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Uncanny valley: A preliminary study on the acceptance of Malaysian urban and rural population toward different types of robotic faces

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Abstract. The proliferation of robotic technologies in recent years brings robots closer to humanities. There are many researches on going at various stages of development to bring robots into our homes, schools, nurseries, elderly care centres, offices, hospitals and factories. With recently developed robots having tendency to have appearance which increasingly displaying similarities to household animals and humans, there is a need to study the existence of uncanny valley phenomenon. Generally, the acceptance of people toward robots increases as the robots acquire increasing similarities to human features until a stage where people feel very uncomfortable, eerie, fear and disgust when the robot appearance become almost human like but not yet human. This phenomenon called uncanny valley was first reported by Masahiro Mori. There are numerous researches conducted to measure the existence of uncanny valley in Japan and European countries. However, there is limited research reported on uncanny valley phenomenon in Malaysia so far. In view of the different cultural background and exposure of Malaysian population to robotics technology compared to European or East Asian populations, it is worth to study this phenomenon in Malaysian context. The main aim of this work is to conduct a preliminary study to determine the existence of uncanny valley phenomenon in Malaysian urban and rural populations. It is interesting to find if there are any differences in the acceptance of the two set of populations despite of their differences. Among others the urban and rural populations differ in term of the rate of urbanization and exposure to latest technologies. A set of four interactive robotic faces and an ideal human model representing the fifth robot are used in this study. The robots have features resembling a cute animal, cartoon character, typical robot and human-like. Questionnaire surveys are conducted on respondents from urban and rural populations. Survey data collected are analysed to determine the preferred features in a humanoid robot, the acceptance of respondents toward the robotic faces and the existence of uncanny valley phenomenon. Based on the limited study, it is found that the uncanny valley phenomenon existed in both the Malaysian urban and rural population.

1. Introduction
The term "uncanny valley" refers to a sense of unease and discomfort when people look at increasingly realistic human. This concept was identified by Masahiro Mori, professor of engineering at Tokyo Institute of Technology as Bukimi no Tani Genshō in 1970 [1]. Prof Mori first reported on this phenomenon in a Japanese journal named Energy. In the subsequent years after its first publication, the paper received almost no attention. His work is only properly translated to English in 2012 [2]. He wrote a paper [1] on how he envisioned people's reactions to robots that looked and acted almost like a human. In particular, he hypothesized that a person's response to a human-like robot would abruptly shift from empathy to revulsion as it approached, but failed to attain, a life-like appearance. This descent into eeriness is known as the uncanny valley. Mori suggested that robot builders should not try to design and build human-like robots, either in motion or appearance. According to Mori's hypothesis, designers must seek a moderate level of realism for the physical appearance of robots and virtual reality agents in order to avoid falling into the uncanny valley [3].

However, with recent advancement in social robots where researchers start building robots with appearance and movements resembling human [4], the concept of uncanny valley has attracted attentions among researches. In recent years, many robots have and will be developed to work alongside humans at homes, offices, hospitals, hotels, etc. Whether the robots' appearance should look human or not is still being debated. If the robot should look human, then should the robot be a male or female? Has short or long hair? Has straight or curly hair? Fair or tanned? Which human features to be incorporated and which features that can be ignored? These are some of the many questions that will be in the mind of roboticists. Different individuals will invoke different feelings when encounter different types of robotic faces. They may be influenced by factors such as personal experiences, upbringing, education level, community they are in and so on. Some people might accept and like a human-like robotic faces while some people will express a certain degree of fear, insecurity and loathe toward the human-like robot.

There are numerous studies conducted in other parts of the world identifying the existence of uncanny valley phenomenon [3],[5],[6],[7]. However, most Malaysians have not heard or aware of uncanny valley phenomenon. There is no known work done yet as far as the authors' knowledge on determining whether this phenomenon exists among Malaysian population. In view of the different cultural background and exposure of Malaysian population to robotics technology compared to European or East Asian populations, it is worth to study this phenomenon in Malaysian context. Malaysian populations may be influenced by local factors such as local taboos, exposure to technology, cultural and social norm. This study to measure the existence of uncanny valley phenomenon among Malaysian urban and rural population is timely to gather preliminary data in order for roboticists to research and design inclusive robots that suit Malaysian populations' psyche.

2. Uncanny valley
Figure 1 below illustrated the concept of uncanny valley [2]. Industrial robots commonly used in factories, do not have a face or legs. Industrial robots can only rotate, extend and retract their articulated arm. Industrial robot's appearance does not look human-like. Industrial robots are designed based purely on their functionalities. Therefore, industrial robots must have functionalities that equal or exceed human while it does not matter whether they look human-like or not. People have less affinity to industrial robot because of its lack of similarities to human being.
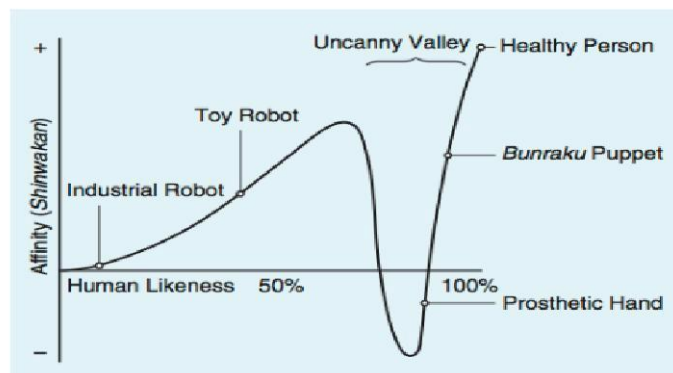
Figure 1. Graph affinity vs human likeness indicating the uncanny valley phenomenon [2].

On the other hand, in designing toy robots, robot designers will focus more on the robot's appearance rather than its functionalities. Toy robots typically have human-like features such as a face with a pair of eyes, body, two legs and two arms. There are many toy robots available in the market such as Paro and RoboHon as illustrated in Figure 2. Adult and children alike will be happy and enjoy interacting with these toy robots. Due to the advancement of silicon technology, people have difficulties in differentiating between a prosthetic hand and a real hand. Some of these prosthetic hands even have realistic skin colour, fingernails, veins and wrinkles [2]. These prosthetic hands are built very similar to human form. However, user will feel the stiffness and coldness during a handshake with its limp boneless grip and lack of tissue. Due to these feelings, people will lose affinity toward it and the hand will become uncanny although it looks real. This example describes the uncanny valley phenomenon. Mori doesn't think, on close inspection, a Bunraku puppet appears very similar to a human being. Its realism in terms of size, skin texture, and so on, does not even reach that of a realistic prosthetic hand. But when audiences enjoy a puppet show in the theatre, they are seated at a certain distance from the stage. The puppet's absolute size is ignored, and its total appearance, including hand and eye movements, is close to that of a human being. So, given human tendency as an audience to become absorbed in this form of art, audiences might feel a high level of affinity for the puppet [2]. Human beings themselves are the final goal of robotics designer, with 100% likeness and maximum affinity.

Figure 2. Paro, RoBoHon, Bunraku puppets and prosthetic hands (clockwise from top left).

3. Methodology

As illustrated in Figure 3, this work is divided into three phases. In the first phase, four suitable robotic faces are designed and fabricated. The robotic faces are designed to have separate distinct looks: Robot 1, cute animal; Robot 2, cartoon character; Robot 3, a typical robot look; and Robot 4, human-like. Robot 1, Robot 2 and Robot 3's characteristics are benchmarked to numerous popular cartoon and movie characters. Robot 4 is benchmarked to characteristics of a human being. The design of the robotic faces consists of mechanical design, prototyping, and electronics design. The robots' structures are designed and simulated in 3D CAD environment. The structures, levers, and motor brackets are 3D printed using plastic material. Miniature geared servomotors are used to actuate the eyebrows, lips, ears, face muscles, and head movement. Motion detection sensors are used to detect the presence of human in order for the robot to interact with human. Coloured light emitting diodes are used to represent the robots' eyes. The interactions are controlled by an embedded microcontroller. The controller is programmed to incorporate friendly and unfriendly behaviours on the robotic faces as illustrated in Figure 4. Phase two consists of designing questionnaire surveys and conducting surveys at selected urban and rural populations. The surveys are conducted at Setapak neighbourhood, Kuala Lumpur (urban) and Kelapa Sawit village, Johor (rural). A total of 50 respondents, 25 at urban area and 25 at rural area, volunteered to take part in the surveys. The respondents are selected randomly from the identified neighbourhood and village. The respondents' genders are spread almost equally with 52% male and 48% female. Figure 5 shows the experimental setup. In the surveys, besides the four robots, a pleasant looking human model is included as Robot 5 to represent an ideal robot as illustrated in Figure 6. Third phase involves analysis of the data collected. It is to determine the existence of uncanny valley among urban and rural population in Malaysia and to determine the preferred features in a humanoid robot.
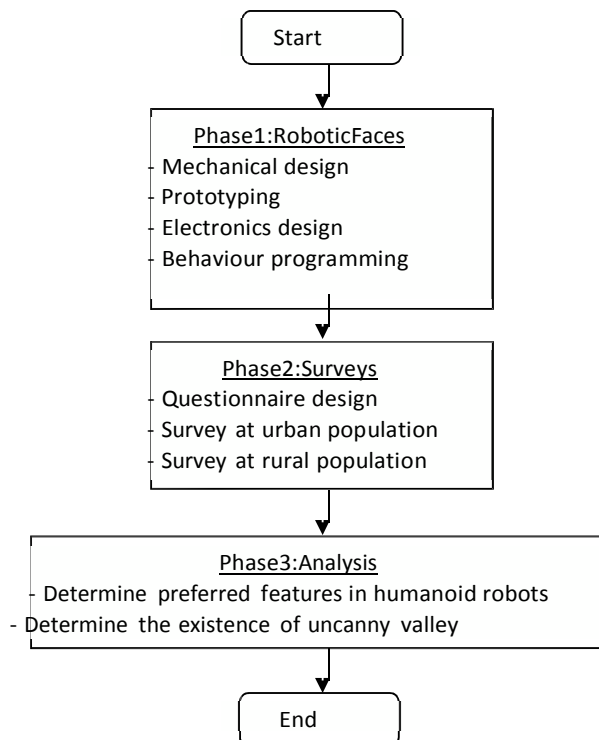

Figure 3. Research methodology flowchart.

Figure 4. Friendly (left) and unfriendly (right) faces.
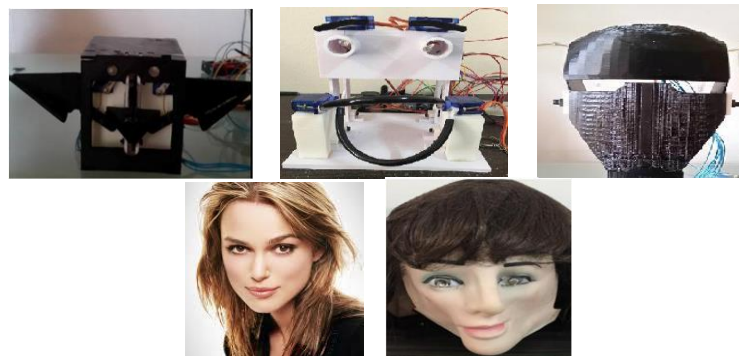

Figure 5. Experiment setup.

Figure 6. Robot 1, cute animal; Robot 2, cartoon character; Robot 3, a typical robot look; Robot 4, human-like; and Robot 5, actual pleasant looking model (clockwise from top left).

4. Results and discussions

The data gathered from the respondents are analysed to determine the preferred features in a humanoid robot. Perceived likeness of the robots to human and human acceptance to the robots are also ranked. Based on the rank of perceived likeness to human and the rank of human acceptance to the robots, the uncanny valley graphs are plotted. The results and discussions are presented in the following sub sections.

4.1. Preferred features in a humanoid robot

In this experiment, the respondents both in the urban and rural areas are requested to indicate their preferred features in a humanoid robot. Before the experiment started, the respondents are briefed on the concept of humanoid robot, a robot that resembles human in appearance and with human capabilities. The respondents are requested to select from a list of five features

namely, limbs, face, eyes, ears and nose. The respondents can pick more than one features. The respondents' preferred features are summarized in Figure 7 below. There is not much variation observed in the result, with limbs the most preferred feature at 21.5% and nose the least preferred feature at 18%. The features ranked from the most preferred to the least preferred are robot's limbs, face, eyes, ears and nose. According to the respondents, face acts as a front of a robot, akin to human face where all the other features are attached to. Hence, face is essential in every humanoid robot. Eyes allow robots to see and limbs to allow robots to work and interact with other humans and the surrounding. Limbs allow robots to be useful, which is the actual motivation of having robot in a household in the first place. The respondents felt that ears and nose are of relatively less importance to a humanoid robot. In robotics, a microphone will allow a robot to hear without the need for elaborate ears. Up to now, it is difficult for layman to imagine a robot that can smell, more so using nose. This insight will be useful for robot designers to identify features to be included or to emphasize in a robot design.
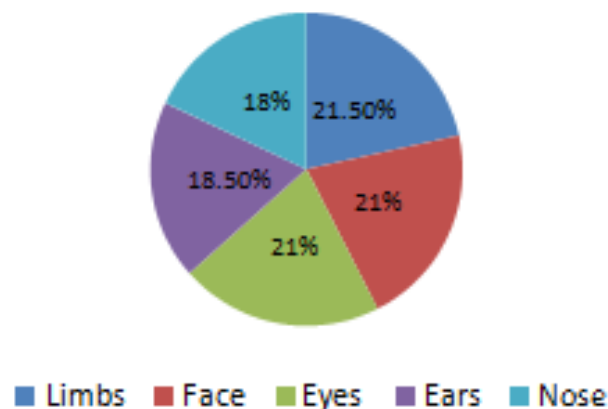

Figure 7. Preferred features in a humanoid robot.

4.2. Likeness to human

In this experiment, the respondents rank the robots' likeness to human being. Table 1 and Table 2 summarize the results obtained from the surveys conducted on urban and rural populations respectively. Both the surveys returned similar results. Robot 5, the human model is ranked most likeness to human at 94%. This is expected as the model is indeed a real and pleasant looking human being. Understandably, Robot 4 the human-like robot, with wigs and silicon skin, is ranked second most likeness to human being. This robot is intentionally built to closely resembles human being. Robot 3, iron man inspired robot is ranked third likeness to human being. It has a head with eyes. Respondents associated the robot with the ironman character in the movie. Robot 2 and Robot 1, cartoon and cute animal inspired robots are ranked by the participants as not having likeness to human. Robot 1 is designed to closely resembles a small animal, in this case a bird while Robot 2 resembles a cartoon character. Robot 2 is ranked higher than Robot 1. This ranking is used to plot the x-axis of the uncanny valley graph where Robot 1 the least likeness to human being to Robot 5 the most likeness to human being.

Table 1. Likeness to human ranking for various robots (urban population)

Robot	Likeness to Human (Urban)					Total Respondents	Likeness Normalised to %
	Very not likeness	Not likeness	Neutral	Likeness	Very likeness		
	1	2	3	4	5		
1	22	1	0	1	1	25	26
2	1	19	3	1	1	25	46
3	0	4	21	0	0	25	57
4	0	1	1	23	0	25	78
5	2	0	0	0	23	25	94

Table 2. Likeness to human ranking for various robots (rural population)

Robot	Likeness to Human (Rural)					Total Respondents	Likeness Normalised to %
	Very not likeness	Not likeness	Neutral	Likeness	Very likeness		
	1	2	3	4	5		
1	20	1	1	2	1	25	30
2	0	14	9	2	0	25	50
3	1	7	13	2	2	25	58
4	3	2	2	18	0	25	68
5	1	1	0	1	22	25	94

4.3. Human acceptance

In this experiment, the respondents are required to rank the five robots from 1 to 5 according to their preferred choice to bring home. The results are summarized in Table 3 and Table 4 below. Rank 1 is the first choice followed by Rank 2 for the second choice and so on. This ranking can be implied as the respondents' acceptance level of the robots. Usually a person will invite another person to his/her home only when he/she accepts the other person as a close friend or a family member. Based on the survey data computed from urban area, Robot 1, Robot 2 and Robot 3 acceptance rate are at 70% or more. It can be implied that, human beings can accept Robot 1, Robot 2 and Robot 3 into their home. Many respondents cannot accept Robot 4 that looks like human being. Most respondents felt that the robot is creepy because of the robot's close resemblance to human being. Surprisingly for Robot 5, the ideal human model, the urban respondents' acceptance rate is at 43% only which is below expectation. Urbanites are usually cautious of being close to a stranger, let alone to bring the stranger home. In current urban scenario, sadly friends usually have to make appointment before visiting one another. Most of the time, the meeting will be held in a neutral venue such as coffee shops, restaurants and malls as opposed to at home as in the olden days. Urbanites are more comfortable having a clear-cut machine (robot) home compared to a stranger or a robot resembling a stranger. The acceptance rate for the ideal robot might be higher had the respondents have the chance to get to know the robot better. However, this is still not possible with the current technologies available.

The results are slightly different for rural populations. The acceptance rate for Robot 1, Robot 2 and Robot 3 are at 67%, 68% and 64% respectively. Although indicating acceptance, it is slightly lower than in the urban area. The acceptance for Robot 4 is low at 34% as expected. The acceptance rate for Robot 4 is similar to the urban respondents. The acceptance rate for Robot 5, the

ideal human model is much higher at 67%. This acceptance rate is high and similar to the acceptance rate for Robot 1 and Robot 2. The rural respondents are more welcoming to strangers into their home. The community spirit in rural setting is still high where usually anyone can freely walk into a neighbour's house for a short chat. The houses in a village are usually situated near one another with the villagers sharing the same common amenities. This encourages acceptance and trust among the villagers. Furthermore, rural respondents are less weary toward strangers due to the relatively low crime rate environment.

Table 3. Human acceptance ranking for various robots (urban population).

Robot	Human Acceptance (Urban)					Total Respondents	Acceptance Normalised to %
	Rank #5	Rank #4	Rank #3	Rank #2	Rank #1		
1	1	4	3	10	7	25	74
2	0	2	13	5	5	25	70
3	1	2	7	6	9	25	76
4	13	7	2	3	0	25	36
5	10	10	0	1	4	25	43

Table 4. Human acceptance ranking for various robots (rural population).

Robot	Human Acceptance (Rural)					Total Respondents	Acceptance Normalised to %
	Rank #5	Rank #4	Rank #3	Rank #2	Rank #1		
1	3	3	8	4	7	25	67
2	1	3	9	9	3	25	68
3	2	6	6	7	4	25	64
4	17	4	1	1	2	25	34
5	2	9	1	4	9	25	67

4.4. Uncanny valley
The relationship between the respondents' acceptance toward the five robots against the measure of robots' likeness to human beings is plotted. The relationship graphs are illustrated in Fig. 8 for urban and rural populations. As shown in Figure 8, there is a pronounce dip in acceptance level for Robot 4, indicating the presence of uncanny valley phenomenon in both the urban and rural Malaysian populations. As stated by Mori in [1], a person's response to a humanlike robot would abruptly shift from empathy to revulsion as it approached, but failed to attain, a lifelike appearance. This descent into eeriness is known as the uncanny valley. This is demonstrated in the Robot 4 design that closely resembles a human being with wig as its hair and silicon skin. However, the design is still not realistic enough to persuade the respondents to accept the robot as part of human. Hence, the respondents felt eeriness, uncomfortable and are scared to interact with the robot. With the shift toward individualism, especially in the urban area, it is unsure whether the acceptance level will increase for a robot that almost 100% resembles a human being.
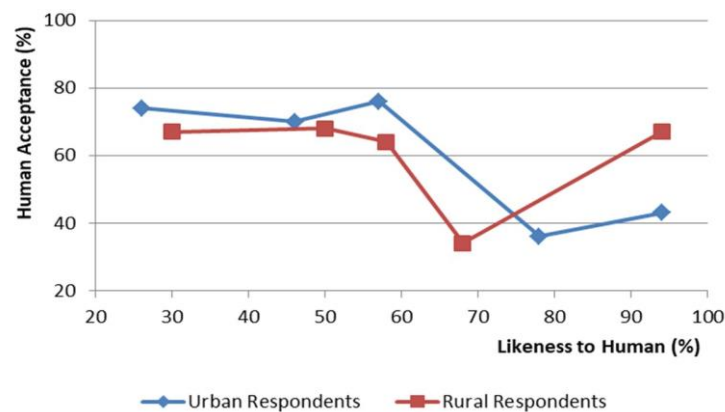
Figure 8. Uncanny Valley graph for urban and rural respondents.

5. Conclusion

In this study, the existence of uncanny valley phenomenon among Malaysian urban and rural population are measured. From the limited study, it is found that the uncanny valley phenomenon is indeed present in Malaysian population. This outcome is in line to many similar studies in other countries. It is interesting to note that for urban population, the acceptance level for a robot that almost 100% resembles a human is still low. Besides uncanny valley, the key robotic features preferred by Malaysians are also measured. This research is important that it provides a local perspective to a global phenomenon. The data will come in handy for social and educational robot designers targeting Malaysian or Asian population. However, further improvement can be made on the robots' physical capabilities to enable meaningful social interaction with human respondents. There is also a plan to extend this survey to include a larger number of respondents from different educational background, race and geographical locations.

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