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Facilitating Driver Interaction with a Robotic Driving Assistant: Some Insights from the Literature

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16. Abstract

Nissan has been exploring the idea of robots as driving aids, first demonstrating the PIVO robot at the 2005 Tokyo Motor Show and PIVO 2 at the 2007 Tokyo Motor Show. The robot consists of the top of an R2D2-like unit, with an expressive face, torso rotation, and speech output. It is positioned on top of the instrument panel of a unique vehicle that has 4 steerable wheels and a rotatable passenger cabin.

This report examines 4 topics related to driver interaction with robots, summarized below.

1. Robot communication with drivers: If a single voice is to be selected, a female voice is preferred, but a voice that can be tailored to the task is even better. Nonverbal cues from a robot such as facial expressions (identified using Ekman's Facial Action Coding System) and eye contact help indicate whose turn it is to speak in robot-driver conversations and help communicate what the robot is saying.

2. Robot appearance: Physical attributes, in particular, chin and forehead dimensions, and width of the face affect the extent to which advice from robots is accepted. However, given the "uncanny alley" phenomenon, making a robot more human-like is not always better.

3. Robot behavior: Desired behavior is task dependent. Standard personality characteristics such as emotional stability, extroversion, agreeableness, etc., also apply to robots and can be assessed using standard psychological scales.

4. Robot acceptance: Acceptance of robots varies with general attitudes toward technology, culture (surprisingly, Japanese are not more accepting), and decreases with age. This can be assessed using NARS (Negative Attitudes Towards Robots Scale).

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INTRODUCTION

International Standard 8373 (Manipulating industrial robots – Vocabulary) of 1994 defines a robot as "an automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications" (Jones, 2008, pp. 330). The first industrial robot, Unimate, was built in 1961. Unimate was used in a General Motors plant to aid in a die casting operation and changed the automotive industry forever (Handwerk, 2003). Some 40 years later, the United Nations Economic Commission for Europe's 2001 Annual World Robotics Survey reported at least 760,000 robots worldwide, with 360,000 of these being in Japan, 220,000 in the European Union, and 100,000 in North America (Rosenberg, 2004).

In addition to traditional industrial applications (machine loading, assembly, welding, painting, etc.), there is increasing interest in using robots in health care, in particular as personal assistants (MILO robot personal assistant, http://www.gizmag.com/go/3410/). In the United States, household robots also help clean floors, vacuum carpets (iRobot Roomba, http://store.irobot.com/home/index.jsp), and mow lawns (Friendly Robotics RoboMow, http://www.friendlyrobotics.com/ and Lawnbott Robot Mower, http://www.robotshop.us/). To some degree, personal use has been encouraged by Hollywood's image of robots as having human qualities (C3P0 and R2D2 from *Star Wars*, the terminator robot, and *Wall-e*). However, these more sophisticated applications are not mere visions of the future, but as machine intelligence increases, will be realized in the near term in such forms as unmanned combat aircraft, such as UCAV (Pike, 2000), and robotic space vehicles (Technovelgy LLC, 2005).

Following those trends, Nissan has been exploring the idea of robots as driving aids. The PIVO robot, first shown at the 2005 Tokyo Motor Show (F.B., 2007) and later in an enhanced form at the 2007 Tokyo Motor Show, has been designed to serve as a driving aid. This robot is currently designed for Nissan's PIVO 2, a unique, 3-person vehicle with electric motors in all 4 wheels that can turn 360 degrees (F.B., 2007). The vehicle looks like a naval gun turret on wheels, without the gun, or the cab from a steam shovel, minus the boom (Figure 1). The robot that sits inside of the vehicle can be seen below in Figure 2. With facial and voice-recognition software, the PIVO 2 robot is expected to improve the state of mind of the driver (Chapa, 2008).

Figure 1. PIVO 2 vehicle

Figure 2. Nissan's PIVO 2 robot inside the PIVO 2 vehicle

When analyzing a robot as a potential driving aid, many different aspects need to be considered. In other contexts of robot use, an operator supervises the robot, but here the robot should need minimal supervision to avoid distracting the driver.

If well designed, the driving aid robot could offer several potential benefits. The PIVO 2 robot will be expected to complete a variety of tasks to create a better driving atmosphere for the driver, including both driving-oriented tasks and non-driving oriented tasks. By completing these tasks, the robot could reduce the driver's stress by aiding in his/her driving task and creating a more enjoyable driving experience. Further, by supporting tasks that drivers do not do very well, driving could become safer.

When designing a system involving people, one must consider who the user is and what task is being completed. Recommendations concerning what people should do and what machines should do are classically expressed in what is known as a MABA MABA table (Men Are Better At, Machines Are Better At), which to be politically correct is now called a PABA RABA table (People Are Better At, Robots Are Better At). See Table 1 (Fallon, 2006). However, beyond this simple characterization, little has been published on what it would be most appropriate for a robot driving aid to do.

Table 1. Typical MABA/MABA and MABA/RABA List Entries

Men (People) are Better At (MABA)	**Machines Are Better At (MABA)**
Detecting masked signals	Detecting signals from many sources
Pattern recognition in light and sound	Detecting signals at speed
Creative and inductive reasoning	Deductive reasoning
Responding to unexpected events	Processing large amounts of data quickly
Improving using small-medium forces	Storing large amounts of data
Men (People) Are Better At (MABA)	**Robots Are Better At (RABA)**
Require less detail in job descriptions	Energy efficient
Flexible (reprogramming not required)	Operate continuously
Require less space	Can apply large forces
Require less capital investment	Have no social or personal needs
Are easily transported	Repeat operations accurately

However, there are other questions for which the literature provides some insights that are important to those designing robots as driving aids. These questions are as follows:

- How can a robot communicate with a driver?
- What should a robot look like to facilitate interaction with a person?
- How should a robot behave to facilitate interaction with a person?
- How does acceptance of robots vary with the user's culture and age?

How the Literature Was Assembled

Given that this was a small undergraduate student project, this review is by no means comprehensive or complete.

To address these questions, Google.com/scholar was used to search for all relevant literature, with a particular emphasis given to the acm.org web site. The most useful keyword was "personal robot." Further, for the communication section, "animatronics" was used. For the section focusing on how to create a friendly robot, the phrases, "robot physical attributes," "affect," and "robot appearance" were used. In the final section about perceptions of robots, "robot appearance" and "friendly robot" were used. The emphasis was on journal articles and proceedings papers. Additional relevant articles were identified by determining commonly cited authors in article reference lists, and then searching for other articles by them.

HOW CAN A ROBOT COMMUNICATE WITH A DRIVER?

There are many ways for the robot to communicate with the user. Due to the workload in the visual modality, speech should be considered as a possible communication technique for the user to communicate with the robot. However, for the sake of time, speech to the robot (issues of recognition, commands, etc.) will not be covered in this paper. Also of interest, but not covered, is the topic of affective computing. Those interested in that topic should read Picard (2003) and Tao (2005).

When considering how a robot could communicate with a person, 2 questions arise:

- How does the robot speak to a person?
- In what nonverbal ways can the robot communicate?

How Does the Robot Speak to a Person?

One aspect of speech that should be examined is the particular voice used by the robot. Lee, Nass, and Brave (2000) examined whether subjects could determine the "gender" of computer generated speech and if the interpreted gender led the user to exhibit gender stereotypes such as trusting male opinions more than female opinions. They had 48 undergraduates (24 women and 24 men) work with a computer to resolve 6 hypothetical social dilemmas. (A social dilemma is "when people follow their own best interests, yet the consequence of their separate choices is sub-optimal for all of them. Classic environmental examples are overgrazing and overfishing" (Arora, Peterson, Krantz, Haristy, and Reddy (undated), p. 3). After reading each scenario, the computer argued for one of the 2 possible actions (referred to as A and B) that could be taken in the scenario, after which subjects voted for 1 of the 2 actions on an 8-point scale (1=Definitely do A to 8=Definitely do B). Subjects identified the correct gender of the synthesized speech significantly more likely than by chance. Gender stereotyping was also found to exist, as participants accepted the male-voice computer's suggestions significantly more than those of the computer with a female voice.

Beukelman, Mirenda, and Eicher (1988) analyzed the preferences of subjects for natural speech or computer-generated synthetic speech, along with the preference of the gender of the speaker. Five men and 5 women from 4 age groups (6-8 years old, 10-12 years old, adolescents, and adults) listened to 11 voices (4 natural and 7 synthetic) and rated their preference of the voices on a 5-point Likert scale. Overall, they found that women generally preferred a natural female voice, whereas men were more flexible in the gender of the voice preferred. However, male listeners did suggest that a female voice should be used for women and female children. Further, children preferred computer synthesized speech, while adults preferred a more natural speech.

The gender of the voice may also have implications for the authority associated with voice and listener comfort. In a 2005 interview, Nass stated that if the voice coming out of a car's navigation system lacks adequate authority, the driver might not trust it. For example, drivers did not feel comfortable when a car's navigation system used the voice of an elderly person. This was true even of older drivers (Valdes-Dapena, 2005).

As people generally desire voices that sound like themselves, or have the same accent (e.g., New Yorkers hearing New Yorkers), and since an incorrect choice in voice can be distracting, it is important to have a large choice for voices. Following this advice, Navtones currently allows drivers to download celebrity voices, such as Kim Cattrall (of the *Sex and the*

City TV series and movie) and Dennis Hopper (of the original *Easy Rider* movie), to their navigation systems, as well as voices some consider annoying such as Mr. T (of the *A Team* TV series, http://www.navtones.com/getnavtones.php). These voices not only sound identical to the user's favorite movie star but also take on the personality of the star. Consumers can visit the online site and listen to short monologues from each of the stars in which the stars attempt to convince the person to download his or her voice. For example, in part of his monologue, Dennis Hopper states, "I'm here to drive you, brother, tell you where to go. Sit back and relax, I'm here to get you there in one piece." By allowing the user to choose their favorite star, they are picking the gender, tone, and personality of their navigation voice.

In What Nonverbal Ways Can the Robot Communicate?

Facial Expressions

Animatronics, which is defined as a figure that is animated by means of electronics, was first implemented by Walt Disney in the early sixties (Lehman, 2006). At the 1964 World Fair in the New York Hall of Presidents, Lincoln gave the Gettysburg address. Lincoln's body language and facial motions were perfectly matched to the recorded speech (Lehman, 2006). The PIVO 2 robot, like the animatronic Lincoln, should match its expressions appropriately to those of a human. According to Ekman, the following emotions have distinct facial expressions (Foreman, 2003):

- Anger
- Sadness
- Fear
- Surprise
- Disgust
- Contempt
- Happiness

Ekman's Facial Action Coding System (FACS) is the most widely used method for both measuring and describing facial behaviors, first published in 1978 by Ekman and Friesen (Ekman and Friesen, 1978). In 2002, a new version of FACS (including all the changes that were previously handed out as addendums to the 1978 book) was published (Ekman, Friesen, and Hager, 2002). FACS is based on 44 action units (AU), behind each facial expression (Ekman, 1979), each of which is associated with the triggering of 1 or 2 facial muscle groups, examples of which are shown in Table 2 (http://www.cs.cmu.edu/afs/cs/project/face/www/facs.htm). Although intended for coding human faces, there is no reason why aspects of FACS could not pertain to human-like robots. Because of the connection between expressions and emotions, it also provides a means to quantitatively assess the extent to which a particular emotion is being conveyed.

Beyond mere description, there is rich literature on factor analysis of facial expressions (Fernandez-Dols and Russell 1997, Pantic and Rothkrantz, 2004, Abboud and Davoine, 2004).

Table 2. Example Action Units

Action Unit	**Facial Muscle**	**Example**
Inner Brow Raiser	*Frontalis, pars medialis*	
Outer Brow Raiser	*Frontalis, pars lateralis*	
Brow Lowerer	*Corrugator supercilii, Depressor supercilii*	
Upper Lid Raiser	*Levator palpebrae superioris*	
Cheek Raiser	*Orbicularis oculi, pars orbitalis*	
Lid Tightener	*Orbicularis oculi, pars palpebralis*	
Nose Wrinkler	*Levator labii superioris alaquae nasi*	
Upper Lip Raiser	*Levator labii superioris*	

Currently, most of the research on robot facial expressions is focused on developing robots that can make the expressions. One example is the "Mobile Dexterous Social" robot being developed by the Massachusetts Institute of Technology's Media lab. This robot's 15 degree-of-freedom face allows for control of gaze, eyebrows, eyelids, and expressive posturing (MIT Media Lab 2008). As seen below in Figure 3, the expressions created are quite apparent (MIT Media Lab 2008). A few of the many other examples include K-bot (Amos, 2003, Figure 4) and the Character Robot (Toshio, Jun, Fumihito, Yasshisa, Daisuke, and Masakazu, 2001).

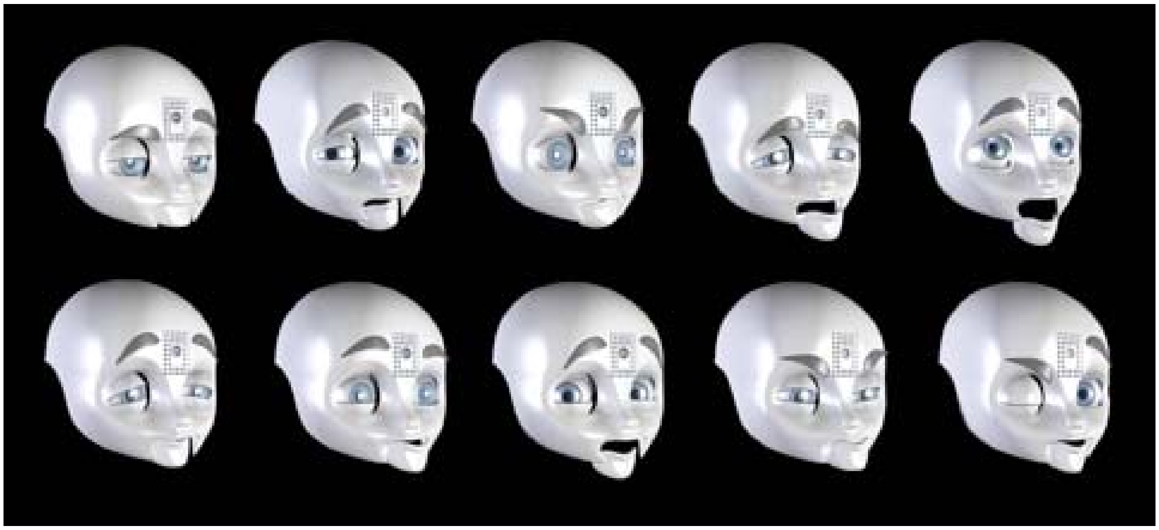

Figure 3. Mobile Dexterous Social Robot at MIT's Media Lab

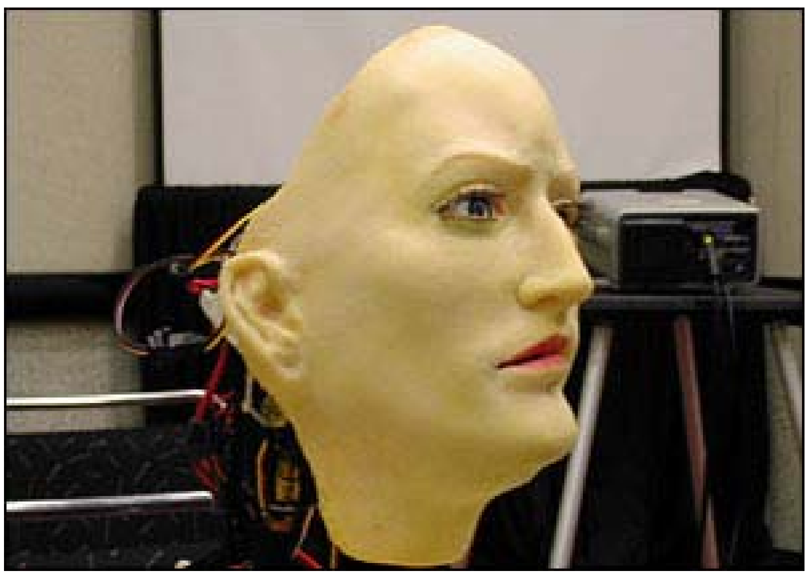

Figure 4. Amos Robot Face
Source: http://newsimg.bbc.co.uk/media/images/38829000/jpg/_38829443_head_bbc_300.jpg

Eye Contact

Eye contact can help the robot communicate emotions. Agah and Butler state that since a driver is stationary within a car, eye contact is a viable option for a driving-aid-robot (Agah, 2001). Also, by using eye contact to inform the human user that the robot is both listening and understanding his or her commands, the comfort level among users will increase, and users will feel more at ease (Agah, 2001).

Another way that eye contact can be used is to gain the driver's attention before speaking. Brezeal (2003) proposed several nonverbal actions a robot could make that would allow it to reinforce what it was saying or provide feedback to a person while the person was speaking (Table 3).

Table 3. Communication Techniques

Robot Action	User's Interpretation of the Action
Break eye contact and/or lean back slightly	Robot gets the attention of the user
Stop vocalizing and re-establish eye contact	Robot's speaking turn ends
Look to the side	Robot holds the speaking floor
Raise eye brows and/or lean forward slightly	Robot relinquishes the floor
Blink	Signals end of a vocalization

To examine these hypotheses, Brezeal (2003) examined the vocal turn-taking behavior of subjects with a robot called Kismet. Kismet is an expressive anthropomorphic head with 3 degrees of freedom that direct the robots gaze, 3 degrees of freedom that control the orientation of the head, and another 15 degrees of freedom to move its facial features (including eyelids, eyebrows, lips, ears, etc) (Figure 5).

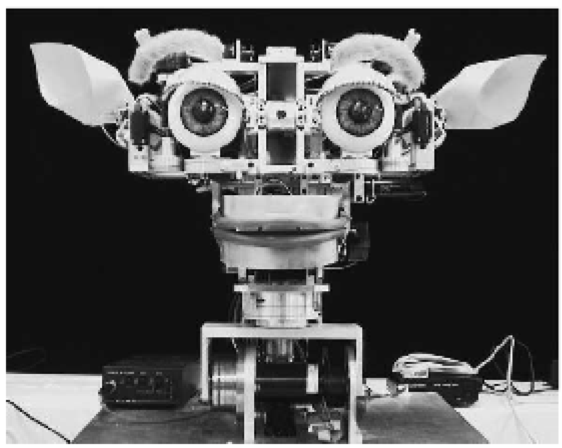

Figure 5. Kismet Robot

Four subjects, ranging in age from 12 to 28 years old, were asked to have a conversation with Kismet while their interactions were recorded. Before beginning the conversation, the subjects were told that Kismet neither spoke nor understood English, but instead babbled in a characteristic manner. The conversations were video recorded, analyzed, and annotated according to the items in Table 4 (Brezeal, 2003). A sample of the annotated exchange between Kismet and one of the subjects can be seen in Figure 6 (Brezeal, 2003).

Table 4. Annotations for Brezeal's Experiment

Type	Option	Annotations
Listener, Speaker	Human	H
	Robot	R
Turn Phase	Acquire floor	Aq
	Start speech	St
	Stop speech	Sp
	Hold floor	Hd
	Relinquish floor	Rq
Cue	Avert gaze	
	Eye contact	
	Elevate brows	
	Lean forward	
	Lean back	
	Blink	
	"Utterance"	
Turns	Clean turn	#
	Interrupt	I
	Missed	M
	Pause	P

Time code	Speaker			Listner		Turns
	S	Ph	Cue	L	Cue	
07:13:05	H	Aq	Eye contact	R	Eye contact	11
		St	"Did you ask me how I am? I'm fine. How are you?"			
07:14:25		Sp:Rq				
07:17:09	R	Aq	Avert gaze	H		12
07:17:10		St	Babble			
07:18:03		Sp	Eye contact			
07:20:05		Hd	Avert gaze			
07:21:24		Rq	Eye contact			
			Raise brows			
07:22:23	H	Aq		R	Eye contact	13
		St	"Are you speaking another language, Kismet?"	Babble		I
07:24:23		Sp:Rq				14
07:24:06	R	Aq:St	Babble	H		15
07:25:04		Sp	Blink			
		Rq	Elev brows			
07:25:14	H	Aq:St	"Sounds like you're speaking Chinese"	R	Eye contact	16
07:27:10		St:Rq				
07:27:20	R	Aq	Lean forward	H		17
07:27:45		St	Babble			
07:28:03		Sp	Eye contact			
07:28:25		Rq	Elev brows			
07:30:08	H	Aq:St	"Hey!"	R	Avert gaze	18
07:30:15		Sp:Rq	Lean forward		Eye contact	
07:31:08	R	Aq:St	Babble	H	Eye contact	19
07:33:01		Sp	Blink			

Figure 6. Sample of exchanges between Kismet and a Human Subject

Emerging from Brezeal's research are 3 main points that should be considered when designing a sociable robot such as the PIVO 2 robot. First, the robot should be pro-active in conversation. Brezeal notes that Kismet's pro-active role in regulating exchanges with the user allows it to neither overwhelm nor under-stimulate the user. Second, the feedback and readability of the robot's expressions cannot be underestimated, including the robot's eye contact and gaze. Humans could not only tell the difference between Kismet looking at them versus away from them, but they could also tell the difference between Kismet looking into their eyes, versus just at their face. For this reason, it is extremely important that the PIVO 2 robot's gaze be closely monitored. Third, Brezeal found that social interactions not only depended on the readability of the robot's expression, but also on the timing of when the robot expressed emotions.

One of the issues found during Brezeal's study was that the human user initially found the conversation with Kismet problematic and interrupted him. However, after switching turns between the robot and human user 4-8 times, these interruptions stopped and the communication techniques in Table 3 became effective.

Cultural norms guiding what is considered to be proper eye contact are reported primarily based upon personal observations, not experimental data, though there may be data in the cultural anthropology literature (which was not examined). Cohen, Colburn, and Drucker state that Japanese subjects use more frequent yet shorter gazes than those in Australia (Cohen, 2000). Li further explains that the Japanese look at the neck level instead of the eye level (Li, 2004). In Nigeria, it is not socially acceptable for a person to look into the eye of an older person or person of higher status during conversation (Li, 2004). In the Chinese culture, no clear rules are set for eye gaze between equals. However, when speaking to a superior or parent, one should look down in order to show respect (Li 2004). Li also states that a study by Watson found that Asians, Indians, and Africans find constant gaze to mean one is superior, disrespectful, threatening, or insulting. However, Southern Europeans, Arabs, and Latin Americans relate lack of gaze as insincere, dishonest, or shy (Li, 2004).

WHAT SHOULD A ROBOT LOOK LIKE TO FACILITATE INTERACTION WITH A PERSON?

Heinzmann, Matsumato, and Zelinsky state that a human-friendly robot must have 2 main components: visual interfaces and safe mechanisms (Heinzmann 1999). The visual interfaces must allow for natural and easy interactions and can be created through items such as facial gestures (Heinzmann 1999). Safety systems must be implemented to ensure that people are never harmed by the physical hardware of the robot. The safety mechanisms of the hardware, which are a mechanical engineer's expertise, are out of the scope of this paper, and therefore only the visual interfaces will be examined.

So, what should human-friendly robot look like? How much should a robot look like a person? One answer to these questions is based upon the matching hypothesis that states that the appearance and social behavior of a robot should match the seriousness of the task and situation (Goetz, Kiesler, and Powers, 2003). To examine this hypothesis, Goetz, Kiesler and Powers presented 2-dimensional robotic heads with 3 levels of human likeness, defined by the researchers as: human, midstage, and machine. The robot heads were either male or female, although the gender of the robot was kept constant for each subject, with half of the subjects judging female robot heads and half of the subjects judging male robot heads (Figure 7).

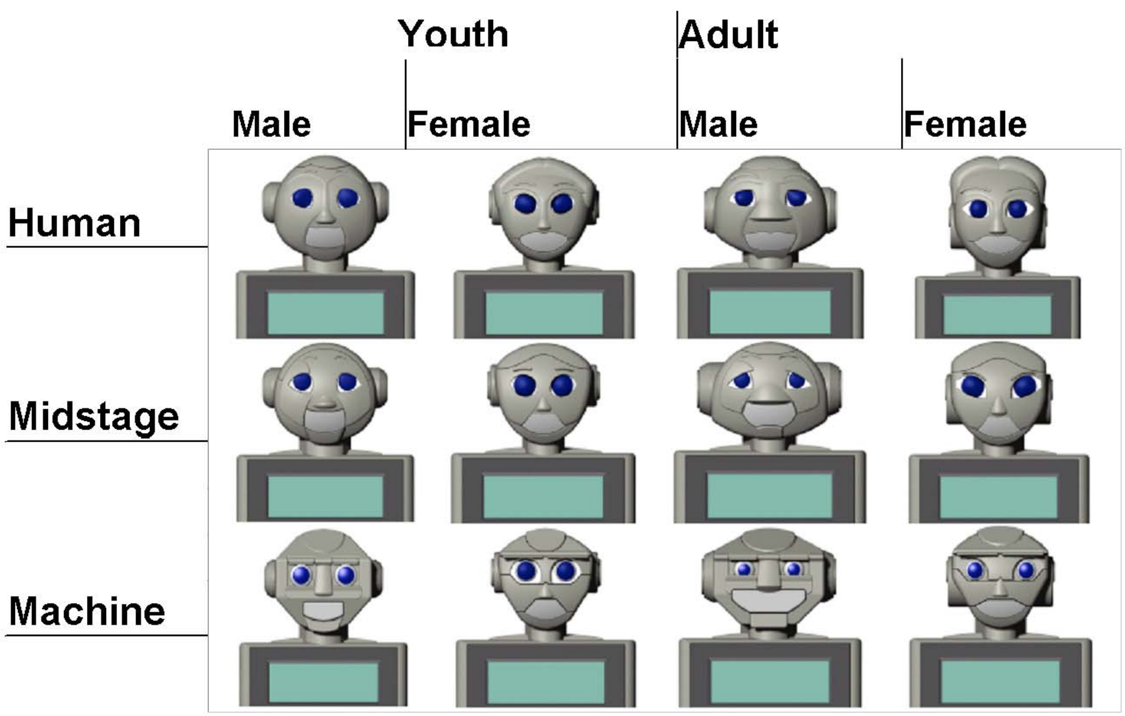

Figure 7. Robot Heads shown during Goetz, Kiesler, and Powers Study

In an online survey, 108 American college and graduate students (average age = 26 years old; 60% male) chose between 2 robots at a time, determining which robot would be suitable for specific jobs. The jobs were chosen from the Strong Campbell Interest Inventory, which categorizes jobs based on the interests of those who occupy them. According to the Strong-Campbell Interest Inventory, the 6 themes a person can be classified as are Realistic, Investigative, Artistic, Social, Enterprising, and Conventional (Table 5).

Table 5. Themes of Strong-Campbell Interest Inventory

Theme	Short Description	Common Occupations
Realistic	Like real, tangible things. Extreme examples are rugged, robust, practical, physically strong, and frequently aggressive in outlook; such people usually have good physical skills, but sometimes have trouble expressing themselves in words or in communicating their feelings to others. They enjoy driving large machines. They enjoy creating things with their hands.	Mechanic, construction worker, fish, wildlife management
Investigative	Includes science and scientific activities. Extremes of this type are task oriented; they are not particularly interested in working around other people. They enjoy solving abstract problems and feel a need to understand the physical world. They like ambiguous challenges, but not highly structured work.	Design engineer, biologist, social scientist, technical writer, meteorologist
Artistic	Like to work in artistic settings where there are many opportunities for self-expression. They have little interest in problems that are highly structured or that require gross physical effort. They describe themselves as independent, original, unconventional, expressive and tense.	Artist, author, cartoonist, composer, singer, dramatic coach
Social	Sociable, responsible, humanistic, and concerned with the welfare of others. They usually express themselves well and get along with other people. They like attention. They do not like working with machines or physical exertion. They like solving problems by discussions with others or by changing relationships with others. They describe themselves as cheerful, popular, good achievers.	School superintendent, clinical psychologist, high school teacher, speech therapist
Enterprising	Extreme types have a great facility with words, which they put to effective use in selling, dominating, and leading; frequently they are in sales. They see themselves as energetic, enthusiastic, adventurous, self-confident, and dominant. They like social tasks where they can take control. They don't like prolonged mental effort in solving problems. They like power, status, and material wealth, and working in expensive places.	Business executive, buyer, hotel manager, industrial relations consultant, political campaigner, realtor, television producer
Conventional	Extremes of this type prefer highly ordered (structured) activities, both verbal and numerical, that characterize office work. They fit well into large organizations but do not seek leadership. They like to work in a well-established chain of command. They dislike ambiguity, preferring to know exactly what is expected of them. They value material possessions and status.	Bank examiner, bookkeeper, some accounting jobs, financial analyst, tax expert, statistician, traffic controller

Source: http://luna.cas.usf.edu/~mbrannic/files/tnm/svib.htm

The results showed that when shown female robots, participants preferred the human-like robot for most jobs in the Artistic, Enterprise, Conventional, and Social themes. However, a machine-like robot was preferred for Investigative and Realistic themes. Although not quite as strong, these patterns were true for the masculine robots as well. This study shows that the human-likeness of the machine should match the tasks it is expected to perform.

The PIVO 2 robot is primarily intended to aid the user in driving tasks. However, the robot is also intended to enhance driver comfort, which may lead to providing the robot with new capabilities not currently found in motor vehicles, in particular being social. ("I am lonely. I think I will talk to the robot in my car."). Although most people would now consider such behavior as bizarre, who knows what the future holds? However, there have been cars that converse on TV (e.g., KITT in Knight Rider (http://en.wikipedia.org/wiki/KITT, retrieved May 17, 2009)), people sometimes give their cars pet names (http://forums.motortrend.com/70/1017480/the-general-forum/whats-your-cars-pet-name/index.html, retrieved May 17, 2009), and some think of their cars as having a personality. Having a robot conversation partner might be useful in a solitary drive late at night, when most people are asleep. For this purpose, a robot with a human-like appearance is desired. Such an appearance may have other benefits, such as enhancing the perceived friendliness of a robot, as is discussed later.

When creating a robot with human-like attributes, developers must be aware of the uncanny valley, first described by Mori (1970). He proposed that as a robot is designed to have a more human-like appearance and motion, the human emotional response will be positive until a certain point beyond which the response quickly turns to repulsion due to the robot looking very human-like but behaving as a robot. This effect can be seen in the translated version of Mori's uncanny valley diagram in Figure 8 (DiSalvo, Gemperle, Forlizzi, and Kiesler, 2002).

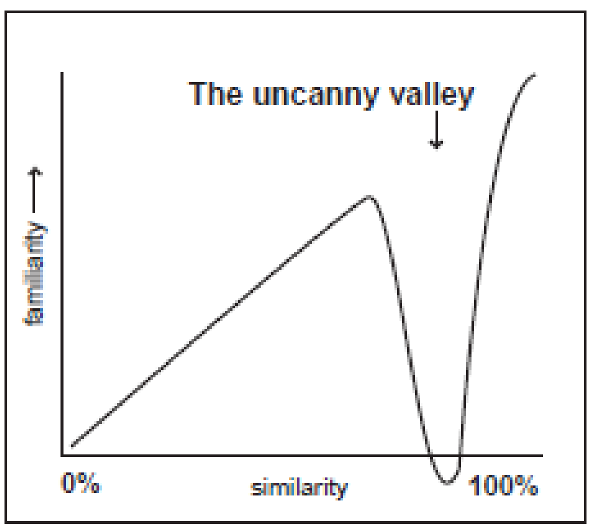

Figure 8. Mori's Uncanny Valley, adapted from Reichard 1978

DiSalvo, Gemperle, Forlizzi, and Kiesler (2002) provide some context. They had 40 participants complete one of two surveys. Each survey contained photos of 24 of 48 robot heads

(Figure 9), which participants rated individually on a scale from 1 (not very human like) to 5 (very human like).

Each of the robot head pictures was looked at for the presence of eyes, ears, nose, mouth, eyelids, and eyebrows, along with the total number of features on the robot head. The study found that none of the facial features were individually significant in a person's perception of the humanness of the robot head. However, the total number of features on the robot's head and the width of the head were found to be significant. Further, the robots with wider heads (compared to the height of the head) were found to be less human-like.

Figure 9. Examples of robot heads in DiSolvo's study

Kiesler and Powers (2006) specifically considered how the forehead and chin dimensions affected the subject's impressions of the sociability of the robot. Via a website, 98 participants (all over the age of 18) watched two short videos of a robot in which the robot gave the subject general health advice about liquid intake, exercise, and body mass index. Each participant saw one of the 4 robots and heard 1 of the 4 voices created for the study. The 4 robot heads varied due to different chin and forehead dimensions (Figure 10). The 4 voices consisted of 1 male voice, 1 female voice, and 2 childlike and more gender-neutral voices.

Figure 10. Four robot heads used by Kiesler and Powers (2006)

The subjects then completed a post-experiment survey, which contained 34 Likert-type items that were combined into 6 scales (Table 6).

Table 6. Scales and Items from Kiesler and Powers (2006)

Scale	Items
Sociability	Cheerfulness, friendliness, warmth, happiness, likable, sympathy, compassionate, gentle, tender, emotion, attractiveness
Knowledge	Competence, knowledge, intelligence, expert, reliability, usefulness, trustworthiness, likable
Dominance	Strong personality, assertive, dominant, dominance, power
Humanlikeness	Natural, humanlike, like a human, lifelike, moves like a human, has a mind
Masculinity	Masculine, manlike, not womanlike
Machinelikeness	Machinelike

They found that the forehead dimension did not significantly affect whether the subject took the robot's health advice, and therefore this variable was dropped from all remaining statistical analysis. However, they did find that 100% of the subjects who listened to a robot with a short chin and a male voice would take the robot's advice. When the chin was long and the robot had a male voice, or when the chin was short and the voice was female, 91% of the subjects said they would take the robot's advice. The child voices lowered these percentages to 55%. However, the robot that convinced the fewest number of subjects to take its health advice (only 50% of subjects) was the robot with a long chin and a female's voice.

The second aspect examined was why the subject was taking the robot's advice. Figure 11 shows the summary of their analysis of how physical features (the chin dimension and voice) lead to impressions that lead the user to follow the robot's advice. The negative sign next to an arrow shows a negative association between the two connected variables. They found that the greater the robot's knowledge and sociability, the more likely the participant was to take the robot's advice. They also found that male voices, humanlike robots, and short chins lead people to think a robot is knowledgeable and sociable.

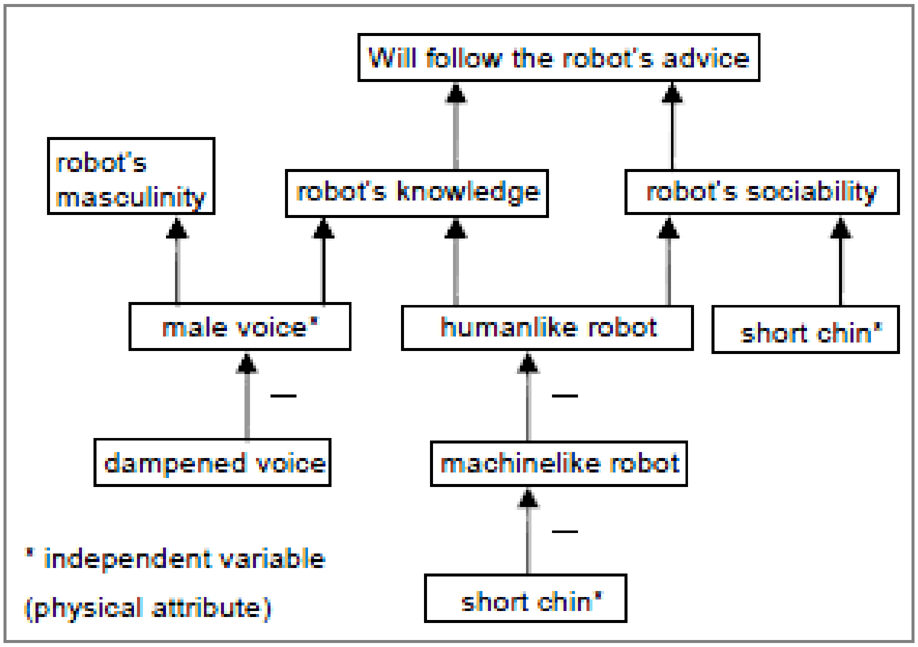

Figure 11. Summary of Kiesler and Power's analysis

HOW SHOULD A ROBOT BEHAVE TO FACILITATE INTERACTION WITH A PERSON?

Before discussing how the PIVO 2 robot should behave with the user, a method for how to measure these interactions must be posed. Daily and Picard suggest that behavior-based methods (that measure bodily movements and/or physiological signals) be used when measuring affective interactions. Due to a lack of time, these methods are not addressed further but can be found in their paper (Daily and Picard, 2005).

Boekhorst, Dautenhah, Koay, Syrdal, and Walters (2007) had 79 undergraduate students complete a questionnaire after watching three videos, 1 of a mechanical robot, 1 of a basic robot, and 1 of a humanoid robot, all attracting the attention of a person (Figure 12).

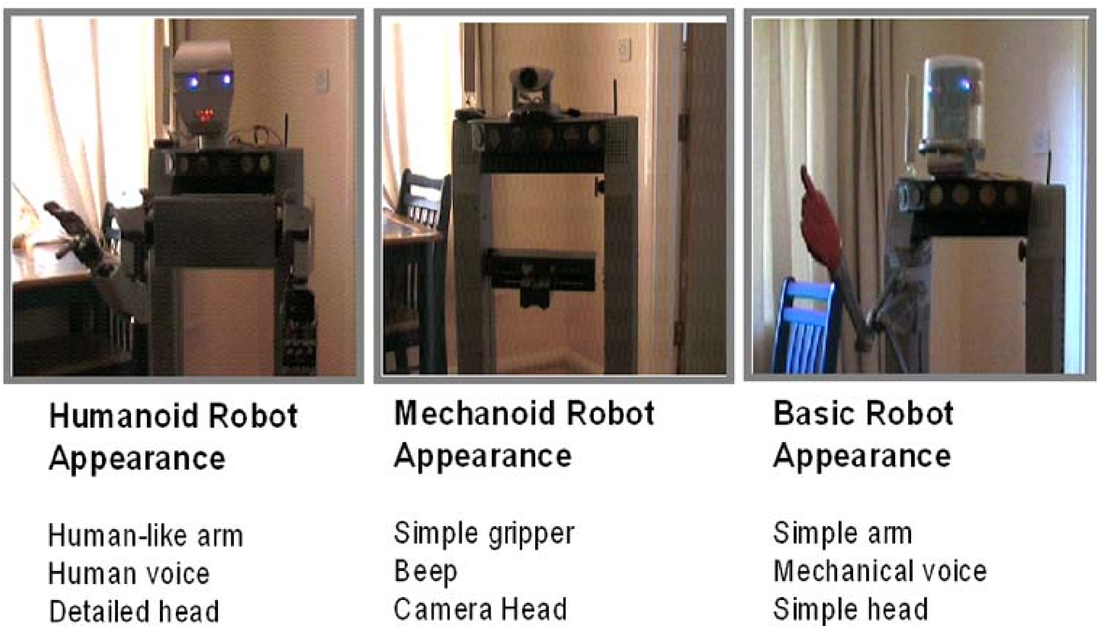

Figure 12. Boekhorst, Dautenhah, Koay, Syrdal, and Walters' Robots

The questionnaire focused on the perceived personality behaviors of the robot. The personality of the robot was specified by 5 items (Table 7), all ranked by the subjects on a 5-point Likert scale ranging from 1 (not at all) to 5 (very). Only agreeableness, extraversion, and intellect were significantly different among the 3 robot appearances.

Table 7. Robot Personality Items

Personality Item	Question	Robot		
		Mechanical	Basic	Humanoid
Emotional Stability	How relaxed and content, or stressed and easily upset was the robot?	3.22	3.33	3.57
Extroversion	How extroverted/introverted was the robot?	2.35	3.08	3.72
Agreeableness	How interested/disinterested in people was the robot?	2.47	3.22	3.75
Conscientiousness	How organized and committed or disorganized/uncommitted was the robot?	3.23	3.45	3.75
Intellect/Openness to Experience	How intelligent or unintelligent was the robot during its tasks?	2.89	3.24	3.67

HOW DOES ACCEPTANCE OF ROBOTS VARY WITH THE USER'S CULTURE AND AGE?

Three main questions are asked in order to help address this question:

- What attitudes do people have toward robots and new technology?
- Are there cultural differences that affect the user's perception of the robot?
- How does the user's age affect his or her perception of the robot?

What Attitudes Do People Have toward Robots and New Technology?

As it is a new idea, no research was found concerning acceptance of robots as driving aids. However, acceptance of a robotic personal driving assistant may be related to general acceptance of new technology. Fornara, Giuliani, and Scopelliti (2005) examined people's attitudes toward new technology. They surveyed 120 subjects (young (age 18-25), middle aged (age 40-50), and elderly (age 65-75)). The questionnaire considered, among other issues, the following 3 topics:

- Attitudes toward technology
- Thoughts on the capabilities of robots
- Emotional response to robots

To determine the subject's attitudes toward technology, statements were presented regarding the characteristics, advantages, and disadvantages of new technology. Table 8 shows the topics examined and statements presented.

Table 8. Factors Analyzed for Attitudes toward Technology

Topic	Statement
Benefit of technology	You don't get tired
	You can perform a lot of activities
	You don't waste your time
	You are not dependant on others
	You have to pay a fair price
	They are easy to use
Disadvantages of technology	They break down too often
	Instructions are difficult to understand
	You forget how to do things yourself
Mistrust	I do not trust
	I am not stimulated
	You become dependant

After analysis of these questions, it was found that with a mean score of 3.11 (on a Likert scale of 0 = "I completely disagree" to 4 = "I completely agree") -- generally attitudes toward new technologies were positive. There were no statistically significant differences between age groups. A factor analysis found that 23.6% of the variance was explained by the "benefits of technology," 13.1% by the "disadvantages of technology," and 10.2% by "mistrust." In general, the elderly were significantly more likely than young people to think robots are more complicated to use. Also, the elderly felt that technology gives them independence from others significantly more often than younger people and adults felt. Finally, older people mistrust technology significantly more than young people and adults do.

In the second section, regarding people's thoughts on robot capabilities, the participants were asked questions about the capability of robots to perform everyday activities in the home, such as cooking. The subjects were then asked to rate each activity as either "impossible to implement," "probably available in the future," or "currently available." The results showed that people perceived object manipulation such as cleaning windows, making beds, or dusting to be much easier to accomplish than it truly is. However, the subjects underestimated the robots ability to complete cognitive tasks such as entertainment and home safety control. The participants were correct in their assumption of the difficulty of tasks such as cooking or cutting the subject's nails.

Section 3, which examined the emotional response to robots, included 16 questions on a 5-point Likert scale focused on emotional response to domestic robots. Positive feelings were defined when a robot was perceived as lively, dynamic, interesting, stimulating, pleasant, and amusing; while negative feelings were defined when robots were perceived as dangerous, scary, potentially out of control, cumbersome, or overwhelming (Table 9).

Table 9. Factors Analyzed for Emotional Response

Feelings	Characteristic
Positive	Interesting
	Lively
	Amusing
	Dynamic
	Stimulating
	Pleasant
	Useful
	Relaxing
Negative	Worrying
	Scaring
	Depressing
	Dangerous
	Out of control
	Embarrassing
	Overwhelming

The extent to which there were positive or negative feelings significantly varied with age, with young people having a more positive emotional reaction to robots than the elderly.

Are There Cultural Differences That Affect the User's Perception of the Robot?

More than 40 studies have shown that different cultures, both those exposed to mass media and those of isolated, preliterate cultures, associate the same facial expressions with particular emotions (Ekman, 1979). Unfortunately, most accounts of cultural variability are qualitative studies made by single observers who did not account for observer or sampling bias (Ekman 1979).

One way to quantify human attitudes toward robots is by using NARS (Negative Attitudes Towards Robots Scale). The validity of this scale was tested by Nomura, Kanda, and Suzuki in 2004 (Bartneck, 2005). This scale asks questions associated with the items seen in Table 10 (Kanda, Kato, Nomura, and Suzuki 2008).

Table 10. Questionnaire Items Associated with NARS (*=Reverse Coded Item)

Subscale	Item
S1: Negative Attitude toward Interaction with Robots	I would feel uneasy if I were given a job where I had to use robots.
	The word "robot" means nothing to me.
	I would feel nervous operating a robot in front of other people.
	I would hate the idea that robots or artificial intelligences were making judgments about things.
	I would feel very nervous just standing in front of a robot.
	I would feel paranoid talking with a robot.
S2: Negative Attitude toward Social Influence of Robots	I would feel uneasy if robots really had emotions.
	Something bad might happen if robots developed into living beings.
	I feel that if I depend on robots too much, something bad might happen.
	I am concerned that robots would be a bad influence on children.
	I feel that in the future society will be dominated by robots.
S3: Negative Attitude toward Emotional Interactions with Robots	I would feel relaxed talking with robots. *
	If robots had emotions, I would be able to make friends with them. *
	I feel comforted being with robots that have emotions. *

Using the NARS scale, Kanda, Kato, Nomura, and Suzuki (2005) surveyed 106 people to determine if Japanese people like robots more than people of other nations do. They found that the 53 Japanese subjects had more negative attitudes toward the social influences of robots than that of either the Chinese (N=19) or the Dutch (N=24) subjects. Further, the study found that the NARS scale should be used in the future to correctly gauge a culture's perception of robots (Kanda, Kato, Nomura, Suzuki, 2005).

Bartneck, Kanda, Kato, Nomura, and Suzuki (2005) also examined cultural differences between nations using NARS. Their study focused on the Dutch (N=28), Chinese (N=20), German (N=69), Mexican (N=16), American (N=22) and Japanese (N=53). Each subject completed a questionnaire consisting of 14 questions on a 5-point scale divided into 3 groups:

- Attitude toward the interaction with robots (interact) (e.g. I would feel relaxed talking with robots)
- Attitude toward social influence of robots (social) (e.g. I am concerned that robots would have a bad influence on my children)

- Attitudes toward emotions in interaction with robots (emotion) (e.g. I would feel uneasy if robots really had emotions)

They found that the Americans were the least negative toward robots (particularly with interacting with them), while Mexicans were the most negative toward robots (particularly with interacting with them) (Figure 13).

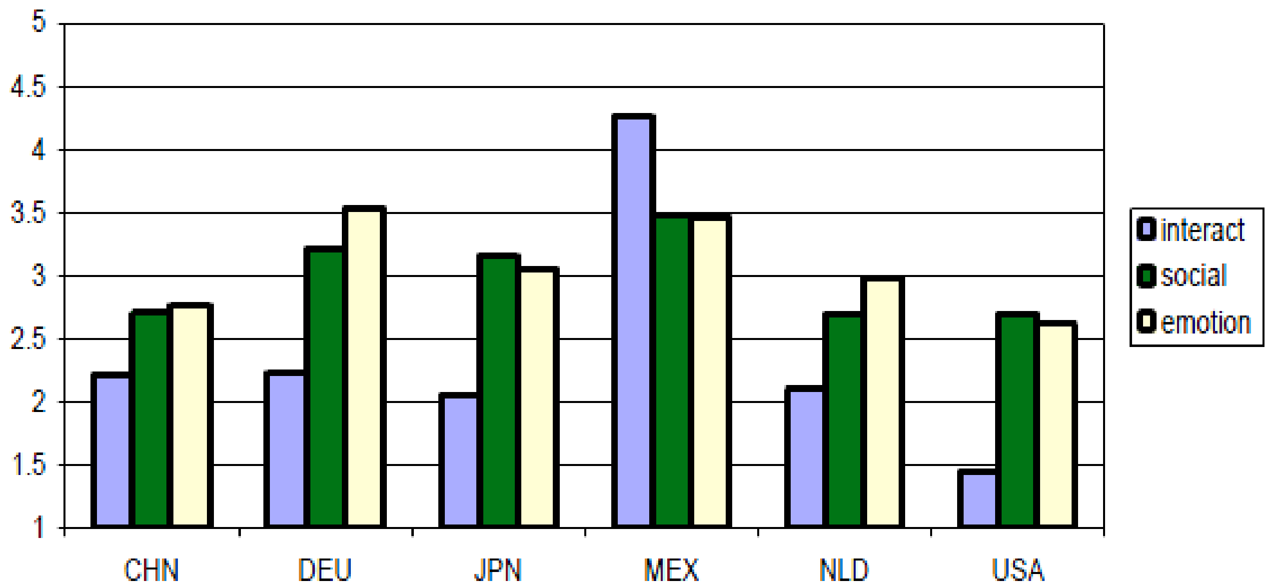

Figure 13. Means of Nationalities Based on the 5-point scale

How Does the User's Age Affect His or Her Perception of the Robot?

Fornara, Giuliani, and Scopelliti (2005) noted the differences between the young, adults, and elderly's openness to using robots. As a whole, elderly people are less confident about the potential of technology to perform cognitive tasks. For example, 60% of elderly people (average age 76 years old) thought that devices exist that can remind users of appointments, while 87% of younger people (average age 24 years old) and adults (average age 54 years old) believed this to be true. The elderly also underestimated the technological ability to create a card-playing robot, while young people (and even more so adults) were more confident in today's technological advances. When differences are looked at between young people and adults, adults seem to be more precise on the abilities of current technology than that of young people.

In terms of a household robot, the majority of young people (72%) would feel safe with a robot performing tasks while wandering freely throughout their house. However, only a small amount of adults (19%) and even fewer elderly people (10%) would be comfortable with a robot performing tasks around the house.

Further, young people were found to want a robot that is lively with humanoid characteristics that are friendly and warm. Specifically, 77% of young people want to personalize the robot, 62% wish it to be smiling and funny, and 90% would like it to speak as a person. The elderly are on the opposite side of this scale, as they prefer slow motion (55%) and simple and slow motions (50%). As may be expected, the adults were the least homogenous group with respect to the physical features or modes of interaction with the robot.

CONCLUSIONS

How can a robot communicate with a driver?

One of the ways the PIVO 2 robot communicates with the driver is through speech. Following Navtone's design of allowing drivers to pick not only a voice and a personality that accompanies the voice, the authors suggest that multiple personalities and genders be provided to the PIVO 2 users. However, if a single voice is chosen for the PIVO 2 robot, the authors suggest that a female voice be provided, consistent with Beukelman, Mirenda, and Eicher (1988) findings that women desire female voices while men are less particular about the gender of the synthesized speech. However, conflicting with this is the finding that people are more likely to follow the advice of a male voice, which is important for warnings and navigation. Potentially, a robot with multiple voices and multiple personalities would be confusing to drivers.

A second form of communication for the PIVO 2 robot is non-verbal communication. To identify the 8 distinct facial expressions (anger, sadness, fear, surprise, disgust, contempt, happiness), Ekman's FACS system should be utilized (Ekman, Friesen, and Hager, 2002). While these expressions will help the PIVO 2 robot communicate emotions, eye contact should be used to help communicate whose turn it is to speak (either the robot or the driver). However, for the communication and turn-taking to be performed smoothly, the driver must overcome the initial confusion of communicating with the PIVO 2 robot. Brezeal (2003) suggests that after 4-8 speaking turns, the driver's conversation with the robot will be smooth with few interruptions. To overcome this initial confusion period, the authors suggest the PIVO 2 robot have a setup assistant that requires the driver to have a short conversation with the robot.

What should a robot look like to facilitate interaction with a person?

In designing a robot, it is very important to avoid the uncanny valley phenomenon, whereby making a robot more human-like is appealing up to a certain point, beyond which the response quickly turns to repulsion due to the robot looking very human-like but behaving as a robot.

DiSalvo, Gemperle, Forlizzi, and Kiesler (2002) found 6 design characteristics of the physical design that significantly affected user response and were important in creating a humanoid robot that does not enter Mori's uncanny valley.

1. The robot's head should be slightly wider than it is tall and the eye space should be slightly wider than the diameter of the eye.
2. The feature set (defined as the length from the brow line to the bottom of the mouth) should dominate the face. This means that less space should be set aside for the forehead, hair, jaw, and/or chin. Since this is in contrast to a human's head, it will help identify the robot as being robot-like (as to not be too human-like and enter the uncanny valley).
3. In order to create human-like eyes, there should be complexity in the surface detail, shape of the eye, eyeball, iris, and pupil.
4. The robot head should include four or more features. Three of these features are suggested to be a nose, mouth, and eyelids.
5. A skin or casing (which can be made of hard or soft materials) should be implemented on the robot in order for the robot to appear finished.
6. The head shape should be organic and should have complex curves in the forehead, back head, and cheek areas in order to create a humanoid robot.

In addition, Kiesler and Powers (2006) suggest a few more design criteria to create a human friendly robot. Specifically, they suggest that the robot should be seen as knowledgeable and sociable. Further, they suggest that a short chin and male voice can help create a humanlike robot. Although their study does not give specific measurements for a chin that they classify as "short," the measurements can be extrapolated from the pictures of the robot heads seen in their report.

How should a robot behave to facilitate interaction with a person?

Because the driver's emotional response to a robot affects its acceptance, determining perception of the robot's personality is important. Boekhorst, Dautenhah, Koay, Syrdal, and Walters (2007) propose a method for that purpose that should be considered for evaluations of driving robots. Table 11 shows the values they suggest are required for a robot to be considered humanoid.

Table 11. Robot Personality Items

Personality Item	Question	Humanoid Robot
Emotional Stability	How relaxed and content, or stressed and easily upset was the robot?	3.57
Extroversion	How extroverted/introverted was the robot?	3.72
Agreeableness	How interested/disinterested in people was the robot?	3.75
Conscientiousness	How organized and committed or disorganized/uncommitted was the robot?	3.75
Intellect/Openness to Experience	How intelligent or unintelligent was the robot during its tasks?	3.67

How does acceptance of robots vary with the user's culture and age?

Research on this topic is just beginning. So far, some simple truisms seem to be verified, for example that younger people are more accepting of new technology than older people. However, it is uncertain how this will translate into acceptance of a driving robot.

There has been some research on acceptance of robots by people from various countries and cultures, in particular using NARS (Negative Attitudes Towards Robots Scale, Kanda, Kato, Nomura, and Suzuki, 2005). The folklore is that the Japanese are the most accepting of robots, but the research seems to suggest otherwise. It may be that there is an interaction between the purpose or task assigned to the robot and its acceptance by a group. Understanding this is important when assessing the markets and market segments to which a driving robot is most suited.

Using a robot to assist with driving is a very novel idea, one for which there is limited research in the driving literature, though many useful cues from the literature on robotics, affective computing, and other fields. These are not topics that have traditionally been explored by human factors professionals but have developed to the point where application is now appropriate.

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