Affective Evaluation of Virtual Kawaii Robotic Gadgets using Biological Signals in a Remote Collaboration of American and Japanese Students

Michiko Ohkura[1], Tipporn Laohakangvalvit[1], Peeraya Sripian[1], Midori Sugaya[1], Hiroko Chiba[2], and Dave Berque[2]

[1] Shibaura Institute of Technology, 3-7-5, Toyosu, Koto-ku, Tokyo 1358548, Japan
ohkura@sic.shibaura-it.ac.jp
{tipporn, peeraya, doly}@shibaura-it.ac.jp

[2] DePauw University, 313 S Locust St, Greencastle 46135, U.S.A.
{hchiba, dberque}@depauw.edu

Abstract. This paper describes our remote collaboration project related to the design and implementation of virtual kawaii robots by Japanese and American university students, and affective evaluation of the robots. Because of the COVID-19 pandemic, we had to change our planned 7-week collaboration from in-person to virtual with a resultant change in the target product of our collaboration from real robots to virtual robots. Based on our new plan for 2021, students designed robots in virtual spaces aiming that each robot elicited a different Electroencephalogram (EEG) and/or Heart Rate (HR) reaction from humans. Based on the persona and scenario for the companion robot authored by each student team, each student designed four robots with the goal that one robot would be most kawaii, a Japanese adjective representing cute and adorable, and others would be less kawaii due to variations in shapes and colors. The affective evaluation of robots was performed both by biological signals (EEG and HR) and by kawaii rating.

Keywords: virtual robot, EEG, heart rate, kawaii

1 Introduction

The International Research Experiences for Students (IRES) program supported by the United States National Science and Foundation (NSF) is explained as follows

The International Research Experiences for Students (IRES) program is one of many programs supported by the United States National Science Foundation (NSF). As described by the NSF, the program supports "…international research and research-related activities for U.S. science and engineering students." [1] The NSF further explains that the program "contributes to development of a diverse, globally-engaged workforce with world-class skills. IRES focuses on active research participation by undergraduate or graduate students in high quality international research, education and professional development experiences in NSF-funded research areas." [1].

The IRES program consists of several tracks and a proposal falls under a track which must provide a cohort international research experience for a group of students. Although each student should have a specific role on the research team, the research experiences must have a single intellectual theme that is aligned with an area that the NSF supports. This project was organized around developing a better understanding the role that kawaii (Japanese cuteness) plays in robot design.

This project focused on kawaii as a Japanese originated Affective value and its application to robot design, because kawaii has a potential impact [2-5] and kawaii design principles are incorporated into successful products that are used globally including robotic gadgets [6, 7]. Prior work that investigates the role of kawaii in user perceptions and user acceptance of robots or robotic gadgets is limited. However, a prior team reported on studies of kawaii-ness in the motion of robotic vacuum cleaners [8-10]. These studies demonstrate that kawaii-ness can be expressed through motion even in the absence of more traditional visual cues; however, the studies did not consider the cultural background.

Based on the accepted proposal, we had designed a 7-week collaborative project for cross-cultural teams to design, build and evaluate robotic gadgets, which would have begun in June 2020 at Toyosu Campus of the Shibaura Institute of Technology in Japan. However, because of the COVID-19 pandemic, it became impossible for students from DePauw University in U. S. to travel to Japan and work together with the SIT students at the SIT campus. In fact, even the SIT students could not enter the campus. Therefore, we designed new remote collaborative approaches and activities based on a previous class and global Project Based Learning (PBL) work previously conducted [11, 12].

Even though the first trial was completed online and obtained useful results [13, 14], we had planned a better implementation of the project in the second trial in 2021. However, because the COVID-19 pandemic did not become better, we had to perform the second trial online again. Based on our proposal, the robots would be affectively evaluated by using biological signals such as Electroencephalogram (EEG) and Electrocardiogram (ECG). This is because there has been much prior research on EEG- or ECG-based affective computing [15-18]. This paper describes the design and implementation of the online collaboration approaches and activities for robotic gadgets by the students from U. S. and Japanese universities, and affective evaluation of the robots using EEG and Heart rate (HR) together with kawaii rating.

2 Design of Collaborative Activities

Our plan for collaborative work revolved around the construction of kawaii robots and the affective evaluation of these robots. However, because the collaboration had to be conducted remotely, we changed from constructing real robots in real space to constructing virtual robots that operated in virtual spaces both in the first trial in 2020 and the second trial in 2021. Unity was employed to construct both the virtual robots and the virtual spaces. Zoom and Slack were employed for weekly and daily communication.

Two teams of students were formed with each team consisting of two students from a U.S. university and two students from a Japanese university. In 2020, each team designed and implemented a virtual space and each student designed and implemented a pair of robots to operate in that virtual space. For each pair of robots, one was comparatively evaluated to the other using various affective adjectives. In 2021, we decided to focus on companion robots. Each team designed the context for their companion robots, creating personas of their users and scenarios of their usages. Then, each student designed and implemented four robots based on the persona and scenario of the team. One robot (#1) was designed to be the most kawaii with animal-like features, round shapes, and kawaii colors. The second one (#2) was created from the first one by changing its color to monochrome. The third one (#3) was non-animal-like and not-round shape. The last one (#4) was created from the third one by changing its color to monochrome. An example of four robots is shown in Fig. 1. Each student was also asked to design robots so that each robot elicited a different EEG and/or HR reaction from humans. To get a certain knowledge on Kawaii Engineering, students had read references [19, 20] before attending this project.

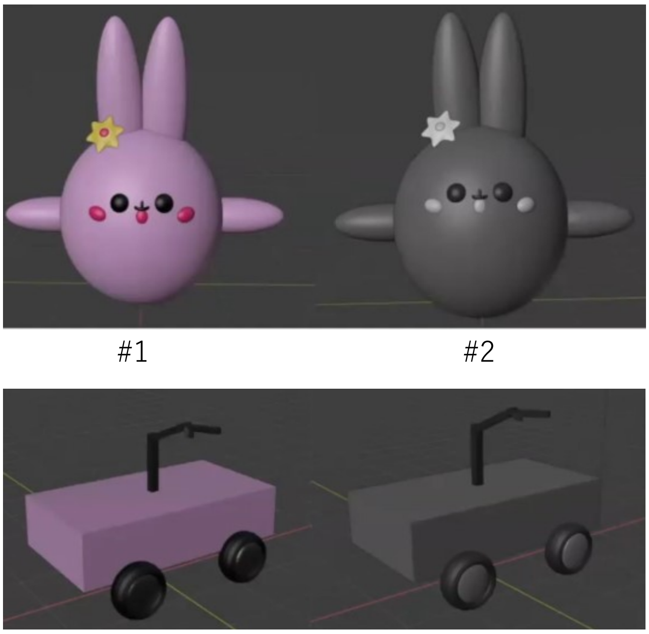


Fig. 1. An example of a set of four robots.

Table 1 shows the schedule of weekly and additional meetings in 2021. Each meeting was held via Zoom.

Table 1. Participant and order of watching.

	EDT	JST	Content
1	23rd May	24th May	Welcome meeting
2	25th May	26th May	Lecture about personas and scenarios
3	1st June	2nd June	Presentation of personas and scenarios
4	8th June	9th June	Presentation of design of virtual robots, Begin development
5	15th June	16th June	Regular meeting with special lecture
6	22nd June	23rd June	Presentations of appearance of robots with EEG and HR
7	29th June	30th June	Regular meeting with special lecture
8	6th July	7th July	Presentation of robots and their evaluation
9	8th July	9th July	Farewell meeting

3 Implementation of Collaborative Practice

The collaborative experiences were organized into seven parts.

3.1 Introduction

After a welcome message from Japanese university and an introduction of the organizers, we introduced the possibilities of virtual reality and the role of robots in future society. Then, the schedule shown in Table 1 was explained.

3.2 Design of persona and scenario

After an explanation of personas and scenarios was given, each team discussed their common persona as a user of a companion robot and scenario related to the role of the robot. In addition, each team decided on a scene of a video in which the robot assists the user. The final personas and scenarios are shown in Table 2.

3.3 Design of four companion robots

Based on each team's persona and scenario, each team member designed four robots.

3.4 Development of four companion robots

Each student began to construct robots individually using Unity. The four robots needed to move and needed to include sound or voice. The action needed to last 20 seconds based on a part of the scenario described in blue in Table 2. In order to confirm that they elicited different reactions in EEG and/or HR, EEG was measured with Mind Wave Moble 2 by NeuroSky. HR was measured with Cardiio provided by Cardiio, Inc. for iPhone users. Heart rate monitor provided by REPS was used for Android users.

Table 2. Persona and scenarios.

Team	Persona/ Scenario	Content
1	Persona	Terry is a 19-year-old first-year university student that is not completely familiar with their campus. Terry frequently gets lost on campus and is late. Terry is nervous about being on time for class and remembering all of their responsibilities. Terry needs help remembering where things are and when Terry needs to do things, such as taking medication, eating properly, and getting enough sleep.
	Scenario	One morning, the robot realizes Terry is not awake 30 minutes before their class, so the robot says 'Terry it is time to get up, you don't want to be late!' and then spins, dances, and claps to wake Terry up. After that, the robot checks Terry's schedule and says, "Good Morning, your first class is at 8:00AM in the Blue Math Building, you have 10 minutes to get ready". The robot brings Terry their medication and breakfast. (continued.).
2	Persona	Sam is a 19-year-old university student, who has become overwhelmed by their schoolwork and obligations. This has led them to lose sleep, miss meals, and consistently forget assignments.
	Scenario	In the evening, Sam's robot does a calendar check and realizes that Sam has an assignment to complete tonight. Sam's robot stands up and says to Sam "You need to do your assignments." The robot then bends its head in a sad manner until Sam starts working. When Sam finishes their assignment, the robot makes fun noises, does a dance, and gives Sam a treat, making Sam feel happy and content with their work.

3.5 Final presentation and evaluation

Each student introduced their own four robots by showing their 20-second video one by one. The robots were evaluated by EEG and/or HR. NeuroExperimenter developed by Fred Mellender was used to measure continuously and collect EEG data. HR was measured every 20 sec. of watching a robot and saved by the same applications as described the section above. The robots were also evaluated by kawaii rating from 1 to 10 after the presentation using the zoom records and Google Form

Averages of Attention and Meditation, indexes provided by NeuroSky, were calculated. The averages while watching robots for 20 sec. and the 20-sec. averages of resting time just before the watching were compared. Examples of the differences of averaged Meditation of EEG of two of the authors are shown in Fig.2 when watching the robots shown in Fig.1 (Set A in Table 3) and another set of robots (Set B in Table 3). Fig.3 shows the HR results of four of the authors when watching the robots shown in Fig. 1. Unfortunately, we couldn't get any meaningful results from EEG at present. In the example shown in Fig.3, HR reduce when watching monochrome robots. This might be because monochrome increases the material perception of metal which reduce the exciting feeling of kawaii color robots.

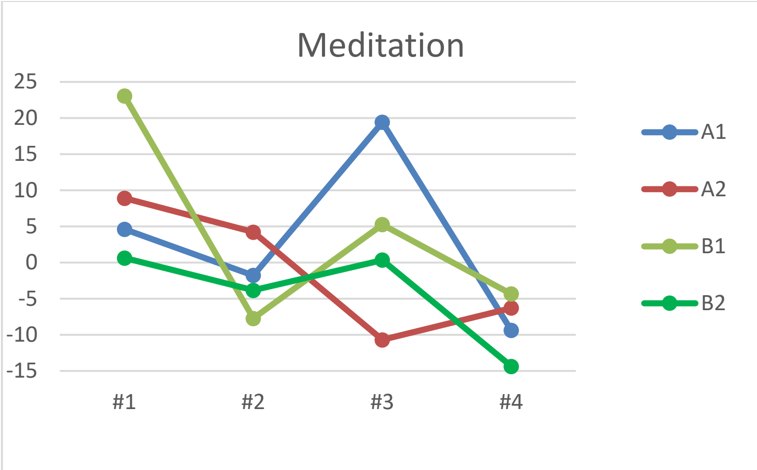


Fig. 2. Examples of Meditation of EEG for two of the authors for the robots shown in Fig.1 (Set A in Table 3) and another robot (Set B in Table 3). A1 and A2 indicate the Meditation for two of the authors when watching the robots of Set A. B1 and B2 indicate the Meditation for the same two authors when watching the robots of Set B.

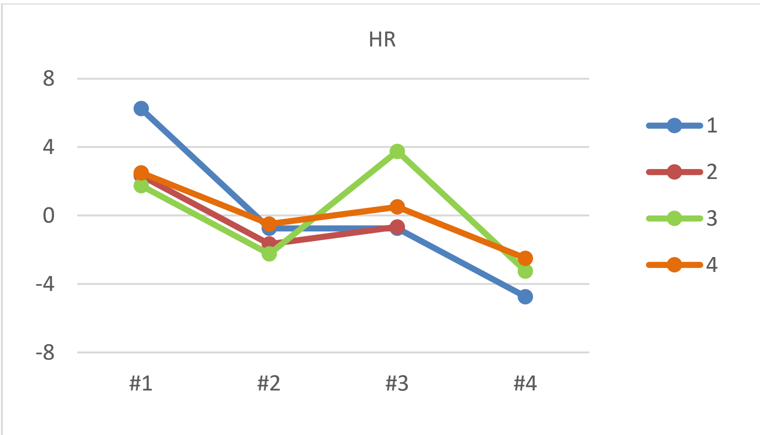
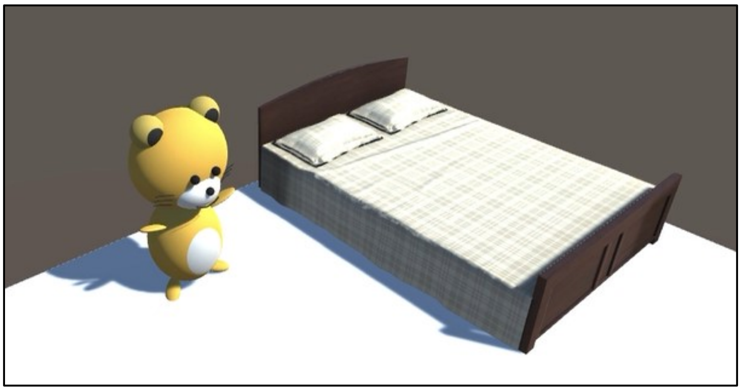


Fig. 3. Examples of HR for four of the authors for the robots shown in Fig.1 (The values are the differences from average for each participant).

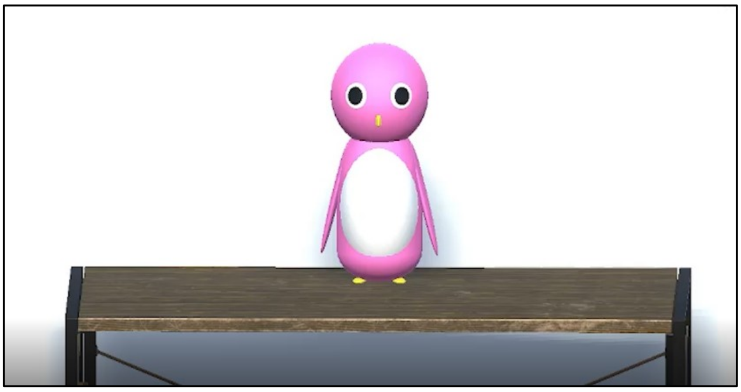
Table 3 shows the averages of kawaii scores evaluated by five of the authors. The four robots of Set A are shown in Fig.1. The robots #1 and #4 of Sets D and H are shown in Figs. 4 and 5. Generally speaking, robot #1 of four robots had higher scores and #4 had lower scores. Some examples with higher kawaii scores and examples with lower kawaii scores are shown in Figs. 4 and 5.

Table 3. Averages of kawaii score for each robot.

Set	#1	#2	#3	#4
A	9.4	7.8	5.2	4.6
B	9.2	8.4	4.0	3.6
C	8.8	7.8	4.8	4.0
D	8.6	7.2	5.4	3.0
E	8.2	7.2	4.6	3.6
F	6.0	4.6	2.6	2.4
G	8.6	7.0	5.0	4.2
H	9.6	7.6	4.0	2.4

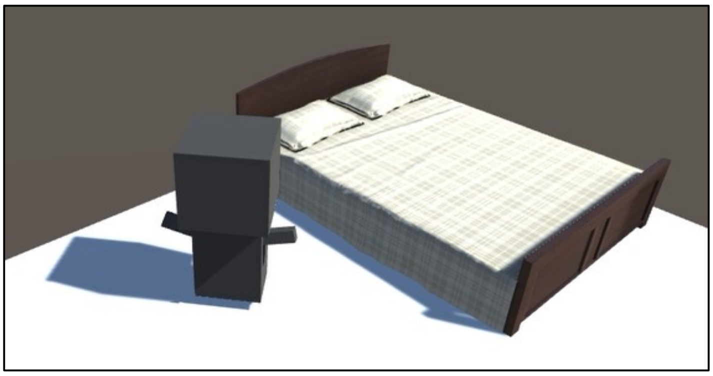


(a) #1 of a student.

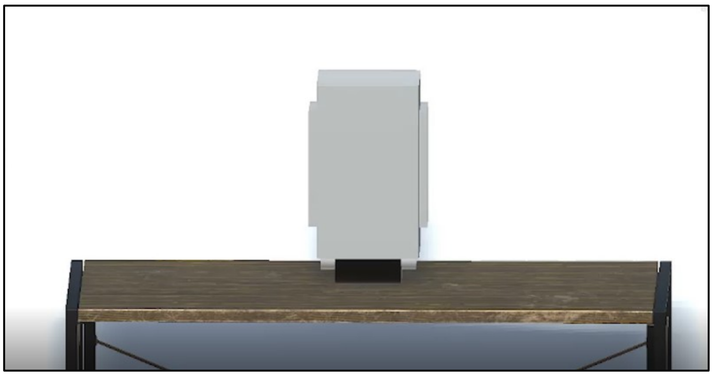


(b) #2 of another student.

Fig. 4. Examples of the most kawaii robots.



(a) #3 of a student.



(b) #4 of another student.

Fig. 5. Examples of the least kawaii robots.

3.6 Special lectures

Two topics were introduced by SIT faculties to deepen understanding of students on Kawaii Engineering [21, 22].

3.7 Farewell meeting

Farewell meeting was held at the last day of the 7-week activities. Certification was given to each student in a VR space created using Cluster by Cluster Inc. as shown in Fig. 6

Fig. 6. Certification was given to each student in a VR space.

4 Discussion

As described in the Introduction, our original plan called for the students and professors from DePauw University to travel to Tokyo, Japan. The U. S. students would have then collaborated with students of the Shibaura Institute of Technology to design and build real robots with kawaii appearances and behaviors. However, because of the COVID-19 pandemic, travel was impossible. Therefore, we designed new remote collaboration approaches and activities in 2020. In 2021, the situation became better because students could enter their own university campus. However, in-person collaboration remained impossible. Based on our improved plan, each student team designed a persona and scenario for a companion robot, and developed four virtual robots.

Affective evaluation of the robots was performed by measuring EEG and HR together with kawaii rating by questionnaire. Based on the previous knowledge that kawaii stimulus can be divided into “exciting kawaii” and “relaxing kawaii” [23], the robot #1 in Fig. 1 seems to be “exciting kawaii” from the HR results shown in Fig.3. However, the results of EEG and HR were uncertain because the insufficient confirmation of each robot to elicit a different EEG and/or HR reactions and difficulties of self-measurement of those bio-signals by authors ourselves. To solve these problems remains as future work.

5 Conclusion

Because of the COVID-19 pandemic, we had to change the targets of our 7-week collaboration from real robots to virtual robots. Based on our new plan for 2021, each student team designed a persona of a user of a companion robot and scenario for the assistance of the robot, and each student developed four different robots under the scenario.

Affective evaluation of the robots was performed by measuring EEG and HR together with kawaii rating by a questionnaire. Improvement of both robots and measurement of bio-signals are necessary for further research.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. OISE-1854255. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. We thank all the participating students: G. Todd, H. Schwipps, N. Jadram, S. Imura, L. Guinee, R. Martinez, N. S. Fong and S. Ohtsuka.

References

1. National Science Foundation International Research Experiences for Students, www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=505656&ods_key=nsf19585, last accessed 2020/02/24.
2. Marcus, A., Kurosu, M., Ma, X., Hashizume, A.: Cuteness Engineering: Designing Adorable Products and Services, Springer, Heidelberg (2017).
3. Ohkura, M.: Kawaii Engineering. Springer, Heidelberg (2019).
4. Nittono, H. et al.: The Power of Kawaii: Viewing Cute Images Promotes a Careful Behavior and Narrows Attentional Focus. Plos One 7(9), e46362 (2012).
5. Nittono, H.: "Kawaii" no Chikara (The Power of "Kawaii"). Kagakudojin, Kyoto (2019). (in Japanese)
6. Cole, S., The Most Kawaii Robots of 2016, https://motherboard.vice.com/en_us/article/xygky3/the-most-kawaii-robots-of-2016-5886b75a358cef455d864759, last accessed 2021/06/28.
7. Bennett, B., Meet all the cute, friendly, useful robots of CES 2019, https://www.cnet.com/pictures/meet-all-the-robots-of-ces-2019, last accessed 2021/06/28.
8. Sugano, S., Miyaji, Y., Tomiyama, K.: Study of Kawaii-ness in Motion - Physical Properties of Kawaii Motion of Roomba. In: Kurosu, M. (ed) HCII2013, LNCS, vol. 8004, pp. 620-629. Springer, Heidelberg (2013).
9. Sugano, S., Morita, H., Tomiyama, K.: Study on Kawaii-ness in Motion - Classifying Kawaii Motion using Roomba. In: Ji, Y. (ed) AHFE2012, vol. Advances in Affective and Pleasurable Design 1st Edition, pp.107-116. CRC Press, Boca Raton (2012).
10. Sugano, S., Tomiyama, K.: "Kawaii-ness in Motion. In: Ohkura, M. (ed) Kawaii Engineering, pp. 77-91. Springer, Heidelberg (2019).

11. Ohkura, M., Sakurai, H., Aoto, T.: A Trial of Interactive Remote Teaching by Shared Virtual Spaces between Two Universities. In: Proc. CollabTech2008, pp. 89-93, Wakayama (2008).
12. Ohkura, M., et al.: Multi-media Global PBL with HTML5 and TECHTILE Toolkit for Japanese and Thai Students. In: Proc. 2017 JSEE Annual Conference, pp. 45-50, Tokyo (2017).
13. Ohkura, M., et al.: Design and Implementation of Kawaii Robots by Japanese and American University Students using Remote Collaboration. In: Proc. ISASE 2021, online (2021).
14. Berque, D., et al.: Cross-Cultural Design and Evaluation of Robot Prototypes Based on Kawaii (Cute) Attributes. In Rau, P. (ed) HCII2021, LNCS, vol. 12773, Springer, Heidelberg (2021).
15. Pei, G., Li, T.: A literature review of EEG-based affective computing in marketing. Frontiers in Psychology, 16, 2021.
16. Tivatansakul, S., Ohkura, M.: Emotion recognition using UCG signals with local pattern description methods. International Journal of Affective Engineering 15(2), 51-61 (2016).
17. Nikolova, D., Petkova, P., Manolova, A., Georgieva, P.: ECG-based emotion recognition: Overview of methods and applications, In: ANNA'18; Advances in Neurral Networks and Applications 2018, pp. 1-5. VDE Verlag, Berlin (2018).
18. Ito, K., Miura, N., Ohkura, M.: Proposal of affective model for a system using ECG. Transactions of Japan Society of Kansei Engineering 18(1), 87-93 (2019). (in Japanese)
19. Ohkura, M., Komatsu, T., Aoto, T.: Kawaii Rules: Increasing Affective Value of Industrial Products. In: Watada, J., et al. (eds.) Industrial Applications of Affective Engineering, pp.97-110, Springer, Heidelberg (2014).
20. Ohkura, M.: Systematic Study on "Kawaii." Information Processing, 57(2), 124-127 (2016). (in Japanese)
21. Laohakangvalvit, T., Achalakul T., Ohkura, M.: A Method to Obtain Effective Attributes for Attractive Cosmetic Bottles by Deep Learning. International Journal of Affective Engineering 19(1), 37-48 (2019).
22. Sripian, P., Miyatake, K., Ohkura, M.: Study on the color feature of Harajuku-type kawaii fashion comparison with street snap images using colorfulness. TNI Journal of Engineering and Technology 8(1), 63-72 (2020).
23. Yanagi, M., et al.: Differences in heartbeat modulation between excited and relaxed kawaii feelings during photograph observation. International Journal of Affective Engineering 15(2), 189-193 (2016).