Appeal and Perceived Naturalness of a Soft Robotic Tentacle

Jonas Jørgensen
Digital Design Department
IT University of Copenhagen
Denmark
jjoe@itu.dk

ABSTRACT

Soft robotics technology has been proposed for a number of applications that involve human-robot interaction. This study investigates how a silicone-based pneumatically actuated soft robotic tentacle is perceived in interaction. Quantitative and qualitative data was gathered from questionnaires (N=47) and video recordings. Results show that the overall appeal of the robot was positively associated with its perceived naturalness. They further indicate a slight user preference for the movements and the tactile qualities of the robot and a slightly negative evaluation of its appearance.

KEYWORDS

Human-robot interaction, soft robotics, aesthetics

1 INTRODUCTION

Soft robots have already been implemented in industry, but applications “in the wild” have also been proposed including uses in care work, surgery, rescue operations, and collaborative robots (cobots). For such tasks, human perceptions of soft robots will play a crucial role in facilitating and designing a desirable human-robot interaction. A primary benefit of soft robotics is increased safety through compliance [1, 2], but soft robots have also been speculated to have a more natural and therefore pleasing aesthetic.

This study was designed to explore perceptions of a soft robotic tentacle in interaction. Based on claims that soft robots have more natural and fluid movements [3] and “enable soft and natural human-robotics interactions” [4], it was hypothesized that there would be a significant relationship between the perceived naturalness of the robot and its appeal rating.

2 METHOD

Participants interacted with a soft robotic platform designed for the experiment. A tentacle morphology was chosen as soft robots based on this design are already being developed for applications that involve human-robot interaction [5-7].

2.1 Soft Robotic Platform

The platform incorporates a publicly available three-chambered soft robotic tentacle design [8] (cast in uncolored Ecoflex 0030 silicone with red wax). It is pneumatically actuated with low noise pumps. By selectively switching on the pumps, the tentacle can bend in all directions around its resting axis. An infrared (IR) distance sensor is positioned to the right on the platform.

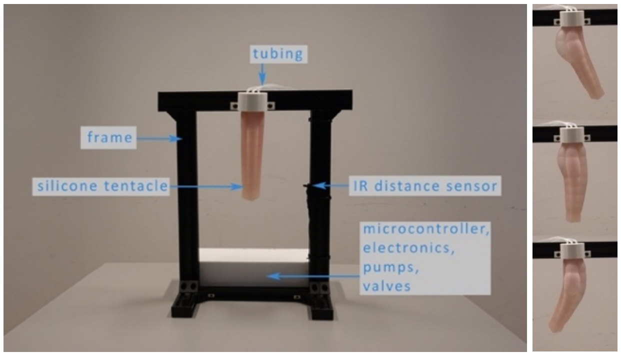

Figure 1: The platform with the tentacle in its initial position (left). Stills showing the tentacle’s motion (right).

2.2 Experiment

The platform was programmed to facilitate two main interaction modes that together constitute a semi-autonomous robot behavior intended to approximate a real-life application:

1. The user can observe the tentacle move about on its own (shifts between pre-programmed movements)
2. The user can interact with the platform by positioning her hand in front of the IR sensor (the tentacle moves towards the hand, touches it, and returns to the initial position).

Participants performed an open-ended interaction task to focus their attention on the experiential aspects of the interaction. The experiment was carried out at a university library at an open house event. Participants (N=47; age: mean 37.3, range 19-70; gender: 47% female, 53% male; 32% w. no prior robot interaction experience) were instructed that the experiment aimed to investigate perceptions of a soft robot. The two interaction modes were briefly described and participants interacted with the robot one at a time. Interactions were video recorded and a questionnaire was administered afterwards (closed questions, 5-point Likert scale questions (1=Strongly Agree, 5=Strongly Disagree), and open-ended questions).

In the following section, preliminary results based on quantitative analysis of questionnaire data are presented.

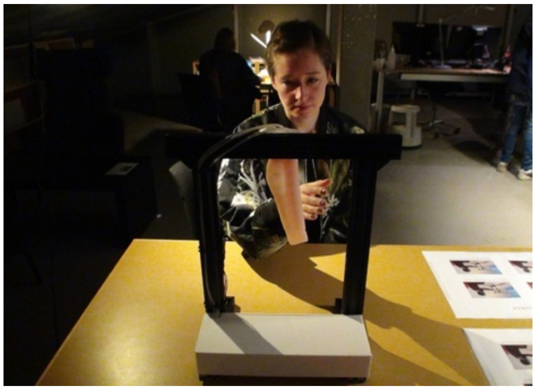

Figure 2: Participant interacting with the platform.

3 RESULTS

Table 1: Select questions with mean ratings and standard deviations

Question	Mean	Std.dev.
1a. *The robot has an appealing appearance*	3.36	1.05
1b. *The robot has a natural appearance*	2.94	1.09
2a. *The robot's movements are appealing*	2.85	1.00
2b. *The robot's movements are natural*	2.89	1.24
3a. *It is appealing to touch and be touched by the robot*	2.79	1.20
3b. *The robot feels natural when I touch it and it touches me*	2.72	1.08
4a. Appeal (=1a+2a+3a)	9.00	2.70
4b. Perceived naturalness (=1b+2b+3b)	8.55	2.69

The primary hypothesis that appeal was positively associated with perceived naturalness was tested with a regression model with appeal (4a) as dependent variable and perceived naturalness (4b) as independent variable (see Table 1). Appeal was significantly positively associated with perceived naturalness ($F_{1,45} = 28.6$, $b = 0.6$, $p < 0.001$). The association was also significant when adjusting for gender, age, and prior robot interaction experience ($p < 0.001$). Secondly, the mean appeal ratings for appearance, movement, and touch were compared using one-way repeated measures ANOVA. The analysis revealed that appearance was rated significantly different ($F_{2,44} = 20.35$, $p < 0.001$) due to a more negative rating compared with movement ($t = 3.01$, $p = 0.001$) and touch ($t = 3.35$, $p = 0.002$).

4 DISCUSSION

The results support the a priori hypothesis that the overall appeal of a soft robot is correlated with perceived level of naturalness. The finding of a significantly more negative rating of appeal for appearance compared with appeal for movement and touch suggests that appearance is the most important aspect to take into account when designing soft robots that are intended to be appealing to the users (using the technology of this experiment).

5 FURTHER WORK

This paper presents an analysis of select data obtained from the described experiment. Further work includes categorization, grouping, and coding of participant answers to the open-ended questions where they were asked to define and elaborate on their understanding of “appealing” and “natural” and describe the robot. A more comprehensive analysis will include this qualitative data that hopefully can enable a more fine-grained identification of determinants of appeal and perceived naturalness. The video recordings of the experiment (5 hours of footage) will also be analyzed to map recurrent types of user behavior as well as the dialogue between participants during the interactions.

The interaction experiment has been replicated with another tentacle of a light-blue color constructed from a slightly harder silicone with internal fiber reinforcements that inhibit radial expansion. These features give the tentacle a less organic appearance than the tentacle used in the present study. Taken together the two designs cover the design space of current soft robotics technology more fully. Results from the two experiments will be compared to develop more specific guidelines for designing soft robots for human-robot interaction.

REFERENCES

[1] Rus and M.T. Tolley. 2015. Design, fabrication and control of soft robots. Nature. 521, 7553 (May 2015), 467–475. DOI: https://doi.org/10.1038/nature14543

[2] R. Pfeifer, M. Lungarella, and F. Iida. 2012. The Challenges Ahead for Bio-inspired “Soft” Robotics. *Commun. ACM.* 55, 11 (Nov. 2012), 76–87. DOI: https://doi.org/10.1145/2366316.2366335

[3] Rolf Pfeifer quoted in J. von Zitzewitz et al. 2013. Quantifying the Human Likeness of a Humanoid Robot. International Journal of Social Robotics. 5, 2 (Jan. 2013), 263–276. DOI: https://doi.org/10.1007/s12369-012-0177-4

[4] J. Rossiter and H. Hauser. 2016. Soft Robotics - The Next Industrial Revolution?. *IEEE Robotics Automation Magazine.* 23, 3 (Sep. 2016), 17–20. DOI: https://doi.org/10.1109/MRA.2016.2588018

[5] Festo. OctopusGripper and BionicCobot (undated). Online: https://www.festo.com/group/en/cms/12745.htm

[6] I-SUPPORT robotic system for bathing (undated). Online: http://www.i-support-project.eu/

[7] STIFF-FLOP (STIFFness controllable Flexible and Learn-able Manipulator for surgical Operations) (undated). Online: http://sssa.bioroboticsinstitute.it/projects/STIFF-FLOP

[8] M. Borgatti. Silicone Robo-Tentacle (2013) Online: https://learn.adafruit.com/silicone-robo-tentacle