Non-Facial/Non-Verbal Methods of Affective Expression as Applied to Robot-Assisted Victim Assessment

Cindy L. Bethel, Robin R. Murphy
Institute for Safety, Security, and Rescue Technology
University of South Florida
4202 E. Fowler Ave., ENB118
Tampa, FL 33620
clb1526@yahoo.com, murphy@cse.usf.edu

ABSTRACT

This work applies a previously developed set of heuristics for determining when to use non-facial/non-verbal methods of affective expression to the domain of a robot being used for victim assessment in the aftermath of a disaster. Robot-assisted victim assessment places a robot approximately three meters or less from a victim, and the path of the robot traverses three proximity zones (*intimate* (contact – 0.46 m), *personal* (0.46 – 1.22 m), and *social* (1.22 – 3.66 m)). Robot- and victim-eye views of an Inuktun robot were collected as it followed a path around the victim. The path was derived from observations of a prior robot-assisted medical reachback study. The victim's-eye views of the robot from seven points of interest on the path illustrate the appropriateness of each of the five primary non-facial/non-verbal methods of affective expression: (*body movement*, *posture*, *orientation*, *illuminated color*, and *sound*), offering support for the heuristics as a design aid. In addition to supporting the heuristics, the investigation identified three open research questions on acceptable motions and impact of the surroundings on robot affect.

Categories and Subject Descriptors

I.2.9 [**Artificial Intelligence**]: Robotics; I.2.0 [**Artificial Intelligence**]: General—*Cognitive Simulation*; J.4 [**Social and Behavioral Sciences**]: Psychology

General Terms

Design, Verification, Human Factors, Experimentation

Keywords

Human-Robot Interaction, Affective Computing, Robotic Design Guidelines, Non-verbal Communication, Proxemics

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1. INTRODUCTION

In a world where disasters appear to be more prevalent, either from terrorists' activities or natural causes, there is an increasing need for the use of search and rescue robots to socially interact with survivors and to act as a virtual presence for emergency responders and medical personnel. There are two main capacities in which these robots have been utilized: (1) to locate victims, and (2) to assess structural damage [10]. These robots provide a virtual presence for support teams and medical personnel located outside of the disaster site [10]. When a victim is located in a disaster site, the robot will be used as a surrogate presence for physicians and medical personnel to perform an initial medical assessment of the victim's condition and to continually monitor the victim's medical status until assistance can arrive (typically 4-10 hours after the victim is located) [15], [18]. In this type of application, the robot must interact with both the victim and the operators. The operators are able to capture images of the victim through on-board cameras as well as communicate with victims using on-board two-way audio. Additionally, the operators work with the medical professionals so that they may interact with the victims through the use of the robot. Under these conditions, the robot is both a team member of the emergency response team in addition to a social agent that must interact with the victim and keep them calm until assistance can reach them for extrication.

After a victim is located, the primary goal of social interaction between the robot and the victim is to keep them calm through the appropriate use of non-facial/non-verbal methods of affective expression. As a part of this social interaction it is necessary to determine the victim's medical status through robot-assisted medical reachback assessments. Social interaction between the search and rescue robot and the victim should include a multi-modal approach for affective expression, as suggested in [2]. A study conducted by Murphy, Riddle, and Rasmussen identifies how the robot interacts with a victim as one of four open research areas [15]. Additionally, participants in the role of a simulated victim reported that the robots were "creepy" when interacting within a distance of three meters or less (See Figure 1) [15]. Search and rescue robots are *appearance-constrained* (*designed to be functional and lack expressive faces*) and must utilize other methods of social interaction and affective expression. In [2] there are five main methods of non-facial/non-verbal affective expression: *body movement*, *pos-*

ture, *orientation*, *illuminated color*, and *sound*. Additionally, the appropriateness of which method to use is dependent on the distance of the robot from the victim with which it is interacting (*proxemics*). From the psychology literature, there are four primary zones of social interaction: *intimate* (contact – 0.46 m), *personal* (0.46 – 1.22 m), *social* (1.22 – 3.66 m), and *public* (3.66 m and beyond) [1].

A set of design guidelines or heuristics was initially developed and presented in [2], refined in [4] a survey of related literature, and this work confirms the appropriateness of the refined heuristics. It was determined from video observations that the heuristics were perceptually significant at the predicted distances. The heuristics address the appropriateness of each of the five methods of non-facial/non-verbal affective expressions by proximity zone (see Figure 2). Inter-agent distances of three meters or less was used because most confined space searches occur within this distance, in addition to most social interactions in general [4]. A simulated victim medical assessment scenario was conducted that was developed for this research study (See Figure 3) from observations of two different medical assessment scenarios conducted by medical professionals in a study by Riddle *et al.* [18]. Confirmation of the heuristics was obtained through video observations of the medical assessment path from three viewpoints (robot-eye, victim-eye, and overview). Results from this verification study indicate that future human-robot interaction studies using these heuristics are viable.

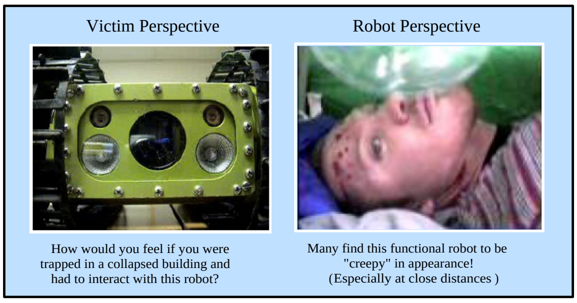

Figure 1: Inuktun robot appears "creepy" from the victim's perspective.

The paper begins with a brief overview of related work including a discussion of the refinements made to the table of heuristics displayed in Figure 2. Section 3 illustrates the suitability of the heuristics described in Figure 2 by examining a canonical robot-assisted medical reachback task where a robot interacts with a simulated disaster victim. The medical assessment path and robot movements, posture, and orientation were derived from observations of videotaped medical reachback assessments performed by emergency medical personnel in the Murphy *et al.* [15] and Riddle *et al.* [18] studies (See Figure 3). Additionally, this paper presents observations related to the non-facial/non-verbal methods of affective expression related to each proximity zone from both the robot's and victim's perspectives.

2. RELATED WORK

There have been limited research efforts in the robotics community to investigate non-facial/non-verbal methods of affective expression with respect to inter-agent distances for social interaction (*proxemics*). Pacchierotti *et al.* [16] [17] discuss that robots should utilize interaction patterns and social conventions similar to those used in human to human interactions. By using these interaction patterns in human-robot interactions, Pacchierotti *et al.* believe it will minimize any possible distress of the person interacting with a robot. Michaud *et al.* [12] discussed the importance of using multiple channels of interaction (sound, voice, lights, and movements) for interactions between their sphere-shaped robot and the children with which it interacts. Research has been conducted dealing with the use of robot movement to express affect, but social distance was not included [9], [11], [13], [14], [20]. Sound has been utilized as a redundant method of affective expression, but the appropriateness of sound based on proxemics was not addressed [6], [9], [19]. Sound has not been investigated as a primary method of affective expression.

Robot body movement has been used to express affect in five robot implementations of interest [9], [11], [13], [14], [20]. El-Nasr and Skubic discuss the use of movement of their mobile robot to express anger (movement in circles), pain (jerky motions), and fear (shaking motion), but do not consider proxemics in their study [9]. Maeda uses body movement of a Khepera mobile robot to express the emotions of joy (innocent wandering around the light source increasing to fast, cyclic motion), anger (fast movement, rushing the light source), and sadness (moves slowly away from the light source and as intensity increases the body will vibrate) in relationship to a light source in a laboratory setting [11]. In research conducted by Mizoguchi *et al.* their mobile robot uses different ballet-like postures, and patterns of movement to display affect in a laboratory setting [13]. Moshkina and Arkin use body movement (tail movement/position, ear position, and body position) to display the emotions of interest, joy, anger, and fear using a Sony Aibo robot [14]. A tank-like robot expresses affect using direction and speed

Appropriateness of Non-Facial and Non-Verbal Affective Expressions by Proximity Zones			
Affective Expression Non-Facial and Non-Verbal	Proximity Zones (Based on Argyle, 1975)		
	Intimate (contact - 0.46 m)	Personal (0.46 - 1.22 m)	Social (1.22 - 3.66 m)
Body Movement	Full body not visible at this distance	Small to medium movements	Large or exaggerated movements
Posture	Full body not visible at this distance	Postures visible at this distance	Exaggerated postures visible at this distance
Orientation	Orientation visible at this distance	Orientation visible at this distance	Orientation visible at this distance
Illuminated Color	Low intensity, dependant on small size to be visible	Medium to bright intensity	Bright intensity
Sound	Low to medium volume	Medium to loud volume, dependant on background and environmental noise	Not audible, due to background and environmental noise

Legend: Appropriate at this Distance; May be Appropriate at this Distance; Not Appropriate at this Distance

Figure 2: Appropriateness of Non-Facial/Non-Verbal Affective Expressions by Promity Zone

of movement, pan/tilt of a camera, and frequency of stopping and starting in research conducted by Shimokawa and Sawaragi [20]. All of these studies were conducted in relatively unconstrained laboratory environments and did not evaluate the appropriateness of these movements in different distance zones between the robot and agent with which it was interacting.

The use of sounds, tones, and/or music has been investigated in three robotic implementations of interest [6], [9], [19]. Kismet, a robot developed by Cynthia Breazeal, uses child-like utterances to reinforce its affective facial expressions [6]. In research conducted by El-Nasr and Skubic [9], their mobile robot makes a crying sound to express pain, a shattering voice to express fear, and an unspecified noise to convey anger. These sounds were used as reinforcement to robot movements for affective expression. Scheeff *et al.* use a sound similar to muffled human speech combined with a french horn to reinforce the emotional state of their mobile robot Sparky [19]. These sounds fall in a range between the beeps/chirps of R2-D2 from "Star Wars" and a human voice; however participants interacting with Sparky found these sounds to be confusing and unappealing. In all of these studies, the sounds were conveyed in a laboratory setting with relatively ideal conditions. The appropriateness of the use of sound under these conditions was not really evaluated, nor was proximity considered as part of these studies. In each of these implementations, sound was used for redundancy purposes and not as a primary method of affective expression.

The heuristics presented in Figure 2 extend and refine the recommendations made in [2], by providing more specific design guidelines for which non-facial/non-verbal methods of affective expression are appropriate by each of the three proximity zones [4]. In the original table of heuristics the entries were generalized to *"Yes"*, *"No"*, and *"Maybe"* which were not very descriptive [2]. The refined table gives descriptive guidelines for each method of expression by proximity zone in addition to the level of appropriateness of use in each zone [4]. The refinements provide not only the level of appropriateness of use, they give specific guidelines that are useful to robot designers.

The appropriateness of body movement, posture, and orientation is dependent on robot visibility and inter-agent distances. In the original table, entries indicate if the method of expression was appropriate to use or not; however in the refined table, these entries have specific recommendations for use. For example, in the *intimate* zone, the full body of the robot is not visible; therefore body movement and posture would not be an appropriate method of affective expression because the expressions would not be interpretable due to visibility. If some portion of the robot is visible, then the orientation of the robot would be visible and appropriate in this zone. In the original table, entries for body movement, posture, and orientation were marked "Yes" in the *personal* zone indicating appropriateness of use. This is not very helpful to robotic designers; therefore the table entries were refined to give more appropriate recommendations. At these inter-agent distances small to medium body movements, postures, and orientation are all observable; therefore they would all be appropriate for use in the *personal* proximity zone. In the *social* distance zone, only large or exaggerated body movements and postures would be observable indicating they are appropriate methods of affective expression in this zone. It is important to be more specific regarding these recommendations because through initial investigation it was determined that small movements such as a camera face tilt of an Inuktun robot was not clearly visible at this distance. Orientation of the robot is visible at this distance and is marked as being appropriate for use in this distance zone [2], [4].

The entries for the appropriateness of color as a method of affective expression were modified from the original table to account for the use of illuminated color and its intensity level [2], [4]. The original entries of "Maybe" and "Yes" did not provide adequate information to designers that may use these recommendations [2]. The refined entries indicate that illuminated color, with low intensity and small size, may be appropriate for use in the *intimate* zone. In the *personal* zone, the illuminated color would need to be medium to bright intensity to be visible and appropriate for use. Bright intensity illuminated color would be required to be visible and appropriate for use in the *social* distance zone.

The appropriateness of the use of sound as a non-facial/non-verbal method of affective expression is dependent on inter-agent distances, volume, and environmental noise levels [2], [4]. The original table entries of "Yes" for sound in the *intimate* zone, "Maybe" in the *personal* zone, and "No" in the *social* zone did not provide adequate information on appropriate use. The refined heuristics clarify the appropriateness of use of sounds, tones, and/or music in each of the three proximity zones of interest [3], [4]. In the *intimate* zone – sounds, tones, and/or music would be appropriate if the volume is low to medium volume. Medium to loud volume is needed for sounds, tones, and/or music to be appropriate in the *personal* distance zone; however it is dependent on the background environmental noise levels. In the *social* distance zone, sound is not audible; therefore it is not an appropriate method to express affect in this zone [3], [4].

3. MEDICAL ASSESSMENT PATH

The details of a robot-assisted medical assessment reachback task (illustrated in Figure 3); robot-eye and victim-eye views at seven points of interest for the task; and the suitability of four of the the five non-facial/non-verbal methods of affective expression in each of the three proximity zones traversed by the robot are the focus of this heuristics verification study. Observations of the robot-eye and victim-eye views at each of the seven points of interest by proximity zone are presented. The appropriateness of use of illuminated color by proximity zone was not investigated in this research study.

3.1 Medical Assessment Path

The robot-assisted medical assessment path depicted in Figure 3, robot movements, postures, and orientation was derived from observations of two videotaped studies conducted by Murphy *et al.* [15] and Riddle *et al.* [18]. During those two studies, medical personnel directed the robot operators regarding the movements, locations, and orientation of the robot with respect to the victim. The positions shown in Figure 3 were literal in terms of the robot's distance from the victim. These positions were key positions for medical assessment; however they naturally coincided with the proximity zones displayed in Figure 3.

Figure 3 contains seven key points of interest in which the robot must perform specific tasks related to victim location

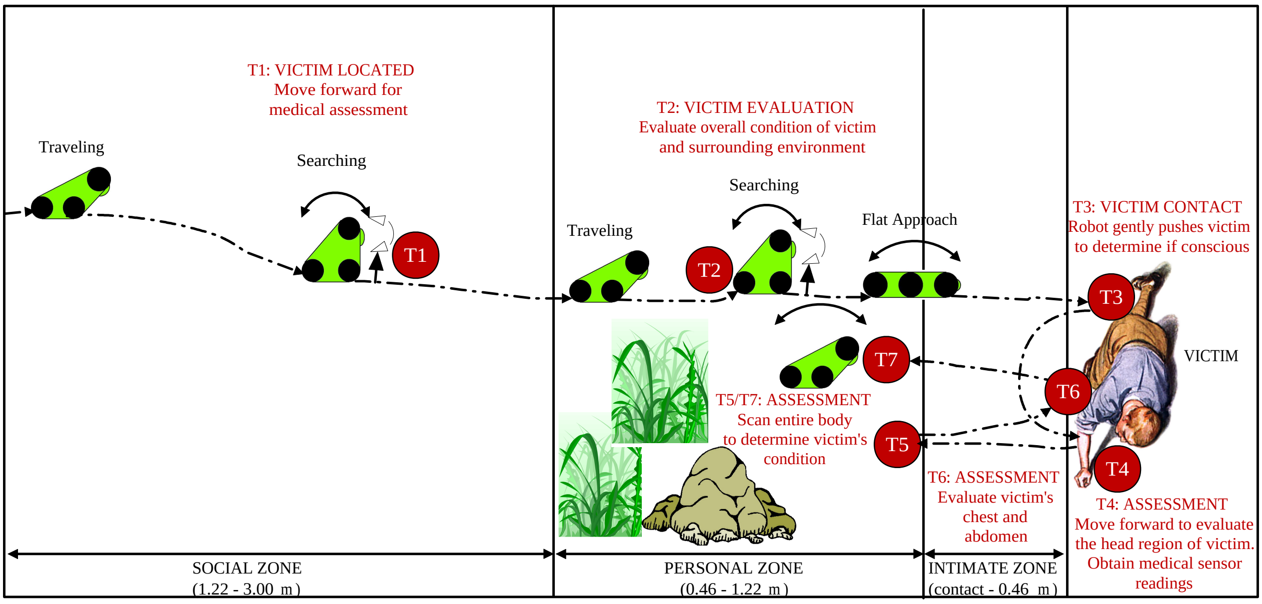

Figure 3: Diagram of the medical assessment path taken by the Inuktun robot in relation to the simulated disaster victim.

and medical assessment.

- T1 (*social* zone) – Robot locates the victim, raises to full height, rotates side-to-side, and tilts the camera face up/down, to survey the area surrounding the victim.

- T2 (*personal* zone) – Robot performs a preliminary medical assessment of the victim and surrounding environment. The robot performs the same sequence of movements that occurred at T1. After completion of the preliminary medical and environmental assessment, the robot lowers to a flat position and moves to point T3 of Figure 3.

- T3 (*intimate* zone) – Robot gently pushes the victim in the foot region to determine if the victim is reactive and conscious.

- T4 (*intimate* zone) – Robot moves to the head region of the victim to obtain medical sensor readings and to determine if the victim is breathing. This is the most intimidating position the robot can be located in relation to the victim (See Figure 9). The robot only stays in this position long enough to obtain the necessary data.

- T5 (*personal* zone) – Robot moves backward into the *personal* zone to survey the overall condition of the victim and the surrounding environment. The robot performs the same motion sequences performed at point T1.

- T6 (*intimate* zone) – Robot moves into the *intimate* zone to the victim's chest and upper abdominal region. The robot focuses on the chest area to determine if the victim has any visible injuries and determine whether the victim has chest movement indicative of breathing.

- T7 (*personal* zone) – Robot moves backward into the *personal* zone to point T7, where it performs another overall victim status assessment similar to point T5. Points T5 and T7 are comfortable locations for continued social interaction and victim monitoring.

3.2 Social Proximity Zone

Robot activities in the *social* zone mainly involve searching, possible victim location, and general structural assessment. Interaction with a victim at this distance is limited; however the victim may be able to see the robot and needs to feel comfortable with it approaching for assessment. Observations at point T1 on Figure 3 indicate that the victim is able to see the robot, what position it is in, large back and forth rotational movements, translational motion, and orientation which is consistent with the heuristics described in the *social* section of Figure 2.

Smaller movements of the robot such as the tilting motion of the camera face are less visible at this distance. Additionally, from the robot perspective at point T1, the robot is able to detect the victim; however it is not able to determine the medical condition of the victim at this distance. Figure 4 presents photos of the victim from the robot perspective in addition to the visibility of the robot from the victim's perspective.

3.3 Personal Proximity Zone

The *personal* proximity zone is appropriate for human-robot social interaction, assessing and monitoring the overall condition of the victim's body, in addition to determining the structural integrity of the environment surrounding the victim. The robot is capable of viewing the entire length of the victim's body, performing a preliminary assessment of injuries, and determine the stability of the structures surrounding the victim at point T2 from Figure 3.

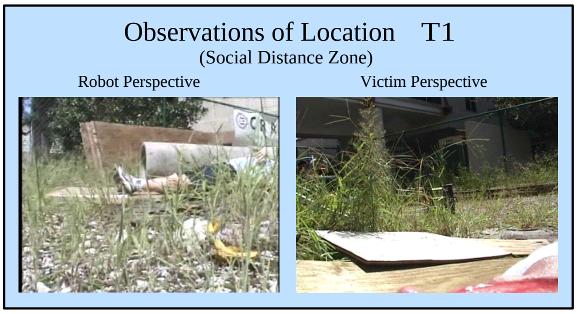

Figure 4: Observations at point T1 from the robot's and victim's perspectives in the *social* proximity zone.

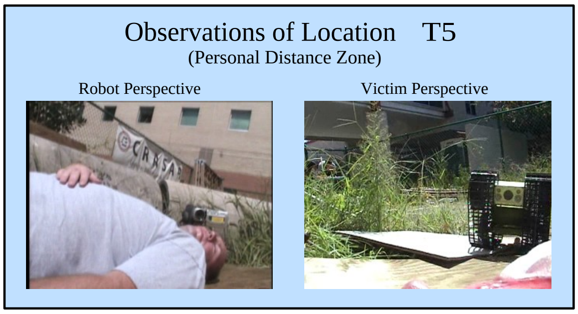

Figure 6: Observations at point T5 from the robot's and victim's perspectives in the *personal* proximity zone.

Consistent with the heuristics described in the *personal* zone entries in Figure 2 the victim is capable of viewing all the movements of the robot including the small movements of the camera face. Additionally, at point T2 the victim can determine the orientation of the robot. At this distance, sounds, tones, and/or music could possibly be heard if it is medium to loud volume and dependent on the background environmental noise [2], [3], [4]. Observations at point T2 are presented in Figure 5 from the robot-eye and victim-eye views.

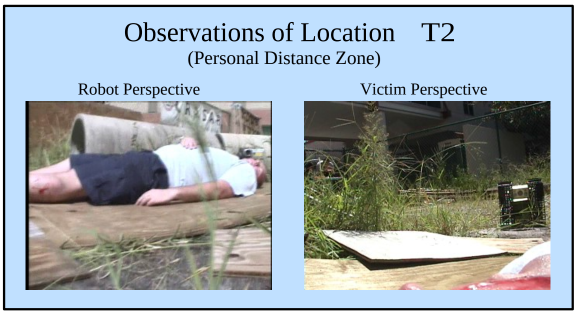

Figure 5: Observations at point T2 from the robot's and victim's perspectives in the *personal* proximity zone.

At point T5 as shown in Figure 3, the robot can perform an overall scan of the victim's body and the surrounding environment. The victim's upper torso and face are clearly visible when the robot is oriented toward the victim's face as shown in Figure 6. From the victim's perspective (see Figure 6), the robot's translational and rotational movements, orientation, posture, and small movements of the camera face are visible. Consistent with the entries in the *personal* zone of Figure 2, the robot is able to communicate affect to the victim through the use of body movements, postures, and orientation. Medium to loud sounds, tones, and/or music could possibly be used for affect redundancy, if the environmental conditions are amenable [3].

The robot is able to perform another overall evaluation of the victim's status and survey the area surrounding the victim at point T7 from Figure 3. This location is also a safe standoff distance to continually monitor the victim's status. Social interactions at point T7 between the victim and the robot would be less stressful for the victim for long-term interactions until assistance can arrive for extrication [2], [4]. As shown in Figure 7 most of the victim's body is visible to the robot when it is oriented toward the face of the victim. Orientation toward the victim's face can indicate liking, interest, and caring in addition to the development of trust between the robot and the victim [5].

From the victim's perspective, as shown in Figure 7, the robot's movements, posture, and orientation are visible; consistent with the recommended heuristics displayed in the *personal* zone entries in Figure 2. Sounds, tones, and/or music may be appropriate for use at this location; however it would depend on background environmental noise levels [2], [3], [4]. Victim monitoring and social interaction could occur at point T5 and/or point T7 in the *personal* proximity zone (See Figure 3). It is important for the robot to maintain a comfortable distance from the victims to keep them calm for the 4-10 hours until they can be extricated.

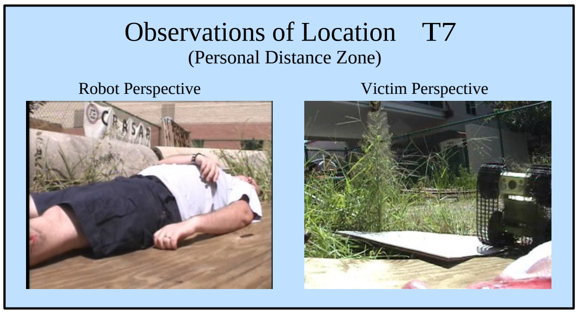

Figure 7: Observations at point T7 from the robot's and victim's perspectives in the *personal* proximity zone.

3.4 Intimate Proximity Zone

The *intimate* proximity zone is useful for close-range victim medical assessment. At this distance participants in the victim role reported the robot as "creepy" in appearance (See Figure 1) especially when the robot is near the face. At this location, it is important that robot movements are performed slowly to avoid startling the victim [4]. From observations of the original medical reachback studies discussed in [15], [18] the robot only remains at this location (T4 in Figure 3) long enough to obtain medical sensor readings from the victim.

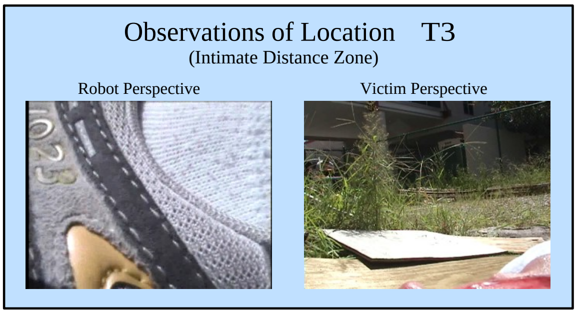

Figure 8: Observations at point T3 from the robot's and victim's perspectives in the *intimate* proximity zone.

At point T3 from Figure 3, the robot is used to gently push the victim's leg to determine if there is any response. At this location, the chest and face of the victim is not visible to determine if the victim is breathing or aware. If the victim moves in response to this push, medical personnel can determine that the victim is displaying awareness [15], [18].

Consistent with the heuristics described in the entries in the *intimate* section of Figure 2, the robot is not visible to the victim in the *intimate* zone at point T3 (see Figure 8). The use of body movement and posture at this location is not appropriate; however sounds, tones, and/or music would be an appropriate method of affective expression [2], [3], [4]. At this particular location, the robot's orientation is not visible to the victim.

The robot can be used to obtain medical sensor readings from the victim's facial area while active at point T4 of Figure 3. At this location, medical personnel can assess the victim's level of awareness and interaction through observation of facial responses (see Figure 9) [15], [18]. From the victim's perspective, the robot is close and reported as "creepy" in appearance at this distance as shown in Figure 9. As per the entries in the *intimate* section of Figure 2 orientation of the robot is visible. Consistent with the *intimate* entries in Figure 2 the full body of the robot is not visible at point T4; therefore the use of body movement and posture would not be an appropriate method of affective expression at this location. Sound would be a more appropriate method of expressing affect at this location in the *intimate* zone [2], [3], [4].

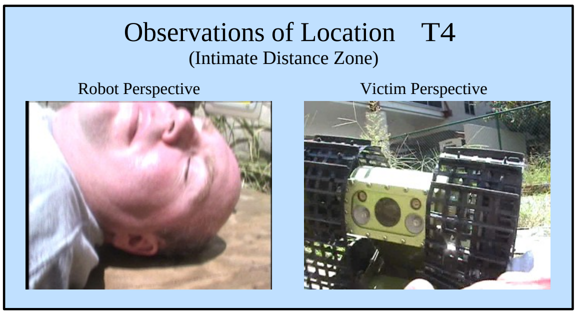

Figure 9: Observations at point T4 from the robot's and victim's perspectives in the *intimate* proximity zone.

The robot can be used to evaluate a victim's breathing and abdomen at point T6 of Figure 3. The robot is not visible to the victim at this location as shown in Figure 10. Consistent with the heuristics described in the *intimate* entries of Figure 2, body movement and posture would not be an appropriate method of expressing affect to the victim for social interaction. In this case, orientation of the robot is not visible. The most appropriate method of expressing affect at point T6 would be sounds, tones, and/or music as indicated in the entries for the *intimate* distance zone of Figure 2.

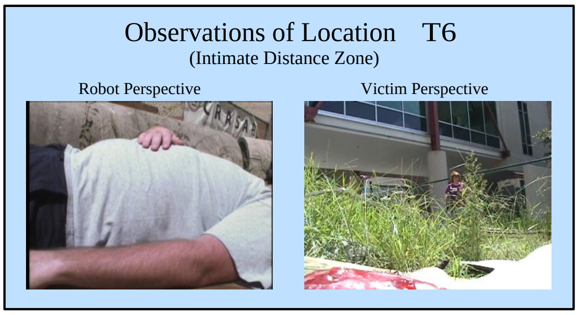

Figure 10: Observations at point T6 from the robot's and victim's perspectives in the *intimate* proximity zone.

4. DISCUSSION

A result of this work is the identification of three open questions: (1) *Does the angle of approach/withdrawal impact the comfort level of the victim?*, (2) *Does the direction of motion impact the comfort level of the victim interacting with the robot?*, and (3) *What constraints need to be considered based on the task to be performed and the environmental conditions when interacting with a victim?* All of these research questions were discovered as a result of observations while conducting the robot-assisted medical assessment reachback task. From the victim's viewpoint, the robot appeared less threatening when approaching at an angle at the victim's face than when approaching from a frontal position. Additionally, it appears from observations that the robot can have quicker movements when withdrawing than when approaching the victim. The medical assessment scenario also indicated that environmental obstacles and the tasks being performed such as medical sensor readings appear to impact the way in which the robot must move in relation to the victim and/or obstacles in the environment.

In order to answer these three open research questions, further human-robot interaction studies will need to be conducted to assess these situational concerns and how the robot's movements impact the level of comfort of the simulated victim when interacting with the robot. These studies should include videotaped observations from both the robot-eye and victim-eye views so that reactions can be recorded and a determination can be made regarding the impact of the robot's movements, speed and direction of approach and/or withdrawal. Additionally, the simulated victim can be interviewed or given self-report assessments to determine their reactions to the robot in these different interactions.

Question one has been studied in a specific application in [8]. Dautenhahn *et al.* discuss studies related to the angle of approach to a seated participant. In this study, participants were most comfortable with the robot approaching from either the right or left but felt the frontal approach was aggressive and made them uncomfortable. These studies were conducted with the participant seated and the robot was a human-scaled PeopleBot which would likely have a different impact than the application discussed in this work.

Mizoguchi *et al.* [13] have done some work related to the second question. They have studied the impact on a participant's comfort level when the robot is approaching and withdrawing. Additionally, Walters *et al.* [21] performed studies to determine how close a robot can approach a participant before they become uncomfortable.

Limited investigation has been conducted by Dautenhahn *et al.*, regarding open question three, on how the physical context of the environment may limit the types of interactions that are likely to occur [7]. In most cases, research related to Human-Robot Interaction has been conducted in very open and relatively unconstrained environments, which perpetuates the need for studies to determine the impact of the environmental conditions that occur in the field. These open questions have been the subject of some limited research; however more attention needs to be given to these areas by the research community.

5. CONCLUSIONS

This work is a confirmation study of heuristics that are based on an extension and refinement of previous work presented for which non-facial/non-verbal affective expressions are appropriate for each of the three proximity zones of interest: (*intimate*, *personal*, and *social*). This investigation illustrates and verifies the suitability of the body movement, posture, and orientation heuristics described in Figure 2. This is accomplished by examining videotaped observations of a canonical robot-assisted medical reachback task where the robot interacts with a simulated disaster victim in an actual rubble pile used for training purposes. The design of this task was developed based on observations of video recordings of robot-assisted medical reachback scenarios conducted by Murphy *et al.* [15] and Riddle *et al.* [18] using actual medical personnel.

Through this robot-assisted medical assessment reachback task, it was determined that there is support for the heuristic entries for body movement, posture, and orientation in all three proximity zones described in Figure 2. More extensive testing and evaluation needs to be conducted in this area. From this investigation it was determined that at points T3 and T6 (See Figure 3) the robot was not visible to the victim at all in the *intimate* zone at these locations. At these points, the use of body movement and posture would not be appropriate. The observation that orientation would not be appropriate in these locations, is not indicated in the table entries in Figure 2. Though the appropriateness of the use of sound was not specifically evaluated in this scenario, the scenario did indicate situations when sound would be appropriate such as in points T3 and T6 where the robot was operating in the *intimate* zone and not at all visible to the victim (see Figures 8 and 10).

The results of this work, can be applied to both anthropomorphic and non-anthropomorphic robots in different applications. In anthropomorphic robots, the use of body movements, postures, orientation, and sound can reinforce facial expressions of affect. Non-facial and non-verbal affective expression and proximity impacts interactions between humans and it would appear these factors would also impact human-robot interaction. Even though, not all the movements performed by this robot in this scenario would generally apply to all robots, the general concepts of translational and rotational movements, orientation, and sound presented in the heuristics is applicable to any mobile robot with audio capability.

Ongoing work includes the development and testing of non-facial/non-verbal methods of affective expression mapping sequences of body movements, postures, and orientation to appropriate affective responses. Once this taxonomy is developed it will be used to program robots to interact socially with humans in an appropriate manner in the confined space, stressful environment of the search and rescue domain.

Further investigation needs to be conducted on the use of sounds, tones, and/or music as a non-verbal method of affective expression in victim-robot interaction. Future work should focus on the development of sounds, tones, and/or music to express affect to victims located in search and rescue applications. It is important for the robot to make sounds associated with a robot and not attempt to anthropomorphize the robot through sounds and tones. The use of music as a method of conveying affect and to provide comfort to a victim until help can arrive needs to be explored. Additionally, once appropriate sounds, tones, and/or music are developed testing should be conducted with human participants through the use of video-recording, self-assessments, and psychophysiological measurements [3].

Another area of future investigation is the appropriateness of using illuminated color as depicted in the heuristics in Figure 2. Research should be conducted to determine if there is an appropriate mapping of color to specific emotions. If a mapping can be developed then a method of implementation for this illuminated color system needs to be determined. Finally tests should be conducted with human participants to determine the appropriateness of use for this system by proximity zone.

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