Soft grippers not only grasp fruits: From affective to psychotropic HRI

Caroline Yan Zheng [1] and **Kevin Walker** [1]

Abstract. Soft robots are an emerging class of biologically inspired machines. From the point of view of affective human-robot interaction design, we hypothesise that they are a promising medium to create more emotionally engaging human-robot interaction experiences. We report a preliminary study and early analysis of the affective qualities of four silicone-based soft robotic artefacts. Results gathered so far suggest that they are impactful in eliciting emotional engagement. We discuss the material and kinetic properties that may contribute to such an impact. The findings suggest opportunities for designing affective interaction that afford novel sensory experience. Meanwhile we question how this new class of robotic artefacts that do not look or feel like machines will impact the affective relationship of human users.

1 INTRODUCTION

Soft robots are an emerging class of "elastically soft, versatile and biologically inspired machines", made primarily of easily deformable materials such as fluids, gels and elastomers which match the properties of biological tissues and organisms [1]. Compared with conventional robots, which are kinematic chains of rigid links that prioritise control, soft robots allow a redundant, or 'infinite', degree of freedom (DoF) in their movement [2]. One of the most practical applications is for grasping and manipulation task in the form of soft grippers [3,4]. Although an infinite degree of freedom poses a challenging issue of control for the roboticist to address[2,5], it creates an appearance of smooth, continuous and organic-like motion. Such a kinetic feature indicates promising potential for aesthetic and relational serendipity, suggesting that soft robotics may be an excellent material for art and design practitioners. There is emerging attention from the creative community to explore the aesthetic potential of soft robotics as an expressive medium: e.g.[6,7,8]. The opportunity and risk in affective relations have been pointed out [7,9] but have been less widely explored in practice.

A typical soft gripper such as [3] and Figure 1a and 1b, consists of bending gripper fingers or elements around an object. Compliable silicone rubber material is used. There are inner chambers designed to allow air or liquid to be injected into the chambers, which causes the deformation of the gripper fingers to "grasp". By configurating the physical structure of the inner chambers and by adding reinforcement into the surface layer, the morphology of movement can be articulated. During earlier interaction with soft grippers, the researcher observed strong emotional reactions toward the robot's biomorphic disposition. As part of a research project for programmable materials suitable for designing affective Human-Robot Interaction (HRI), we are exploring the affective qualities of soft robotics artefacts made from silicone rubber. This short paper presents the results of a preliminary study and an early analysis of the affective qualities of kinetic soft robotic actuators that may contribute to this emotional engagement. By affective quality, we refer to "the ability of an object or stimulus to cause changes in one's affect" [10]. By breaking down the holistic disposition to material and interactive elements, we aim to facilitate the study of each designable module.

2 PRELIMINARY STUDY AND ANALYSIS

2.1 Material and method

The artefacts

As shown in Figure 1, four artefacts were made and presented to participants to interact with. They have been selected to include the basic kinetic features of soft robotic actuators: expansion, contraction and bending [11]. The artefacts shown in Figure 1a, 1b and 1d were adapted from existing designs.[2] A short video of these artefacts can be found in the link below.[3] These artefacts could be controlled manually by participants via a hand-squeeze bulb. Participant could freely touch and manipulate the artefacts in their hands or position on their bodies. Participants were also encouraged to interact with each other using the artefacts.

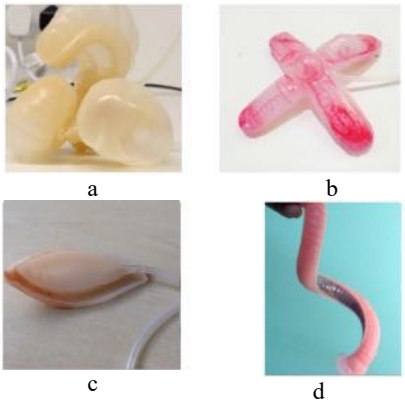

Figure 1. Artefacts Used in the Preliminary Study

[1]Information Experience Design & Fashion, School of Communication, School of Design, Royal College of Art, SW7 2EU, UK. Email: yan.zheng@network.rca.ac.uk, kevin.walker@rca.ac.uk

[2] https://www.instructables.com/id/Air-Powered-Soft-Robotic-Gripper/ and https://softroboticstoolkit.com/book/fiber-reinforced-bending-actuators

[3] https://feuetbois.net/2016/02/01/preliminary-study-on-affective-qualities-of-soft-robotic-artefacts/

Participants

The questionnaire evaluation on the affective qualities of the soft robotic artefacts is part of the activities during two co-design workshops. These were first an AcrossRCA 2016 workshop [12] in which Master's students from various art and design programmes at the Royal College of Art were recruited by a dedicated project coordinator, and second, one that was held during the 2016 STATE of Emotion festival in Berlin [13], where willing adult festival audiences emailed the workshop coordinator to register their participation.

Of the workshop participants, 24 completed the questionnaire (n=24). The age ranged from 18 to 49, with half participants between 18-29 and the other half between 30-49, 15 female, 7 male, 2 not indicated.

The questionnaire

A questionnaire was provided for the participants to document how they felt about interacting with the artefacts. The questionnaire asks five questions, as shown in Table 1. In Question 1, 24 emotion labels were taken from Plutchik's "Wheel of Emotions" [14], shown in Figure 2. Participants could choose more than one label. If none of the labels applied, participants could choose "other" and write down their own emotion labels.

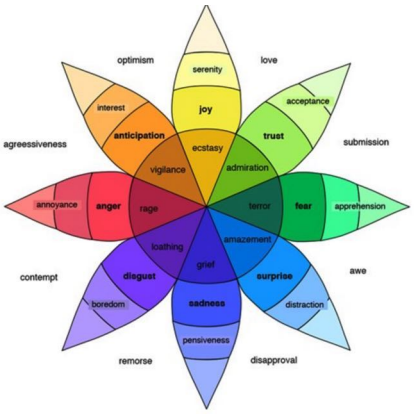

Figure 2. Plutchik's Wheel of Emotions (2001)

Figure 3. Word Cloud of Response for Question 1.

	Question	*Response*
1	How does the artefact make you feel?	Figure 2
2	With what property do you associate the feeling(s)?	100% movement 75% surface texture 50% touch 17% other 8% sound
3	Why does it (the artefact) evoke such a feeling?	Grouped in six features: a. aliveness b. novelty/uncanniness c. tactile sensations d. unpredictability e. activeness f. intentionality
4	Would you say it is a positive or a negative feeling?	79.1% positive 8.3% neutral 4.2% mixed 4.2& negative 4.2% other
5	How strongly does the artefact affect your feeling? 1 being no impact at all, 10 being most impactful.	Mean value 6.58

Table 1. Questions and Responses

2.2 Results and Analysis

The results are shown in Table 1 and Figure 3.

The response to Question 1, "How does the artefact make you feel?" has been mapped onto a word cloud, shown in Figure 3. The words shown include both the 24 emotional labels provided and those suggested by the participants. The emotional labels suggested by the participants include "delight", "affection", "rejection", "sexual", "pleasure", "basic", "primal", "empathy (twice)", "kindness", "affective". The top-rated labels are "joy", appearing 14 times, "surprise" 13 times and "interest" 11 times.

The response to Question 2 suggested strongly that movement, surface texture and tactile were the properties that evoked the most emotion.

In Question 4, participants responded overwhelmingly with positive emotions towards the soft robotic artefacts. And in Question 5, the average rating for the level of impact of the artefacts was 6.58 out of a score of 10.

Question 3 was open ended, and asked participants to discuss "Why does it (the artefact) evoke such a feeling?" We preliminarily inferred six features (Table 1) based on the responses. We discuss what material and interactive elements may have contributed to such attribution and we include participants' responses, below.

Aliveness

The responses indicated that movement, organic kinetic forms and the morphology of the soft silicone rubber material give an animal-like visual impression. A pneumatic air supply enables a pulsating movement. The sound during inflation and deflation resembles the sound of inhaling and exhaling. The combination of

the movement and the sound may contribute to the association with life or breathing. For example, participants wrote:
"Heartbeat", "suspended between life and death", "It's filled with breath!", "It seems like it's a little live pet".

Novelty/uncanniness
The responses indicated that there was an element of surprise between the artefacts' kinetic behaviour and participants' expectations, and participants had not yet experienced an existing category of identity to associate with this type of artefacts. For example, participants wrote: "It's something alien", "I've never seen something like this before", "new & unusual shape change", "Surprising movement".

However, this level of confusion of identity did not lead to a feeling of threat, but rather to positive surprise. For example, one participant wrote: "Element of surprise, leading to delight, unexpected quality".

The quality of tactile sensation
The quality of tactile, skin-like sensation contributed to the association of human touch. For example, participants wrote: "The feeling of the material when it moves against my hand", "Feels human".

Unpredictability
Some feedback indicated the unpredictability of the movement with participants commented as "surprising". Research has shown that unpredictability in robot motion leads to increased attention from human interactants and make the robot appear to be more "natural" and lifelike [15,16].

Activeness
Static, passive artefacts require human to enact the touch action for physical contact. Vibratory motors are popular medium to introduce tactile sensation; however, they do not produce visual movement. Compared with the above two, these soft robotic artefacts are capable of performing "active touch" through visual shape changing to enable physical contact with the participants. For example, participant wrote: "… it moves against my hand".

Intentionality
Participants seemed to empathise and project identity and intentionality onto the artefacts. For example, participants wrote: "Appears helpless, in pain", "It is looking for a connection".

We have summarised the results. Participants rated the hand-sized soft robotic artefacts as impactful for invoking emotions, and they overwhelmingly attribute positive emotion. The highest-rated emotion labels are "joy", "surprise", and "interest". Among the listed elements, movement and tactile stimuli are highest rated elements to contribute to the association with an emotional response. From participants' description of what they think contribute to evoking emotional responses, we preliminarily inferred six features of the soft robotic artefacts: aliveness, novelty, tactile sensations, unpredictability, activeness, intentionality.

3 DISCUSSION

The findings suggests that artefacts designed with soft robotics with biomorphic movements have strong agency in attracting emotional investment from users or an audience, which echoes Arnold and Scheutz's remarks about soft robotics, in terms of "how easily people can attribute emotionally charged personal qualities to a robot, even when it is fairly clear that the robot cannot reciprocate feelings of any sort" [9]. However, this emotional quality is not found through deliberate design into the machine by mimicking a human or animal veneer, but emerges from the artefact's biomorphic quality in its compliant material and kinetic forms. It is these characteristics that contribute to the enactment of agency and evoke interactants' anthropomorphic projections.

Anthropomorphism plays an important role in the human projection of relations with objects. Anthropomorphism is the projection of human-like agency onto non-humans [17]. It involves the interpretation of an entity as a character, with emotions, intentions and purpose. Vidal[18] considers it the most spontaneous register through which humans establish strong relationships with artefacts or other non-human beings.

Movement plays a significant role in triggering such projections. Wolf and Wiggins[19] investigated how different types of movement affect people's affinity with robots to associate them with machines, animals or humans. The result of Question 2 evidenced this attribution.

Opportunities for designing affective HRI
Given the findings, if the soft grippers are only considered in relation to their functionality e.g. applications in handling fragile objects and for safer interaction with human users, an opportunity will have been missed. It is exciting to imagine a new space for designing interactive robots that are emotionally engaging and afford novel sensory experiences, now that this novel medium with such emotionally engaging properties are at the disposal of designers for affective HRI. The affective characteristics lie in several sensory channels – visual, tactile and acoustic – which suggest that soft robotic artefacts could be designed for multi-model sensory experiences.

A more emotionally engaging HRI experience could be designed by exploiting anthropomorphism and the affective qualities of soft robotic mechanisms. Several studies have already advocated affect-centred design for HRI. They propose that high affective quality agents help designers create a more positive user experience and more harmonious results [10,20].

Risk for affective HRI
However, such a level of emotional engagement might be a double-edged sword. It also suggests risk and unintended relational outcome. The ostensible purpose might be subverted when human users unexpectedly bond emotionally with such robots. "Unidirectional bonding" with social robots is a phenomenon that continues to draw scrutiny [21,22]. When humans respond easily to the affective qualities of the soft robotic artefacts with trust and openness, it also suggests a state of vulnerability to emotional exploitation. A projection of the unpredictable and psychotropic emotional relations caused by the mediation of robotic interiors boasting high affective qualities can be found in J.G. Ballard's science fiction story 'The Thousand Dreams of Stellavista' [23,24]. The dexterity developed in soft grippers not only enables them to grasp soft fruits and manipulate objects[3]: they can also be emotionally manipulative agents. Arnold and Scheutz call for more thorough investigations of the "experienced behaviour or disposition" of soft robots, and a fuller grasp of their "relational consequences" [8]. Such a task calls for collaborative and cross-disciplinary efforts in the fields of creative design, social science, robotic engineering and affective computing.

4. LIMITATIONS AND FUTURE WORK

The analysis on the emotion evoking features is rather preliminary and needs further analysis which may involve re-grouping, elaboration and putting in context of thorough review on relevant literature and practice. This preliminary study had a small sample size. The findings, however, are valuable for informing a more rigorous study design in a specific application context as part of future work to facilitate more in-depth inquiries on the relational impact. In this study, the soft robots could be manually controlled by participants. Research has shown that robots with different degrees of autonomy influence the way human users' respond emotionally. For example, in the study by Złotowski et al.[25], exposure to more autonomous robots evoke more negative attitudes. Future work includes employing studies of soft robots with different degrees of autonomy.

REFERENCES

[1] C. Majidi, 'Soft Robotics: A Perspective—Current Trends and Prospects for the Future', *Soft Robotics*, vol. 1, no. 1, pp. 5–11, Jul. (2013).

[2] D. Trivedi, C. D. Rahn, W. M. Kier, and I. D. Walker, 'Soft robotics: Biological inspiration, state of the art, and future research', *Applied Bionics and Biomechanics*, vol. 5, no. 3, pp. 99–117, Jan. (2008).

[3] J. Shintake, V. Cacucciolo, D. Floreano, and H. Shea, 'Soft Robotic Grippers', *Advanced Materials*, vol. 30, no. 29, p. 1707035, Jul. (2018).

[4] F. Ilievski, A. D. Mazzeo, R. F. Shepherd, X. Chen, and G. M. Whitesides, 'Soft Robotics for Chemists', *Angew. Chem. Int. Ed.*, vol. 50, no. 8, pp. 1890–1895, Feb. 2011.

[5] G. Sumbre, Y. Gutfreund, G. Fiorito, T. Flash, and B. Hochner, 'Control of octopus arm extension by a peripheral motor program', *Science*, vol. 293, no. 5536, pp. 1845–1848, Sep. (2001).

[6] J. Jørgensen, 'Leveraging Morphological Computation for Expressive Movement Generation in a Soft Robotic Artwork', in *Proceedings of the 4th International Conference on Movement Computing*, New York, NY, USA, 2017, pp. 20:1–20:4.(2017).

[7] J. Jørgensen, 'Prolegomena for a Transdisciplinary Investigation Into the Materialities and Aesthetics of Soft Systems', in *Proceedings of the 23rd International Symposium on Electronic Arts*, 2017, pp. 153–160 (2017).

[8] I. Wald, Y. Orlev, A. Grishko, and O. Zuckerman, 'Animating Matter: Creating Organic-like Movement in Soft Materials', in *Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems - DIS '17 Companion*, Edinburgh, United Kingdom, pp. 84–89 (2017).

[9] T. Arnold and M. Scheutz, 'The Tactile Ethics of Soft Robotics: Designing Wisely for Human–Robot Interaction', *Soft Robotics*, vol. 4, no. 2, pp. 81–87, May (2017).

[10] P. Zhang and N. Li, 'The Importance of Affective Quality', *Commun. ACM*, vol. 48, no. 9, pp. 105–108, Sep. (2005).

[11] C. Laschi, B. Mazzolai, and M. Cianchetti, 'Soft robotics: Technologies and systems pushing the boundaries of robot abilities', *Science Robotics*, vol. 1, no. 1, p. eaah3690, Dec. (2016).

[12] C. Y. Zheng, 'The Sentimental Soft Robotics', in *Workshop during AcrossRCA*, Royal College of Art, London, http://across.rca.ac.uk/?page_id=1634, (2016).

[13] C. Y. Zheng, 'Workshop: Extimacy! "Wear your heart on the sleeves?" Why not the sofa or the curtains?', in *STATE of Emotions Festival*, Berlin, https://state-studio.com/program/2016/iuymys263yher8kzcjn4sdy11e5x2u, (2016).

[14] R. Plutchik, 'The Nature of Emotions: Human emotions have deep evolutionary roots, a fact that may explain their complexity and provide tools for clinical practice', *American Scientist*, vol. 89, no. 4, pp. 344–350 (2001).

[15] J. Saldien, B. Vanderborght, K. Goris, M. Van Damme, and D. Lefeber, 'A Motion System for Social and Animated Robots', *International Journal of Advanced Robotic Systems*, vol. 11, no. 5, p. 72, May (2014).

[16] A. J. . Va Breemen, 'Bringing robots to life: Applying principles of animation to robots', in *Shaping Human-Robot Interaction workshop held at CHI,2004*, (2004).

[17] N. Epley, S. Akalis, A. Waytz, and J. T. Cacioppo, 'Creating social connection through inferential reproduction: loneliness and perceived agency in gadgets, gods, and greyhounds', *Psychol Sci*, vol. 19, no. 2, pp. 114–120, Feb. (2008).

[18] D. Vidal, 'Anthropomorphism or sub-anthropomorphism? An anthropological approach to gods and robots', *Journal of the Royal Anthropological Institute*, vol. 13, no. 4, pp. 917–933 (2007).

[19] O. O. Wolf and G. Wiggins, 'Look! It's moving! Is it alive? How movement affects humans' affinity to living and non-living entities', *IEEE Transactions on Affective Computing*, pp. 1–1 (2018).

[20] L. Riek and P. Robinson, 'Affective-Centered Design for Interactive Robots', in *Workshop on New frontiers in human-robot interaction, Artificial Intelligence and the Simulation of Behaviour Convention*, Edinburgh, (2009).

[21] M. Scheutz, 'The Inherent Dangers of Unidirectional Emotional Bonds between Humans and Social Robots', in *Robot Ethics: The Ethical and Social Implications of Robotics*, P. Lin, K. Abney, and G. A. Bekey, Eds. MITP, (2012).

[22] S. Turkle, *Alone Together: Why We Expect More from Technology and Less from Each Other*, 1st ed. New York: Basic Books, 2012.

[23] J. G. Ballard, 'The Thousand Dreams of Stellavista', *Amazing Stories*, vol. 36, no. 3, Mar. (1962).

[24] C. Y. Zheng and C. Liao, 'the Psychotropic interior', in *Interior Futures*, G. Brooker, K. Walker, and H. Harris, Eds. Crucible Press, (2019).

[25] J. Złotowski, K. Yogeeswaran, and C. Bartneck, 'Can we control it? Autonomous robots threaten human identity, uniqueness, safety, and resources', *International Journal of Human-Computer Studies*, vol. 100, pp. 48–54, Apr. (2017).