

# Scaling a Robot's Social Behavior via Proxemics

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## Introduction

### Proxemics

During interactions humans influence each other based on their proximity to one another. This space can be divided into four proximity zones. By occupying a particular zone during an interaction, corresponding behaviors are expected.

### Our Contribution

Quantitative functions for scaling robot social behavior via proxemics autonomously remain unexplored and unestablished, preventing autonomous generation of social behavior which accounts for proximity. Our work presents and compares two scaling functions for shaping the social behavior of a search and rescue robot.

### Proxemics In Robots

While many have explored proxemics as it relates to robots, Bethel et al. provide the most relevant information for use in behavior scaling applications.

| Proxemics Design Recommendations for Non-Facial and Non-Verbal Affective Expression by Proximity Zone |                                                   |                            |                            |
|-------------------------------------------------------------------------------------------------------|---------------------------------------------------|----------------------------|----------------------------|
| Bethel and Murphy, 2006 - Modified after experimentation                                              |                                                   |                            |                            |
| Affective Expression                                                                                  | Intimate                                          | Personal                   | Social                     |
| Body Movement                                                                                         | Full body movement and subtle head/neck movements | Subtle head/neck movements | Subtle head/neck movements |
| Facial Expression                                                                                     | Subtle head/neck movements                        | Subtle head/neck movements | Subtle head/neck movements |
| Posture                                                                                               | Subtle head/neck movements                        | Subtle head/neck movements | Subtle head/neck movements |
| Characteristics                                                                                       | Subtle head/neck movements                        | Subtle head/neck movements | Subtle head/neck movements |
| Behavioral Color                                                                                      | Subtle head/neck movements                        | Subtle head/neck movements | Subtle head/neck movements |
| Sound                                                                                                 | Subtle head/neck movements                        | Subtle head/neck movements | Subtle head/neck movements |

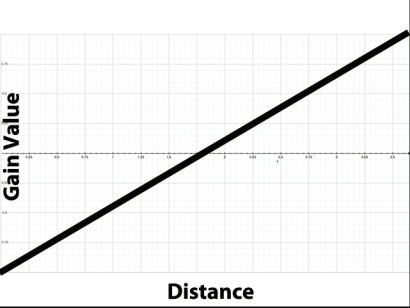
Table From: Bethel 2011  
"Non-Facial and Non-Verbal Affective Expression for Appearance-Constrained Used in Victim Management"

## Approach

### Minimizing Stimuli Perception

Our work focuses on developing a tactical behavior which can scale all active behaviors of a robot based on a scaling function. The focus of our experimental work is in finding a scaling function which produces desirable social characteristics in a robot which employs proxemic scaling.

The two scaling functions examined in this work attempt to minimize stimuli as the robot becomes closer to a human. These functions were derived from considering the inverse-square law, Steven's Power Law, and the Weber-Fechner Law.



**Linear Mapping**  
We examine a linear function as one condition. The function is:  
 $y = .55d - 1$



**Human-Perception Mapping**  
We developed a Human-Based-Perception function as a second condition. The function is:  
 $y = -\ln(-d + 4.22) + .44$

## Experiments

### Setup

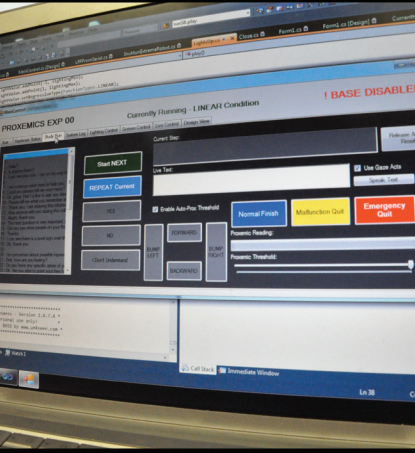


A 1x3 between-participants study containing the conditions: *no scaling*, *linear scaling*, and *human-perception-based scaling*, was designed. An a priori power analysis with a medium effect size indicated a minimum requirement of 42 participants. In total, 72 participants took part in the study.



◀ The robot scaled its range of movement, speed, and lights.

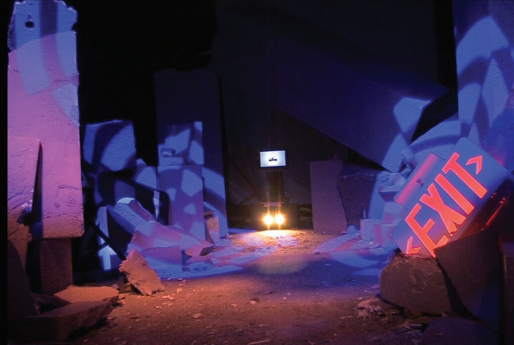
The interaction was implemented using a Wizard of Oz scheme.



### Interaction



The robot approached participants beginning in the public zone. It engaged in a dialog with the participant and engaged in head gaze acts. The robot moved towards the participant, travelling through each proxemic zone.



Once in the intimate zone, the robot concluded its interaction by asking the participant to place their hand on the robot. Once the participant's hand was on the robot, a set of head gaze acts were performed.



### Measures

Self-report surveys were used to understand how participants felt about the robot in each condition. Attributes measured included: *comfort*, *natural movement*, *personal space*, *safety*, *self-control*, *intelligence*, *likability*, and *submissiveness*. These categories were measured with previously used HRI surveys and multiple-item reliable groups for areas which had not been previously measured.



Interactions were video recorded in order to capture the participant's performance in a memory task.



Physiological measures including: GSR, pulse, respiration, and temperature were also recorded throughout the interaction.

## Results

|                  | Constant | Linear | Perception |
|------------------|----------|--------|------------|
| Comfort          | 4.771    | 5.639  | 6.201      |
| Natural Movement | 4.375    | 4.042  | 5.875      |
| Personal Space   | 5.083    | 5.833  | 6.361      |
| Safety           | 5.958    | 6.458  | 6.708      |
| Self-Control     | 5.333    | 5.792  | 6.250      |
| Intelligence     | 5.167    | 5.833  | 6.271      |
| Likability       | 5.396    | 5.708  | 6.500      |
| Submissiveness   | 4.208    | 4.917  | 6.167      |

### Human-Perception Scaling Best

In most attributes HPB scaling proved to be significantly better than no scaling. While linear scaling indicated no significant difference opposed to no scaling, except in the cases of comfort and personal space consideration. In the area of comfort, a clear rank was demonstrated with significance between all conditions.

### Scaling: More Socially Consistent

Results indicate that all of the primary attributes (comfort, personal space consideration, safety, natural movement and self-control), along with three of the secondary attributes (intelligence, likability and submissiveness) out of a total of 12 attributes proved to be significantly better in conditions which employed scaling as opposed to the condition which did not.

|                  | Con v. Lin | Con v. Perc | Lin v. Perc |
|------------------|------------|-------------|-------------|
| Comfort          | p<.001     | p<.001      | p=.024      |
| Natural Movement | p=ns       | p<.001      | p<.001      |
| Personal Space   | p=.015     | p<.001      | p=ns        |
| Safety           | p=ns       | p=.014      | p=ns        |
| Self-Control     | p=ns       | p=.019      | p=ns        |
| Intelligence     | p=ns       | p<.01       | p=ns        |
| Likability       | p=ns       | p<.01       | p<.05       |
| Submissiveness   | p=ns       | p<.001      | p=.002      |

## Conclusions

### I. Scaling is Significant

Though most participants rated the robot highly across all conditions, a clear and significant increase in social consistency is perceived when the robot scales its behavior with respect to proximity. Specifically, HPB scaling proves to be a preferable method of scaling for improving robot ratings, with the exception of personal space, which can be improved with either linear or HPB scaling.

### II. Three Suggestions for Designers

First, our study illustrates the importance of considering proxemics when designing social behavior. Second, we have illustrated that the choice of scaling function has a significant impact on the perceptions of the robot. Finally, we recommend that designers begin with a HPB scaling function.

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