLY	.123	**.843**	.105
Did you feel comfortable looking at CHARLY?	**.638**	.267	.360

The PCA on the variables intended to investigate the usability aspects of the game itself found a unidimensional construct formed of three variables which had an eigenvalue of 1.69 and explained 57% of the variance as follows:

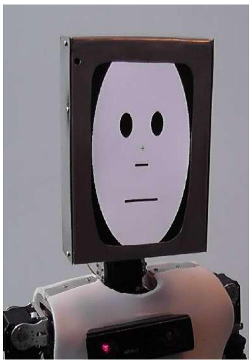

Figure 6. The Simple Static cartoon-like robot face display

Figure 7. The Morphing User face display

Table 3: PCA of the Robot Evaluation Variables

Variable	Factor Loading
Did you find it difficult to play the game?	.75
Did you like the interface of the game?	.65
Did you find it difficult to understand the game?	.84

3) *Robot Evaluation.*

The PCA on the variables intended to investigate the views of the robot in the interaction (Table 2) found three factors. The first factor had an eigenvalue of 2.63 and explained 33% of the variance. It was named General Robot Evaluation and is described below in terms of factor loadings. The Second Factor was named Robot Voice Evaluation with an eigenvalue of 1.77 and accounted for 22% of the variance. The Third Factor was named Robot Distraction with an eigenvalue of 1.24 and accounted for 16% of the variance. In total these three factors accounted for 70.5% of the variance.

B. *Significant differences for the four face display conditions*

There was no significant relationship between success at the game and the face display conditions ($\chi^2(3)=2.10$, $p=.553$), and also no relationship between success at the game and any of the Global, Game or Robot Measures.

ANOVA tests between the four face display condition groups' responses indicated that in terms of Global Enjoyment, there was a differentiation between the different facial displays. LSD post-hoc tests found that this difference was due to participants rating the Simple Expressive face as less enjoyable. However, there was also a significant interaction effect with face display type and gender ($F(3,71)=3.18$, $p=.029$). This relationship is illustrated in Figure 9 and suggests that male participants rated the Static Simple face display significantly higher

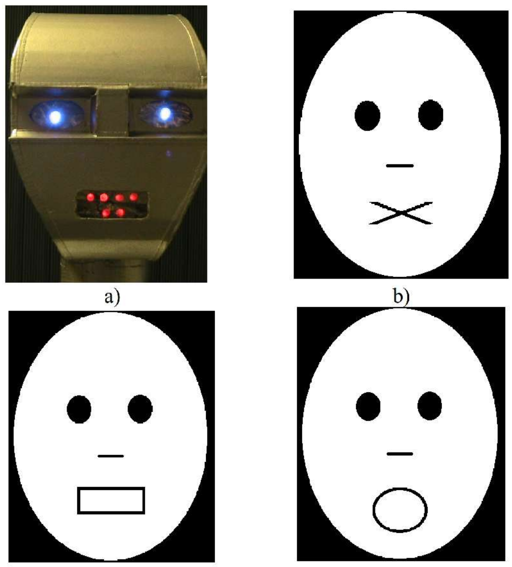

Figure 8. a) The real robot face display and Simple Expressive robot face which displays game intention; b) Scisssors, c) Paper and d) Stone.

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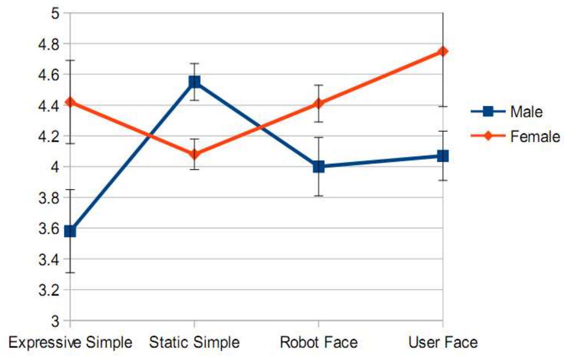

Figure 9. Interaction Effect for Gender and Face Display Conditions in terms of global evaluation.

than female participants and the opposite is true of the other display types. The effect was most pronounced for the Simple Expressive and the User Faces.

Table 4: ANOVA indicated significant differences between the four face conditions and participants' enjoyment of the interactive game experience (F(3,75=2.775, p=.047)

Group	N	Mean	Std Error
Simple Face	22	4.46	0.13
User Face	23	4.30	0.14
Robot Face	23	4.16	0.13
Expressive Face	12	3.86	0.22

There was no significant relationship between Face Display Condition along the other measures. There was, however a significant main effect for for Gender and the General Robot Evaluation measure ($F(1,72)=4.27$, $p=.042$). This effect suggested that female participants were more likely to rate the robot more positively along this dimension. The results also suggested that overall, participants rated the interaction positively.

C. Relationship between Prior Use of the Kinect Interface and Measurements.

There was no relationship between Prior Use of the Kinect and the Evaluation measures ($F(1, 77)<.010$, $p>.99$, $\eta^2<.001$) and no relationship between Prior Use of the Kinect and Success at the Game. In fact, there was a non-significant trend in which participants with no experience of the Kinect were *more* likely to succeed ($\chi^2(1)=.522$, $p=.470$).

Table 5: Correlation Matrix for Evaluation Measures

Measure	Global	Game	Robot General	Robot Voice	Robot Distract
Global	1				
Game	**.197***	1			
Robot General	**.254****	**.380****	1		
Robot Voice	.191	-.039	.088	1	
Robot Distract	.104	**-.287****	.171	-.141	
Note: *p<.01, **p<.05					

This combined with the overall high scores given for Evaluation, suggest that the gestural interface was suitable for a wide section of participants, not just those accustomed to such interfaces from previous use.

D. Correlations between the Measures

The different measures were correlated using Pearson's r, and the results are presented in Table 5 which suggests that there are results approaching significance between Global Evaluation, Game Evaluation and the General Robot Evaluation measures. In addition, the Distraction measure was negatively correlated with the Game Evaluation.

V. DISCUSSION AND CONCLUSION

Regarding the first research question: While there was a difference between the Face Display conditions in terms of Global Evaluation, post-hoc tests found that this was caused by the sample as a whole rating the simple expressive display less favourably than the other displays.

Significant gender differences in the sample were found, with female participants being more positively inclined towards the Expressive, Robot and User Face conditions than the male participants. This suggests that male participants overall preferred a simple, unchanging face display, while female participants were more positive towards a richer, more dynamic display. This finding echoes those from [19] where male participants had a tendency to prefer robot behaviours that facilitated the explicit goal of the interaction, while female participants attached more value to the more social and intrinsically rewarding aspects of the interaction. This also mirrors results found in [20] where female players of games seemed to value the non-competitive aspects of computer-mediated games in comparison with male players. Also, the female participants may have been able to process the richer facial displays more efficiently than male participants as found in [21]. This suggests that while some participants found it problematic to deal with split attention in such interactions, the use of rich and dynamic face displays will still be evaluated. However, the simple expressive face which predicted the robot's next game move was not highly rated by participants, and it is therefore likely that they were so concentrated on the game display, that they did not pay much attention to the face display. The problem of split attention has been remarked upon in some previous studies [22][23][24] and these findings seem to reflect a similar phenomenon.

For the second research question the data supports using the Kinect based gestural interface as a feasible way to interact and control the robot. Although half the participant sample had previous computer game experience, most had no previous experience of playing a Kinect-based (computer) game. Even though participants' interaction time was typically less than 10 minutes, their ratings for usability were relatively high irrespective of their previous experience of the Kinect interface.

This study has shown that there are differences in how participants evaluate the use of a robot. It has highlighted the trade-off in the current system between the potential problem of split attention with competing sources of expressive and game task feedback. Differences were found between male and female perceptions' of the interaction; game interaction and control, versus the intrinsic reward of a richer, more dynamic face display. Future work should address the issues of incorporating a gestural interface integrated with social feedback mechanisms in a more seamless manner for service robots in human-oriented environments.

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