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Overcoming The Uncanny Valley Through Shared Stressful Experience with a Humanoid Robot

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Summary

Previous research has shown that people sometimes feel uncomfortable in the presence of objects that appear almost, but not quite, human-like. This phenomenon, known as the Uncanny Valley effect, may present an impediment to the widespread acceptance of humanoid robots in everyday life, e.g. as school teachers, nurses, nannies, or clerks. It is therefore important for the field of human-robot interaction to identify ways in which the Uncanny Valley effect can be overcome. The current study was designed to test the hypothesis that sharing a stressful experience with a robot may serve to establish rapport with that specific robot, leading to a boost in people's willingness to interact with the robot. To this end, we conducted an experiment in which participants underwent a pleasant experience with one virtual agent and a mildly stressful experience with a second virtual agent (the Induction Phase). Next (the Test Phase), they carried out a new series of tasks, before each of which they selected one virtual agent (either one of the two familiar agents or one of two unfamiliar agents) to be their partner for that task. The results indicate that participants chose to partner with the virtual agent with whom they had shared the stressful experience more often than the virtual agent with whom they had shared the pleasant experience, and more often than either of the other two agents. This finding, as well as the results of questionnaires that were administered at the end of the experiment, support the hypothesis that shared stressful experiences help overcome the Uncanny Valley effect.

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Introduction

As technology advances, we grow ever closer to the day when robots will be fully integrated into human activities. Whether as school teachers, nurses, nannies, or clerks, robots may well become part of our everyday routines. However, we are not yet at that point. Robotic assistants are still a fantasy to most except those in high-tech labs and universities, such as the Italian Institute of Technology or Boston Dynamics. Despite the limited integration of robots into everyday life, progress is being made quickly. With progress come prototypes, and these prototypes may look or act in ways that people find off-putting. One reason for this is the so-called "Uncanny Valley" effect, or the phenomenon that people feel uncomfortable in the presence of non-living objects that appear human-like (1) (**Figure 1**). It is an important challenge for current and future research to identify ways of designing robots that humans feel comfortable around (2). One starting point in addressing this challenge is to recall that human-likeness is not the only factor modulating trust in interactions with anthropomorphized robots. This means that one could potentially alter or control some other factor(s) to decrease the untrustworthiness brought by the Uncanny Valley effect.

In the current study, we tested the hypothesis that a shared stressful experience improves feelings of trust and commitment towards a robot. While this may at first sound surprising, it is in fact well-known that sharing stressful experiences can contribute to the development of rapport and the cultivation of deep and strong relationships. An example is the bonding of soldiers through traumatic wartime experiences (3). Two complete strangers could become close through shared experiences with life-threatening situations. Similarly, the use of pain in rites of passage, such as those performed by the of the Tsonga tribe, may function to establish emotional bonds among group members (4). This conjecture is also supported by the results of a recent study in which groups of participants were instructed to leave their hands in ice water for as long as possible compared with a no-pain control treatment (5). After this (mildly) stressful experience, each member of the group had the task of choosing a number representative of a reward and its worth between 1 and 7. Choosing "7" could bring the biggest payoff but only if every single group member chose "7," too. If choices differed within the group, the lowest number would give the highest payoff. Interestingly, researchers found that

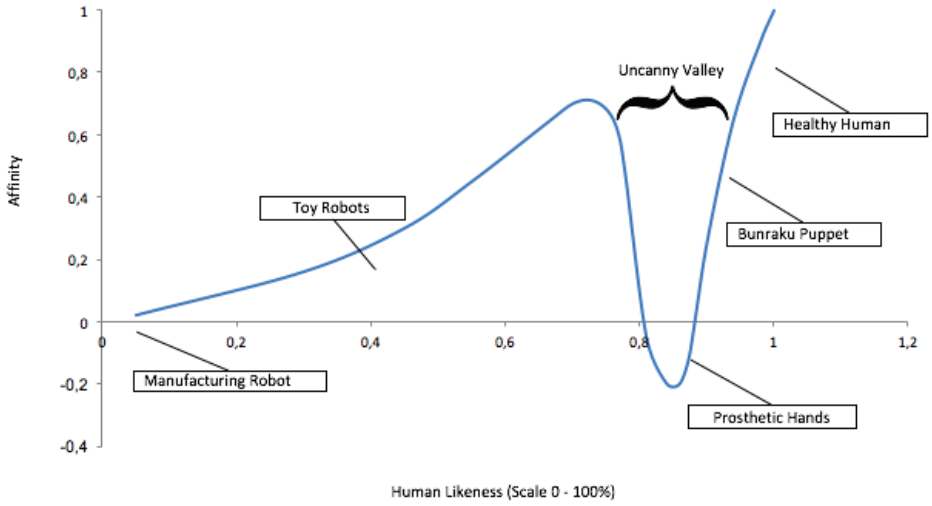

Figure 1. The Uncanny Valley. Human observers' affinity with an object generally increases as a function of the object's human-like appearance—unless the object exhibits a very high degree of resemblance to humans but is nevertheless distinguishable in appearance from humans, in which case it can elicit an eerie, or uncanny, feeling.

the members of the test group were more likely than members of the control group to pick the number "7," the most profitable number for all members of the group. As a further example, consider "Stockholm Syndrome," the phenomenon whereby hostages develop compassion toward their captors (6). This curious phenomenon has been closely studied, and researchers who have conducted case studies have suggested that social bonds are formed in such cases as a coping mechanism to deal with stress. As a side-effect, when the stressful event is over, the bond can sometimes remain (7).

These findings suggest that shared stressful experiences may elicit a coping mechanism which leads to the formation of positive emotional bonds. If so, then sharing a stressful experience with a robot may help to overcome the uncomfortable feelings brought on by the Uncanny Valley effect. The present study was designed to test this hypothesis. To this end, we implemented a version of the "Sing-a-Song Stress Test," or SSST (8). In this test, participants are informed that they will be required to sing in front of an audience. This has been shown to make most people extremely nervous and is therefore well-suited for the creation of a controlled stressful experience. We hypothesized that this uncomfortable and stressful experience, if shared with a virtual robotic agent, would cause the human participant to form a bond with the virtual agent. If bonds form, the human participant would prefer to interact with this robot repeatedly on subsequent tasks rather than with an alternative virtual agent.

Results

During the Induction Phase of the experiment, participants were introduced to two virtual robotic agents, both of whom were human-like in appearance. The first robotic agent and participant listened to a song together. This phase was designed such that they would share a pleasant experience. Next, they were introduced to the second virtual robotic agent and immediately put into a stressful situation. The participant and robotic agent were instructed that they had two minutes to prepare to sing a song to our staff. Participants' heart rate was recorded and compared to their resting heart rate to assess whether a significant change had occurred.

Afterwards, participants had to complete a series of tasks (the Test Phase). Before each task, they were instructed to choose one of two virtual agents to be their partner. The pool of potential partners consisted of the virtual agent with whom they had shared the stressful experience, a second virtual agent with whom they had shared a pleasant experience, and two unfamiliar virtual agents.

When faced with the choice between the agent with whom they had shared the stressful experience and the agent with whom they had shared the pleasant experience, participants chose the agent with whom they had shared the stressful experience 58% of the time. A one-sample t-test did not reveal a significant difference from chance, $t(25) = 1.86$, $p = 0.075$. When faced with the choice between the agent with whom they

Figure 2. Procedure. The three phases of the experiment.

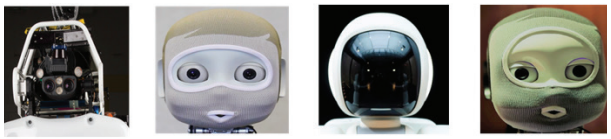

Figure 3. The Virtual Agents. From left to right, these are the images of Kelly, Pat, Alex, and Sam, which were presented to participants during the course of the experiment. Pat and Sam were the virtual agents introduced to the participants in the first phase of the experiment. The Kelly photo is courtesy of Boston Dynamics as "Atlas." The Pat and Sam photos are the same robot being developed by the Italian Institute of Technology as "iCub." The Alex photo is courtesy of Honda as "Asimo."

had shared the stressful experience and an unfamiliar agent, participants chose the agent with whom they had shared the stressful experience 65.3% of the time. A one-sample t-test revealed a significant difference from chance, $t(25) = 2.43$, $p = 0.015$, $d = 0.515$. When faced with the choice between the agent with whom they had shared the pleasant experience and an unfamiliar agent, participants chose the agent with whom they had shared the pleasant experience 62.5% of the time. A one-sample t-test did not reveal a significant difference from chance, $t(25) = 2.43$, $p = 0.09$.

Finally, participants completed a questionnaire assessing their impressions of the four virtual agents. Participants were instructed to indicate which of the four virtual agents they would prefer to interact with in the future and were asked to rate how favorably they viewed each of the agents on a scale of 1 to 7 (7 being the most favorable).

Machinelike	1	2	3	4	5	6	7	Humanlike
Unconscious	1	2	3	4	5	6	7	Conscious
Dead	1	2	3	4	5	6	7	Alive
Inert	1	2	3	4	5	6	7	Interactive
Dislike	1	2	3	4	5	6	7	Like
Unfriendly	1	2	3	4	5	6	7	Friendly
Incompetent	1	2	3	4	5	6	7	Competent
Foolish	1	2	3	4	5	6	7	Sensible
Anxious	1	2	3	4	5	6	7	Relaxed
Agitated	1	2	3	4	5	6	7	Calm

Figure 4. Impressions of the Virtual Agents. Participants indicated their impressions of the virtual agents using a 7-point Likert scale.

The participants' mean rating of the virtual agent with whom they had shared the stressful experience (4.6 out of 7) was numerically higher than their mean rating of the virtual agent with whom they had shared a pleasant experience (4.42 out of 7), although this difference did not reach statistical significance, $t(25) = 0.637$, $p = 0.116$. Their mean ratings of the other two virtual agents were 3.62 out of 7 and 3.59 out of 7. A paired-sample t-test revealed that participants found the virtual agents they had met previously to be, on average, more human-like and pleasant ($M = 4.62$) than the other virtual agents with whom they had not had any previous encounter during the induction phase ($M = 3.64$), $t(25) = 2.83$, $p = 0.009$, $d = 0.557$.

In response to the question about which robot they would want to interact with in the future, 46.2 % of them chose the robot with whom they had shared the stressful experience while only 7.7% of them chose the robot with whom they had shared a pleasant experience. The control robots were selected 23.1% of the time. A one-sample t-test revealed a highly significant preference for the virtual agent with whom they had shared a stressful experience over the one with whom they had shared a pleasant experience, $t(25)$ 7.92, $p<0.001$ (**Figure 5**).

Discussion

The results from the questionnaire phase revealed that most of the participants would prefer to interact with the virtual agent with whom they had shared the stressful experience. This supports the hypothesis that sharing a stressful experience with a humanoid robot can serve to establish rapport with that robot and thereby boost people's willingness to interact with the robot. One unexpected finding was that participants were significantly less likely to choose the familiar agent with whom they had shared a pleasant experience. We might speculate that in evaluating the familiar agent with whom they had shared the pleasant experience, participants unconsciously compared it to the agent with whom they had shared the stressful experience, and found it by comparison less appealing. This hypothesis is consistent with the finding that each of the unfamiliar agents was chosen nearly one-quarter of the time. This means that the high number of participants choosing the familiar agent with whom they had shared the stressful experience came at the expense of the familiar agent with whom they had shared a pleasant experience.

The results from the test phase were also consistent with our hypothesis. Participants chose to interact with the virtual agent with whom they had shared the stressful experience more often than the other virtual agents, although this difference did not reach statistical significance. Crucially, it is highly unlikely that our findings could have resulted from any other factor. Participants were informed that all four virtual agents were equally competent and the visual appearances, names, and dialogues of the robots were counterbalanced.

Future research should aim to replicate the findings reported here with a larger sample size. Moreover, it would also be important to explore other ways of overcoming the Uncanny Valley effect. For example, it would be interesting to probe the effect of time of cooperation on people's relationships with humanoid robots. This could potentially be more easily applicable than inducing stress in a person in order to develop a relationship. Directly implementing stress into feasible opportunities for relationship growth between humans

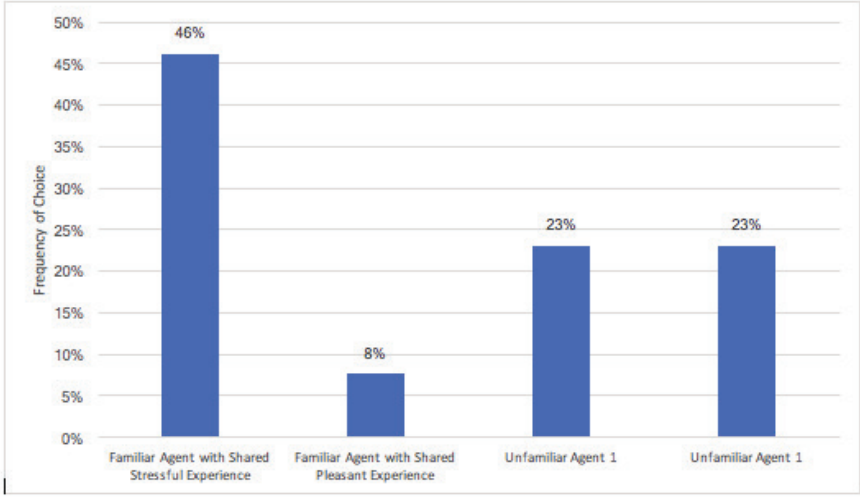

Figure 5. Preferred Future Interaction Partners. Participants indicated which virtual agent they would prefer to interact with in the future.

and robots could potentially discourage relationship building or emotionally harm people. However, a regimen of relationship building that uses stressful situations over a longer period of time could be more effective.

Applications for smartphones could be made as a training program to acquaint humans with robots using a series of team-building games that induce stress in different ways. Smartphone applications are an optimal way of implementing this research and applying it to existing technologies. Stress induction in this case will not be as strong because the SSST would not be practical in this environment due to its need for a large audience. Novel means of stress would have to be introduced for these smartphone application games. A monetary or point system that induces a feeling of risk could be a way to add stress to games played with an anthropomorphic robot. An experiment would have to be done to test whether this method of inducing stress could be an effective way of developing relationships between humans and robots. With continued research and varying stress induction processes, one could possibly determine more effective ways of building better bonds with anthropomorphic robots.

Methods

Participants

Using G*Power 3.1 (9), a sample size of 27 was calculated to provide 80% statistical power for detecting a medium-sized effect (d = 0.54) equivalent to that observed in a pilot study with a similar design that had been conducted at the same lab, assuming a two-tailed t-test and an alpha level of 0.05. After the initial data collection, eight participants were excluded (see *Exclusion Criteria*, below), so eight additional participants were then recruited. Thus, a total of thirty-five participants were recruited from the research facility's lab website pool. Each of them received a gift voucher for their time. The experiment was conducted in accordance with the Declaration of Helsinki and was approved by the United Ethical Review Board for Research in Psychology (EPKEB).

Having chosen a time slot through the online participant recruitment page, each participant was introduced to the researcher and asked to read an information sheet outlining the general research questions and procedures. After signing consent forms, they were read a script giving a basic outline of the experiment and told how long it would approximately take to run the experiment to its completion. They were debriefed and told that their information would be kept anonymous and confidential. They were also told that they could leave at any time. The time slots were usually very close together to maximize the number of participants in a day. 45-minute slots were scheduled with a 15-minute break period in between to get the experimenting room reset and to gather the electrocardiograph (ECG) data before resetting the program.

Instructions

The researcher always read the instructions prior to the participant starting the experiment. The instructions were then presented on the screen and participants again had the opportunity to ask a researcher or lab assistant to clarify any questions they may have. The (shortened) instructions read:

> "You are here today to take a joint-task action experiment with an artificial agent as a partner. This artificial agent is a robot in a joint lab operating in real time and will react to your responses. The first phase will have you participating in music-related activities with an artificial agent. The second

phase will have you answer math-related multiple-choice questions to the best of your ability with assistance from an artificial agent of your choice. All artificial agents have the same level of competency. For this experiment, your heart rate needs to be recorded. A device will be placed on areas of your chest to record the electrical activity from your heart. If at any point you feel uncomfortable you can withdraw. All of your data will be kept confidential and remain anonymous."

ECG Recording

The electrocardiograph device used to record heart rate throughout this experiment was a BioNomadix wireless transmitter with an RSP ECG amplifier. The BioNomadix was a small device that would either be in the pocket or on the lap of the participant while recording. It had wires that connected to electrodes which were placed on the chest of the participant. New sterile electrodes were administered for each participant. These electrodes were placed on the participant's right chest, left chest, and lower left abdomen to record heart rate as per protocol. The heart rate was recorded in real time and could be reviewed after the experiment was conducted using the AcqKnowledge software. To save on the storage space and the data of the participant, only the 10-12 seconds were recorded of the participant reading the pleasant and stressful event prompts.

Apparatus and Stimuli

The experiment was programmed using Microsoft's Visual Basic. The digital interface helped to create the illusion of a real robot acting jointly with the human participant. A robot would appear on screen as tasks would also appear. This constantly reminded the participant of a partnership and helped the participant remember the virtual agents' faces during the questionnaire portion of the experiment. If this illusion was not maintained it could have affected the validity of the individuals' responses when asked their preference of robotic partner because they would not have taken it seriously.

Procedure

The experiment itself consisted of an induction phase followed by a test phase and a questionnaire phase (**Figure 2**).

Induction Phase

In the first phase of the test, each participant experienced two musical activities after being wired up to a BioPac machine. The first musical activity was meant to be a pleasant control situation and required the participant to listen to Queen's "We Will Rock You" with a virtual agent. The virtual agent, a picture of which was displayed on the screen during the musical activity, was perceived to be a real robot with intelligence as it made comments on the song as it was played. For the second musical activity, participants were introduced to a second virtual agent that appeared on the screen during the activity. As in the first activity, the participant listened to Queen's "We Will Rock You" together with the virtual partner. However, in this case, the participant was instructed to prepare to sing the song together with the virtual agent, and informed that they would then be asked to sing it in front of the research staff. The second musical activity was closely matched to the first, with the exception that it was intended to induce stress. At the end of the second musical phase, participants were informed that, because of time constraints, they would not have to sing the song after all.

Test Phase

In the test phase, the participant answered a series of 32 multiple choice mathematics questions at a 6-7th grade-level difficulty. Participants were allowed to use scrap paper if they needed to and were also under the impression that points were earned for every correct question answered. Before every mathematics question, the participant was presented with a binary choice between two virtual agents, one of which they could select to be their partner and to provide assistance for the upcoming question. The choices ranged among four virtual agents: Kelly, Pat, Alex, and Sam (**Figure 3**). These names were chosen because they were short and gender-neutral for the region from which participants were recruited. Pat and Sam were the two virtual agents with whom they had shared the two musical experiences in the induction. Which of these two had been the partner during the stressful experience was counterbalanced. Alex and Kelly were virtual agents with whom the participants had not shared any previous experience and who therefore provided a baseline.

Questionnaire Phase

The participants were distributed a set of questionnaires after the test and were asked to leave the room they were currently occupying. When they left, they were asked to stay in the waiting room and complete the set of questionnaires. This process took about five minutes. Each one of the first four pages was dedicated to one of the four virtual agents introduced to the participant. Participants were asked to rate their impression of the virtual agent from 1-7 on a 7-point Likert scale (**Figure 4**). These scales were developed specifically to assess human perception and attitudes for first impressions on robots (10). The last page offered insight as to whether the person themselves thought they were under stress during the first phase of the

stress-induction event. They were asked to rate the two experiences, listening to and preparing to sing the song, respectively, on a scale from 1 (not nervous) to 7 (nervous). The last question on the last page asked the participant which virtual agent they would prefer to interact with in the future if the opportunity arose. This question provides a point of comparison with participants' choices during the binary choice phase of the test.

Exclusion Criteria

For the analyses, we excluded three participants because they indicated that they had been "not nervous" during the second musical activity in the induction phase and because the ECG data revealed no detectable change in heart rate. In addition, we excluded five participants who, owing to experimental error, were not presented with the binary choice between Alex and Pat a minimum of four times.

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