Emotional Robotics: Tug of War

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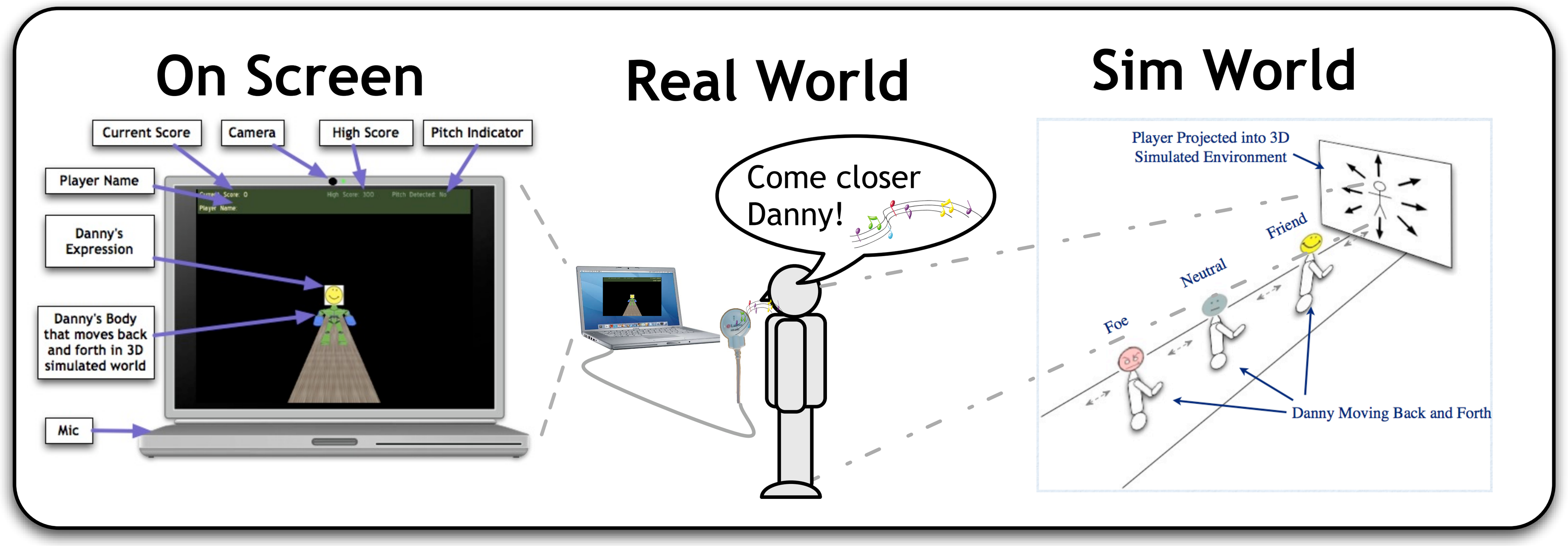
Abstract

Emotional communication skills are dominant in biological systems. Although the rules that govern creating and broadcasting emotional cues are inherently complex, their effectiveness makes them attractive for biological systems. Emotional communication requires very low bandwidth and is generally easy to interpret. Despite the advantages of emotional communication, little or no research has explored which emotional cues are the most effective when used by a robot. To study this question, we introduce an interactive environment in which a person can learn the robot's emotional responses through interaction. We then present a one player game in which a person attempts to attract the robot's attention, make it move towards and stay close to the person. We further develop this concept into a two player version, in which the players engage in a Tug of War game, competing for the robot's heart. We propose our system as a potential test bed for human-robot interaction, both for engineers, and clinical psychologists.

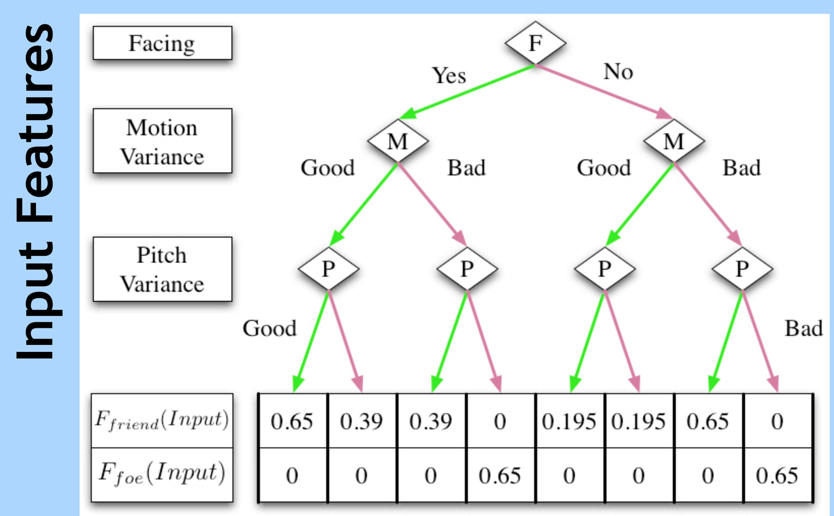
Research Question

Can these expressions supplement motion as feedback from a robot for improved human learning?

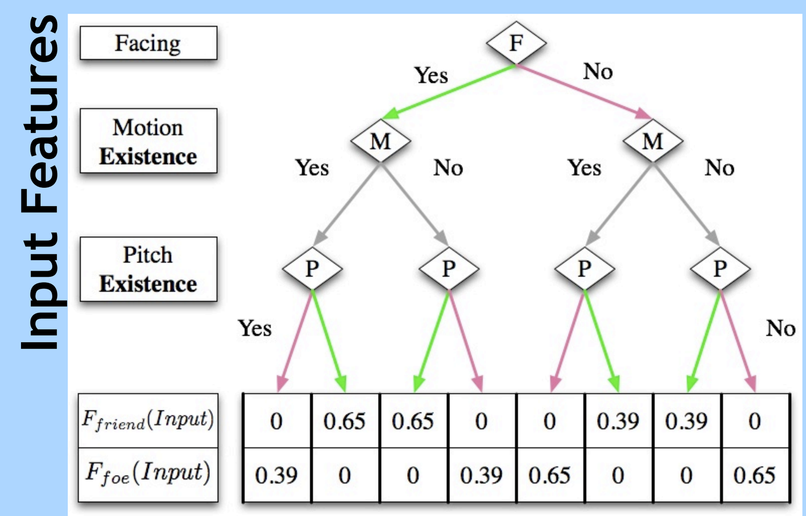
Setup



Input Features



Input Function Values



Input Function Values

Danny focuses on 3 features, facing, motion variance in range, and pitch variance in range. These features are used to compute the input function.

States and Transitions

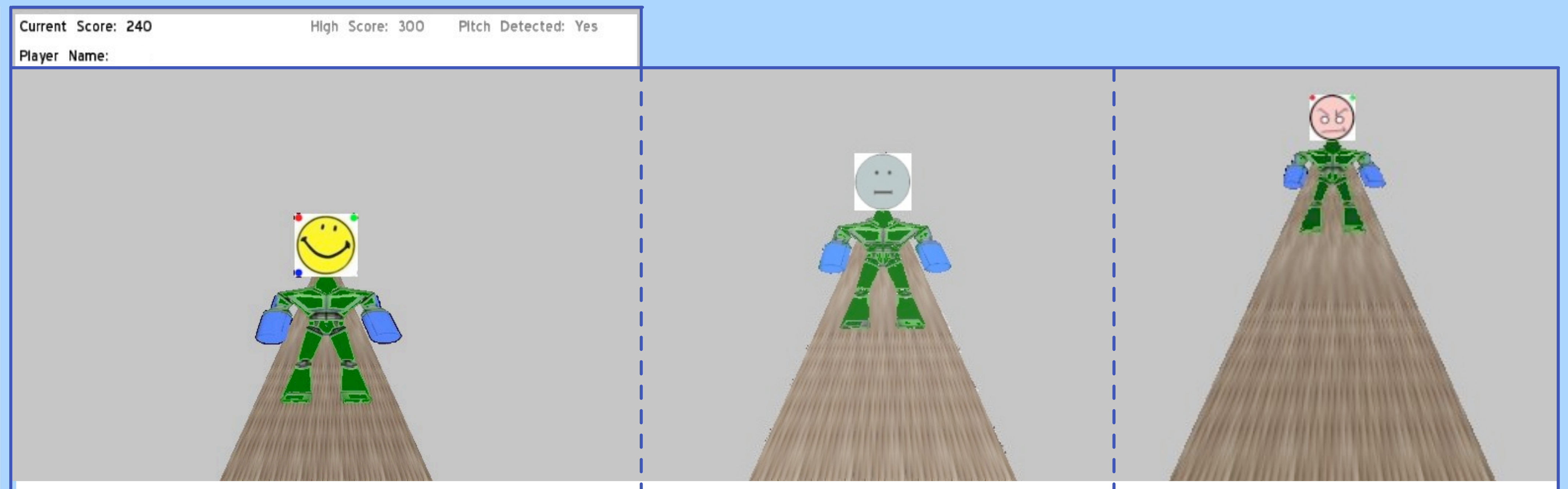
The emotional algorithm continuously evaluates and acts upon the robot's internal emotional state vector: $s = [s_{friend}, s_{foe}, s_{absorbed}]$
This vector is updated as follows:

$$s_{friend} \leftarrow s_{friend} + w \cdot f_{friend}(Input)$$
$$s_{foe} \leftarrow s_{foe} + w \cdot f_{foe}(Input)$$
$$s_{absorbed} \leftarrow s_{absorbed} + w \cdot f_{absorbed}(Cycle)$$

Where w is a constant between 0 and 1, acting as a low pass filter, all states and functions yield values between 0 and 1, and the state is normalized by the $\mathcal{L}_1$ norm after each update.

Output Features

State Value	Face	How Friendly	Steps Towards Person	Change in Score
friend > 0.80		+3	+3	+3
friend > 0.65		+2	+2	+2
friend > 0.55		+1	+1	+1
friend & foe <= 0.55		Neutral	0	0
foe > 0.55		-1	-1	0
foe > 0.65		-2	-2	0
foe > 0.80		-3	-3	0



Friendship: The robot approaches and smiles as it likes the participant.
Neutral: The robot stops and has a neutral face.
Dislike: The robot withdraws with a scowl.

State to Output: The resulting state values are used to determine the action of the robot, Danny, as shown to the left. The actions always include motion, and the experiments vary whether facial expression, as above, or score are shown as feedback as well.

Experimental Design

4 x 4 mixed factorial design
Factor A: Emotional Feedback
- **control** , **score**, **face**, **both**

Factor B: Desired Behavior (Mood)
- **low**, **medium**, or **high** variance
- **only motion or only sound**

4 subjects per Emotional Feedback condition
4 Desired Behaviors randomized for each subject
3 subsequent trials for each Desired Behavior
Example presentation order:
Feedback: **Control**
Desired Behavior: **3 low, 3 either/or, 3 high, 3 med**

Exit Questions

Which Mood was easiest to figure out?
1st 2nd 3rd 4th

Which Mood was hardest to figure out?
1st 2nd 3rd 4th

Did the feedback help? (Yes No)

How/Why/What would have helped more?

Do you know what makes the robot happy in each Mood? If so, please describe.

Results

First Hypothesis

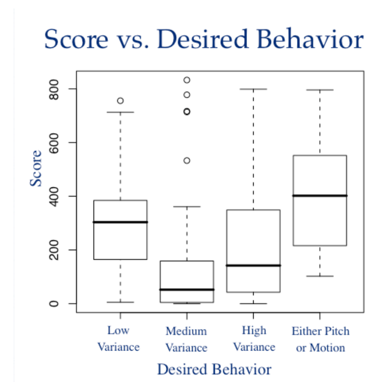
$H_{feedback-0}$: mean scores of Emotional Feedback conditions are equal.
Result: F-score = 1.92, p-value = 0.127:
failure to reject, however not enough power to accept $H_{feedback-0}$

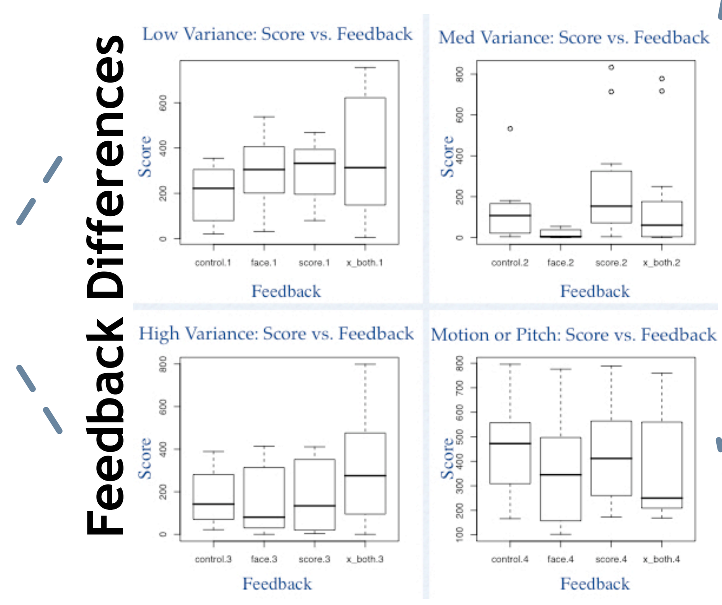
Second Hypothesis

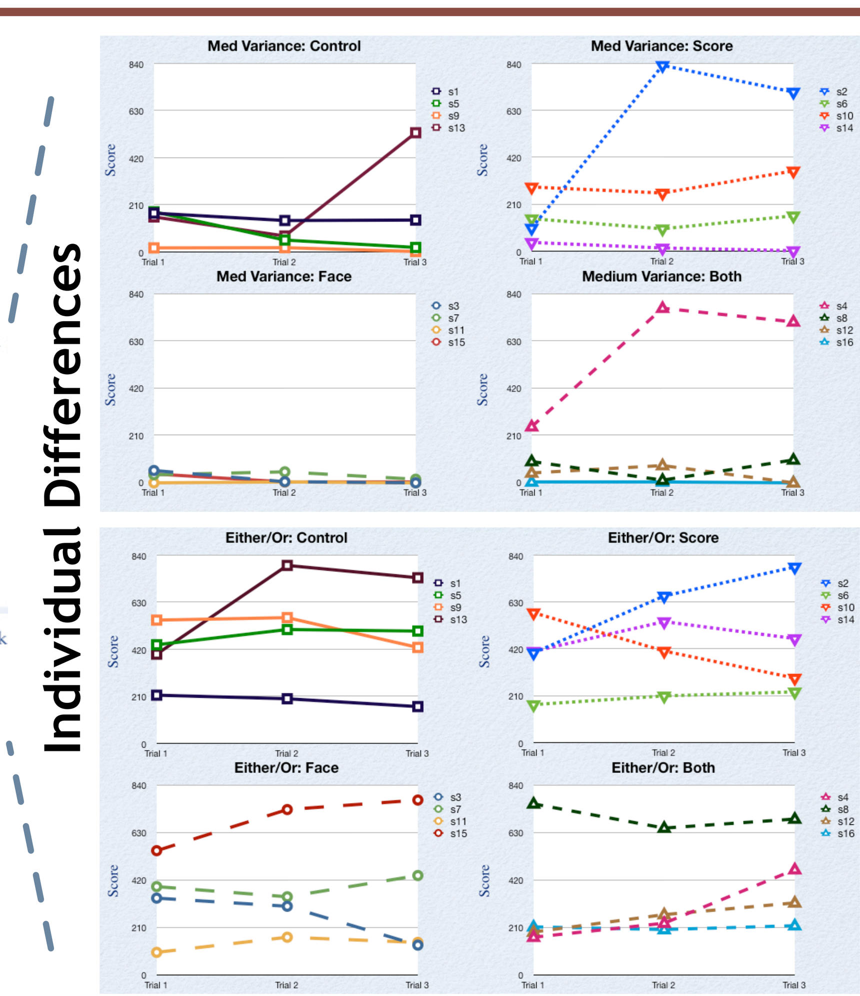
$H_{behavior-0}$: mean scores of Desired Behavior conditions are equal.
Result: F-score = 8.86, p-value = 0.003:
reject $H_{behavior-0}$

Alternative to Second Hypothesis

Medium Variance Desired Behavior causes the lowest scores.





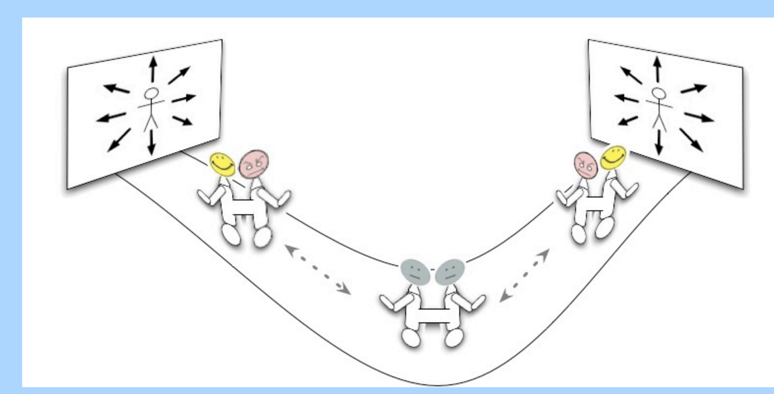


Conclusions/Future Work

Secondary Feedback has small effect if any.

Participants enjoy/want facial expressions.

Two Player Tug of War may increase effect of secondary emotional feedback.



Explore Instantaneous Feedback of facial expression. Learn emotional behavior.