Entertaining Robots

Cynthia Breazeal
MIT Media Lab

Robots in "Entertainment"

- Location Based Entertainment
  - Audio Animatronics
  - Motion rides
- Film
  - Cinematography
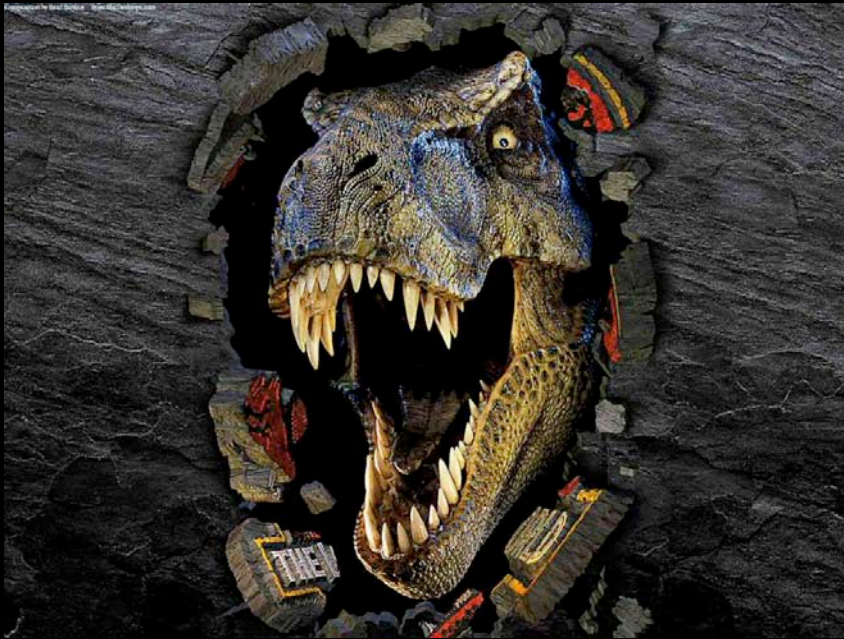 - Special Effects

Synthetic Performers

Stan Winston

- From Human Actor's Point of View

Synthetic Performers

- From Human Actor's Point of View
- Advantages & Limitations of Virtual Characters
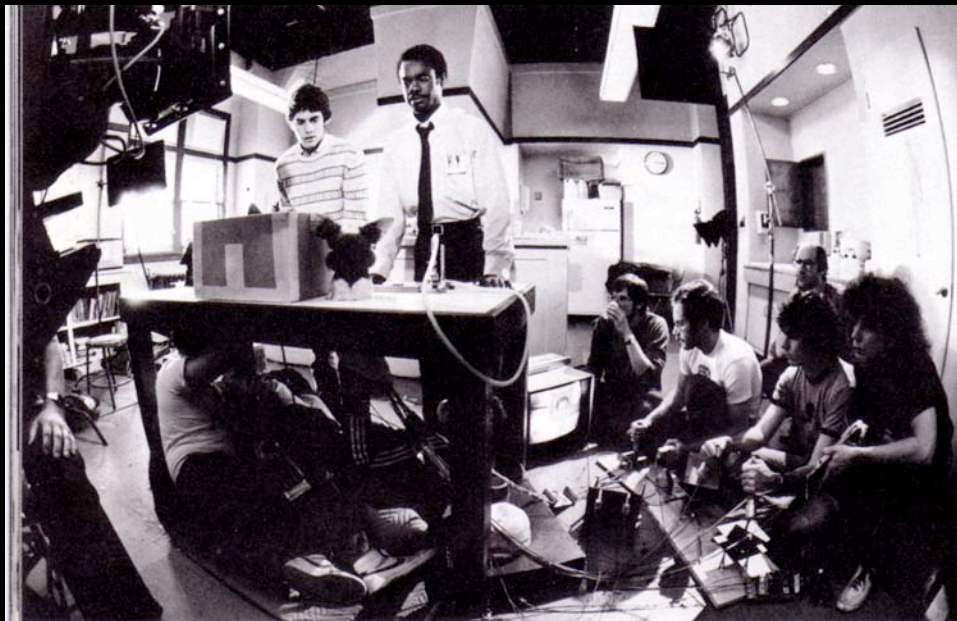 - Golem (based on human actor)
  - T-Rex or Gizmo?

Synthetic Performers

- From Human Actor's Point of View
- Advantages & Limitations of Virtual Characters
- Advantages and Limitations of Physical Characters

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"Real" Character

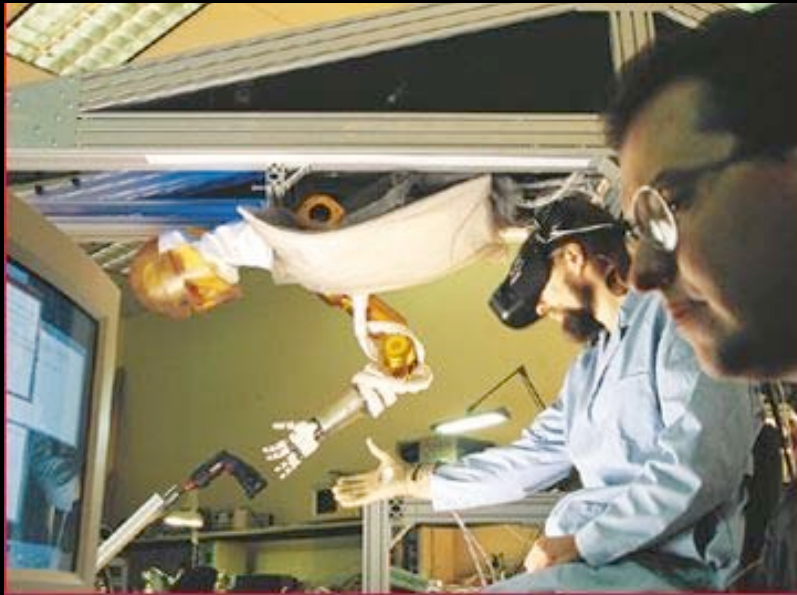
- Goal: **BELIEVABILITY**
- Challenge*: n* Puppeteers:1 robot
- "In the limit": *Real* Character

"Real" Character

- Collaboration with SWS to add autonomy to performance
  - Precise gaze control and eye contact
  - Automatic Lip synchronization
  - *Autonomous, Socially Interactive Robots*

Robots with a Day Job

- NASA JSC's Robonaut

- Goal: **HUMAN-ROBOT TEAMS**

- Challenge: Limitations of Tele-operation & cognitive load

Robot Teammates

- Goal: Robot as Teammate
  - "just like interacting with a human astronaut"
- Social interaction is basis for
  - Cooperative work
  - Teaching new tasks

Robot Teammates

TEACHING ROBOTS AS
A COLLABORATIVE DIALOG
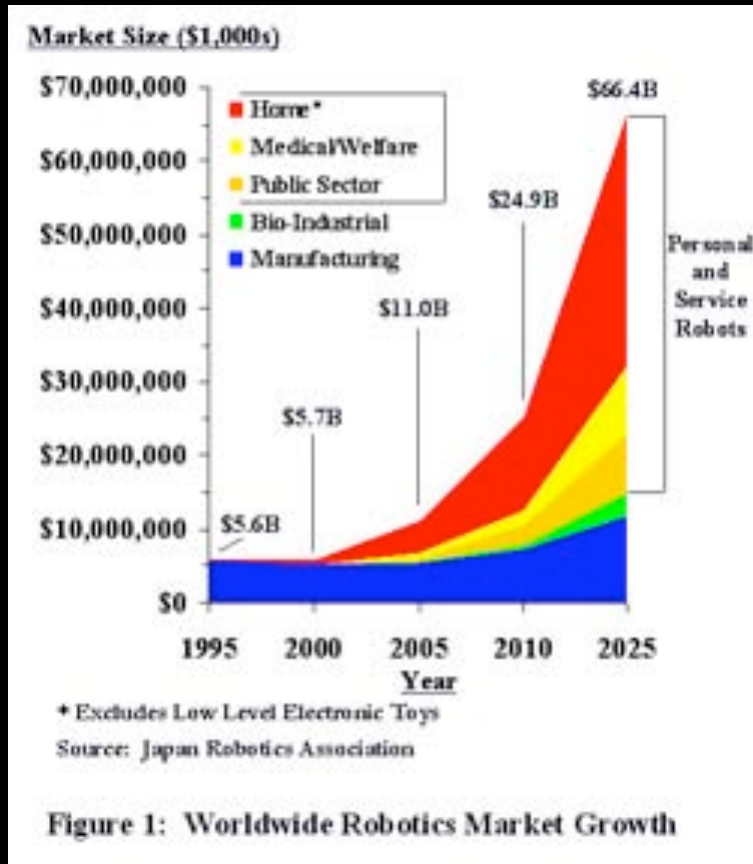
Robotic Life Group
MIT Media Laboratory

- Collaboration with NASA JSC to add autonomy to teamwork and teaching
- Robonaut's bolt task
- Leonardo's button task

The "Final Frontier"

- Robots in YOUR home
- Interacting with the average (untrained) consumer
- On a daily basis and over the long term

Why Now?

Market Size ($1,000s)

- Home* — $66.4B
- Medical/Welfare
- Public Sector
- Bio-Industrial
- Manufacturing

$5.6B, $5.7B, $11.0B, $24.9B

Personal and Service Robots

* Excludes Low Level Electronic Toys

Source: Japan Robotics Association

Figure 1: Worldwide Robotics Market Growth

UNEC & IFR 2002 Study

- **Personal Robots: "assist, protect, educate & entertain"**
- **Convergence**
  - Mobile computing
  - Government mandate
  - Societal needs of aging societies

Consumer Appeal

Oh, the horror…the horror…

- "Entertainment" can be interpreted far more broadly
- *"Why are you going to welcome this thing into your home?"*

Consumer Appeal

This time, the virtual pet craze had gone too far...

Oh, the horror…the horror…

- "Entertainment" can be interpreted far more broadly

- *"Why are you going to welcome this thing into your home?"*

- *"What's going to keep you interacting with it over the long haul?"*

Design Issues

- Useful
- User-FRIENDLY
- Helpful
- Trust
- Acceptance
- Enjoyment
- Etc.

- *Cognitive abilities*
- *Learning capability*
- *Social interaction*
- *Expressive*
  - •
  - •
  - •

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Design Issues

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- *Cognitive abilities*
- *Learning capability*
- *Social interaction*
- *Expressive*
  - •
  - •
  - •
- *Emotion & Affect*

Robot "Emotions"?!

Scientists & Designers

Hard, but YES!

Engineers

Eek! Irrational robots, NO!
Why bother?
It's wrong!
Impossible.

# Scientific Perspectives on Emotion & Affect

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Emotion and Intelligent Behavior

- Humans are the most emotional, social, expressive of all species
- Not an accident, we evolved our complex emotions to
  - Communicate and predict behavior of others
  - Tailor our thought processes to handle complex, changing, unpredictable world.
  - Survive and thrive better in our world
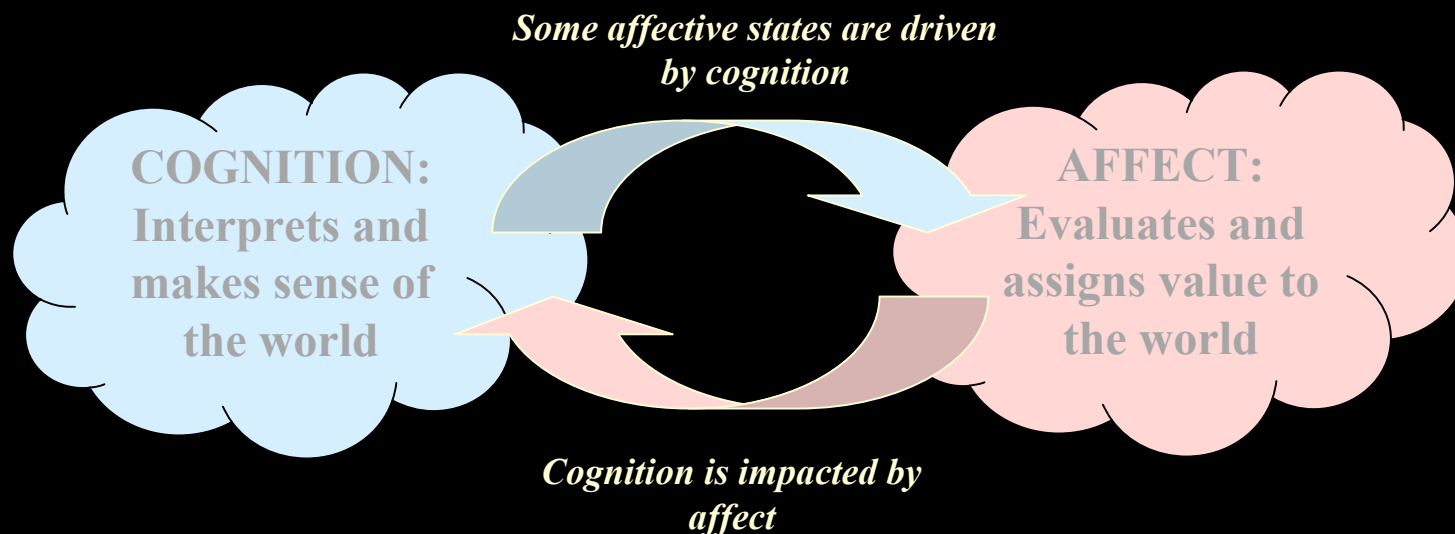
Cognition & Emotion
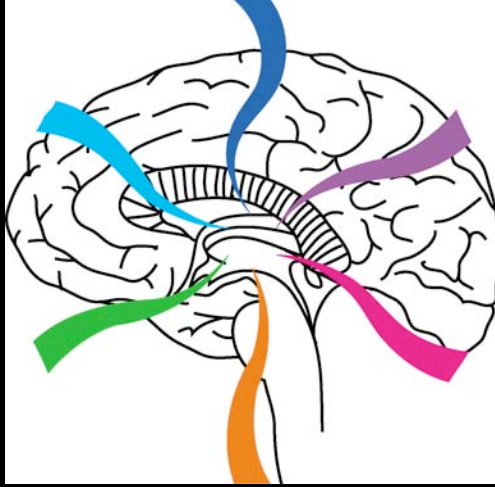
Emotion is tightly intertwined with cognition, contributing to rational thinking, memory, decision-making, perception, attention, prioritization, and more.

Two Info Processing Systems

- Cognition and Affect can be considered as two distinct information processing systems
- Different functions & operating parameters
- Fundamentally Intertwined

Some affective states are driven by cognition

COGNITION:
Interprets and makes sense of the world

AFFECT:
Evaluates and assigns value to the world

Cognition is impacted by affect

Affect and Decision Making

- Too little emotion impairs decision making (Damasio, 1994)

- Patient suffers frontal lobe disorder
  - Interferes with cortex ability to communicate to limbic system
  - Otherwise score normal intelligence

- Lack of somatic markers that associate positive/negative feelings with decisions
  - Scheduling an appointment results in astronomical search of rational possibilities
 - Make repeated bad investments

NOT like Spock!!!

Affect and Decision Making

- **Positive affect facilitates creativity** (e.g., Isen, Daubman, and Nowicki, 1987; Isen, Johnson, Mertz, and Robinson, 1985)

- **Negative affect narrows attention and facilitates analytical problem solving** (e.g., Broadbent, 1971; Bruner, Matter, & Papanek, 1955; Schwartz, 2002)

Duncker's Candle Task: Affix the candle to the wall and light it, in such a way that it doesn't drip on the ground.
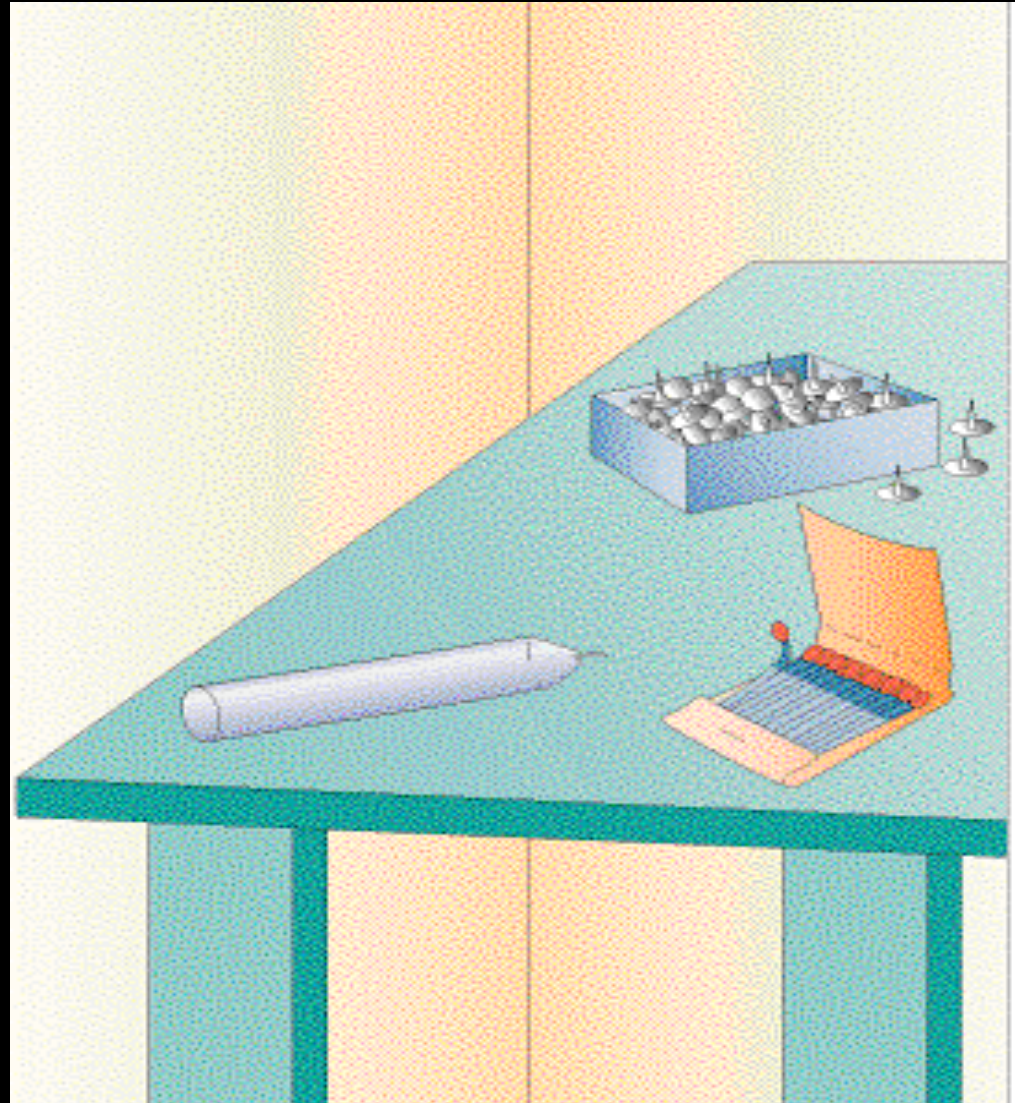
(Isen, Daubman & Nowicki, 1987)

Remote Associations Test: Provide the word that relates these three words (Estrada, Isen & Young 1994)

guy	owl	man	
soul	busy	guard	
athletes	web	rabbit	
mower	atomic	power	
widow	board	cat	
arrow	laced	narrow	
club	gown	mare	*night*

47% (positive affect) verses 13% (neutral) got 2+ right

Why care about emotion in the design of artifacts?

Emotion in Interfaces Cliff Nass (forthcoming)

Toyota's emotion car: the Pod

- Emotions impact human
  - Attention
  - Performance
  - Judgment
- Driving a car requires the same
- What are the implications for voice interfaces in cars?
  - Enthusiastic and cheerful
  - Calm and subdued

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Emotion in Interfaces

- First, Show subjects movies to induce affect
  - Happy videos
  - Upsetting videos
- Then 15 min driving simulator with talking Virtual Passenger
  - Half matched, half mismatched
- 2x FEWER ACCIDENTS when matched!
  - Conflict is distracting and demands more cognitive effort
  - Poorer performance
  - Poorer attention to road.

Elder Care Design Hirsch, Forlizzi, *etal*. (2000)
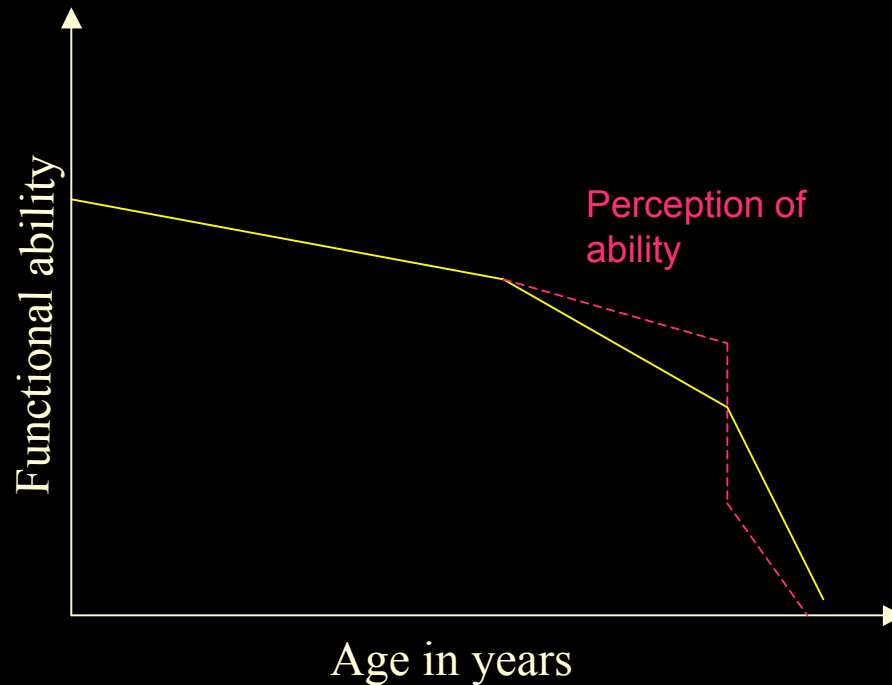
- **Physical condition AND quality of life (social & psychological factors)**
- **Shifting perceptions of ability are often out of step with actual capability**

"one elderly woman broke her hip during a fall. After surgery she primarily used a wheelchair for mobility, even though fully recovered and able to walk. Her muscles eventually atrophied, making her totally reliant on the wheelchair."

Choosing to Use or Not

- **"Need" is not enough**
  - Design can hinder adoption by highlighting disability and contribute to social stigma associated with that disability
- **It's not just what it does, but *how it makes you feel* (pride, fear) and *how you think others feel about you***
  - Stigmatizing aesthetic contributes to late-life depression
  - User's perceived need for technology is dominated by desire to not feel reliant on it
  - Contributes to over/under-estimation of functional abilities

US FOE, 2004

Why build robots with emotion systems?

Why build robots with emotion systems?

- **Lessons from science**
  - Emotion and affect are fundamental to intelligent behavior *(address the "eek, not irrational robots!)*

- **Lessons from designers**
  - Technologies should adapt to our changing emotions & moods *(address the "It's wrong!")*
  - How it makes us feel is as important as what it does. *(address the "why bother?")*

Emotion Theories

BASIC HUMAN EMOTIONS

- **Basic emotions: discrete categories**
  - E.g., "Ekman six"
  - Linked to universal distinct facial expressions, innate
  - Others learned (mixtures)
- **Continuous dimensions**
- **Cognitive Appraisal**

Emotion Theories

arousal

surprise

afraid

angry

elated

stress

excitement

frustrated

happy

displeasure ←——————————→ pleasure

neutral

sad

content

depression

calm

fatigued

relaxed

bored

sleepy

sleep
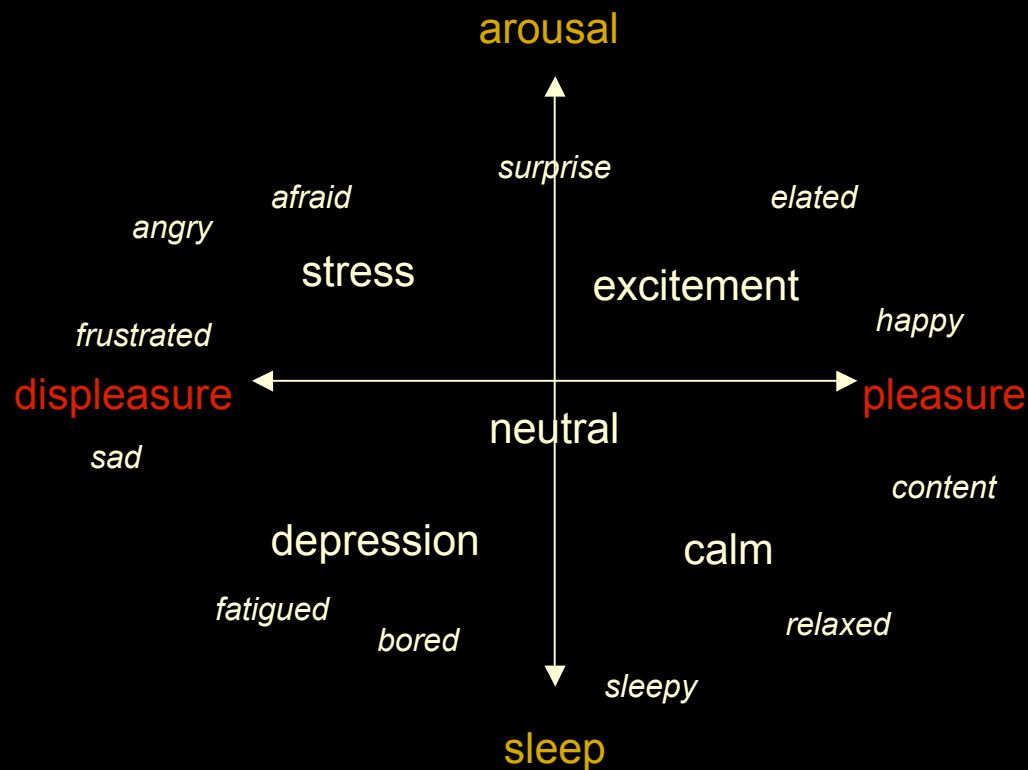
- **Basic emotions: discrete categories**
- **Continuous dimensions**
  - E.g. Russell's Arousal/Valence
  - Debate number of dimensions
- Cognitive Appraisal

Emotion Theories

Valenced reaction to

- Consequences of events
  - pleased displeased, etc.
    - Focusing on
      - Consequences for other
        - Desirable for other / Undesirable for other
          - happy-for resentment / gloating pity
          - Fortunes-of-others
      - Consequences for self
        - Prospects relevant
          - hope fear
            - Confirmed / Disconfirmed
            - satisfaction fears-confirmed / relief disappointment
            - Prospect-based
        - Prospects irrelevant
          - joy distress
          - Well-being
- Actions of agents
  - approving disapproving, etc.
    - Focusing on
      - Self agent / Other agent
        - pride admiration shame reproach
        - Attribution
          - gratification remorse / gratitude anger
          - Well-being/attribution compounds
- Aspects of objects
  - liking disliking, etc.
    - love hate
    - Attraction

Figure 7.1
The OCC cognitive structure of emotions. (Reprinted from Fig. 2.1 of Ortony, Clore, and Collins (1988) with permission from Cambridge University Press.)

- **Basic emotions**
- **Continuous dimensions**
  - E.g. Russell's Arousal/Valence
- **Cognitive Appraisal**
  - E.g. OCC model
  - Rule-based criteria, group by cognitive elicitors
  - Used to reason about emotions

Emotion Theories
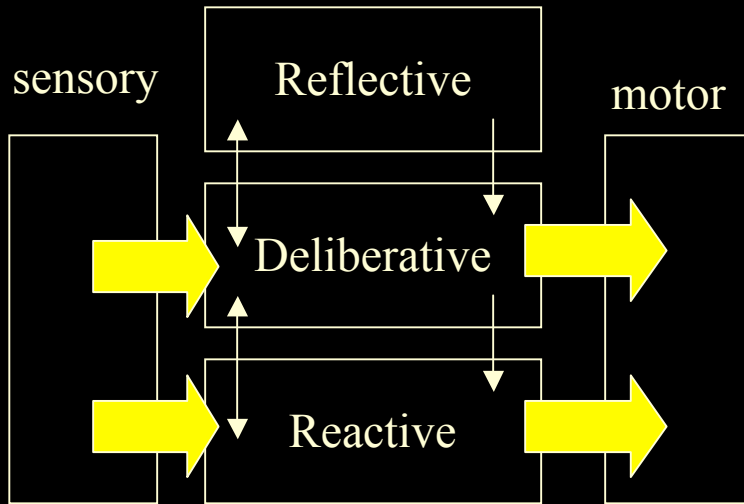
- **Layered models**
  - E.g. Norman, Sloman
  - Reactive: innate (startle, disgust)
  - Deliberative: cognitive appraisals (pleased at success)
  - Reflective: self-monitoring (guilt, shame)
- **Behavioral models**

Emotion Theories
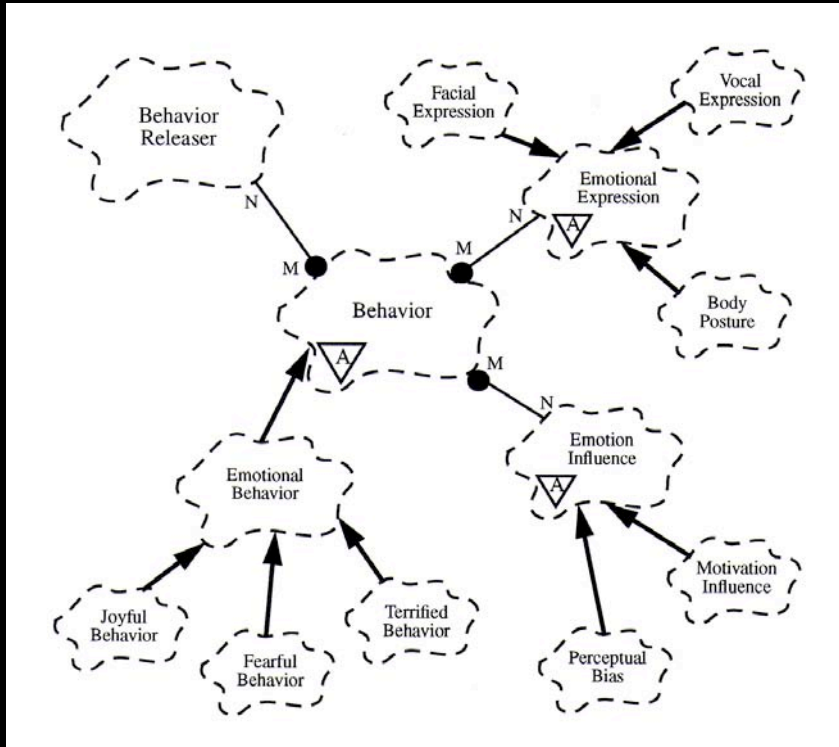
- Layered models
- Behavioral models
  - E.g. Cathexis
  - Homeostasis of agent with environment
  - Inspired by ethology, neuroscience

Kismet: the nature of the beast

- **Inspired by social development of infants and early interactions with adults**
- **Robots have limited abilities compared to people**
  - Motor skills
  - Perceptual abilities
  - Mental abilities
- **Kismet's social and emotive interactions naturally guide human to help robot achieve its goals**
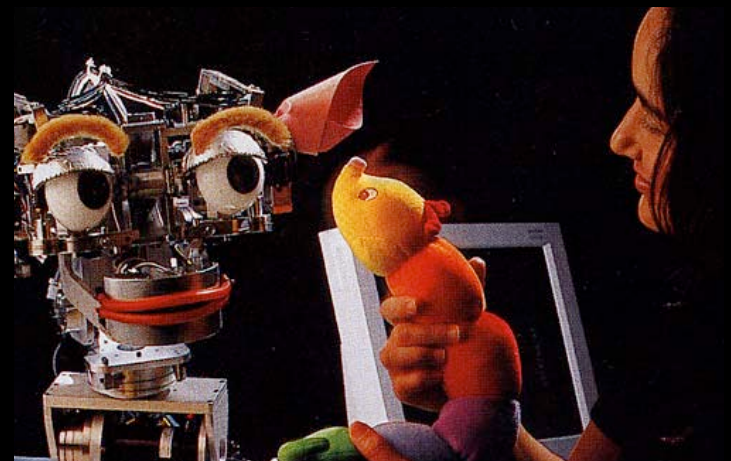
Kismet's Design

- **Agent-based model comprised of network of interacting processes**
    - Excite/Inhibit other processes
    - Send information
    - Temporal dynamics really matter for interaction and communication
- **Cognition system & Emotion system are parallel and intertwined**
- **Mixture of several emotion models & theories**
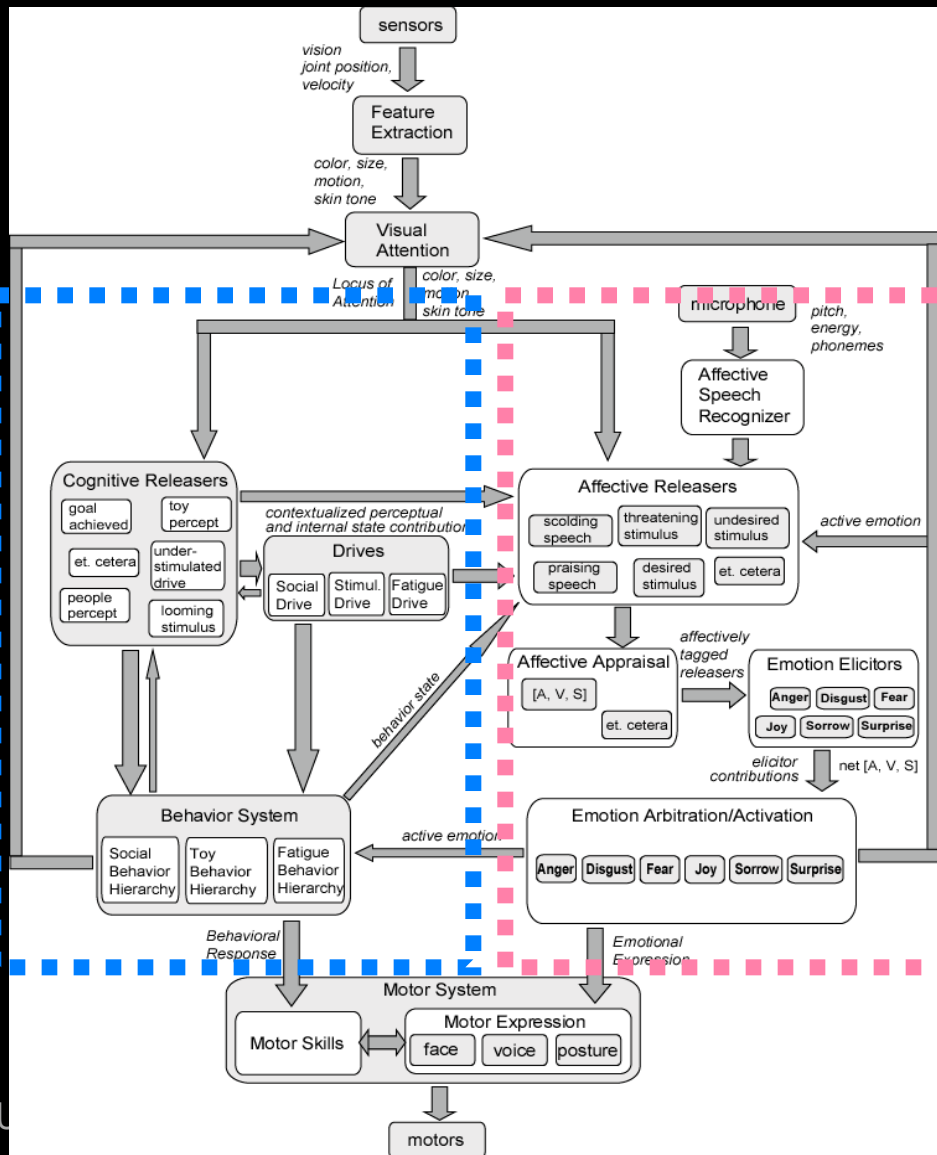
Recognition of Vocal Affective Intent

- Four cross-cultural contours of infant-directed speech
  - A. Fernald

- Exaggerated prosody matched to infant's innate responses

That's a good bo-o-y!

approval

No no baby.
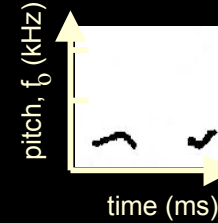
prohibition

Can you get it? Can you get it?
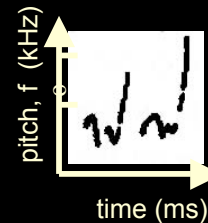
attention

MMMM Oh, honey.
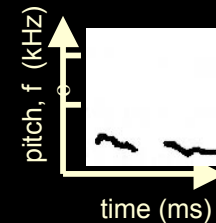
comfort

Evidence for Fernald-like Contours
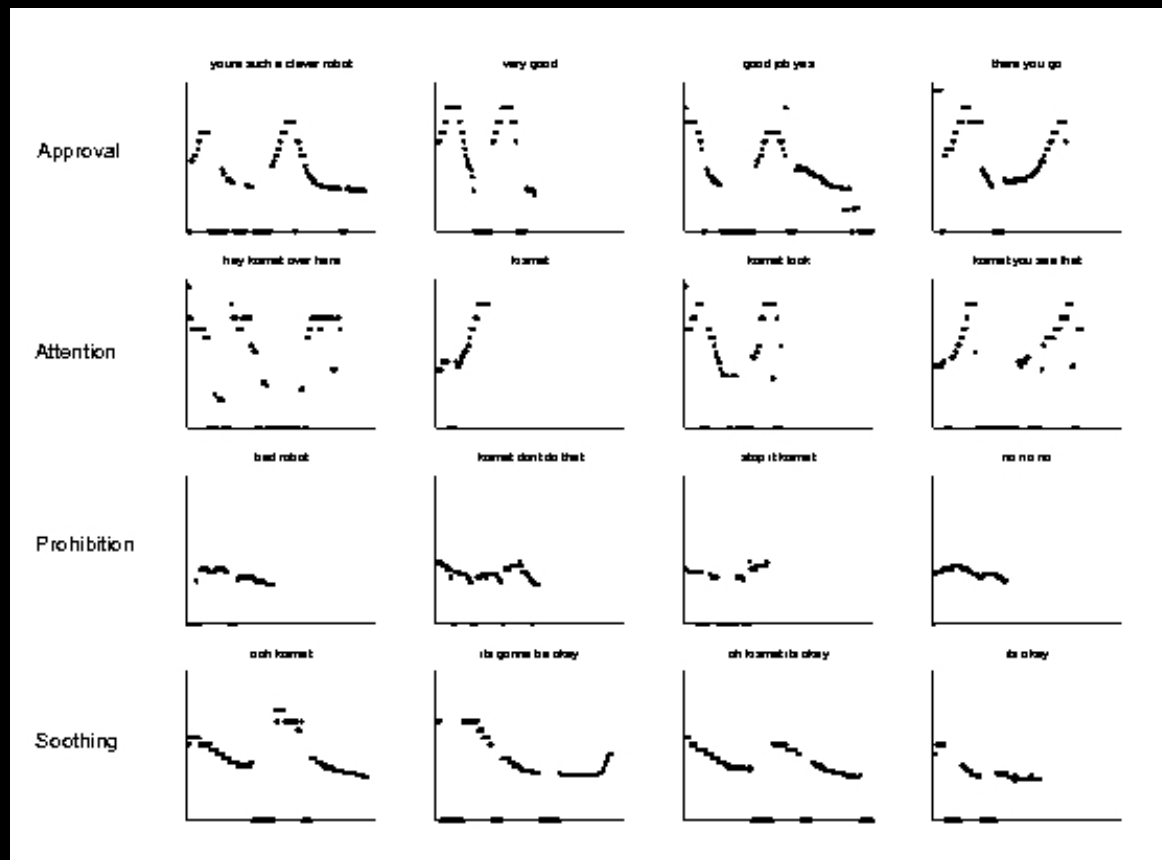
Valence and Arousal in Feature Space
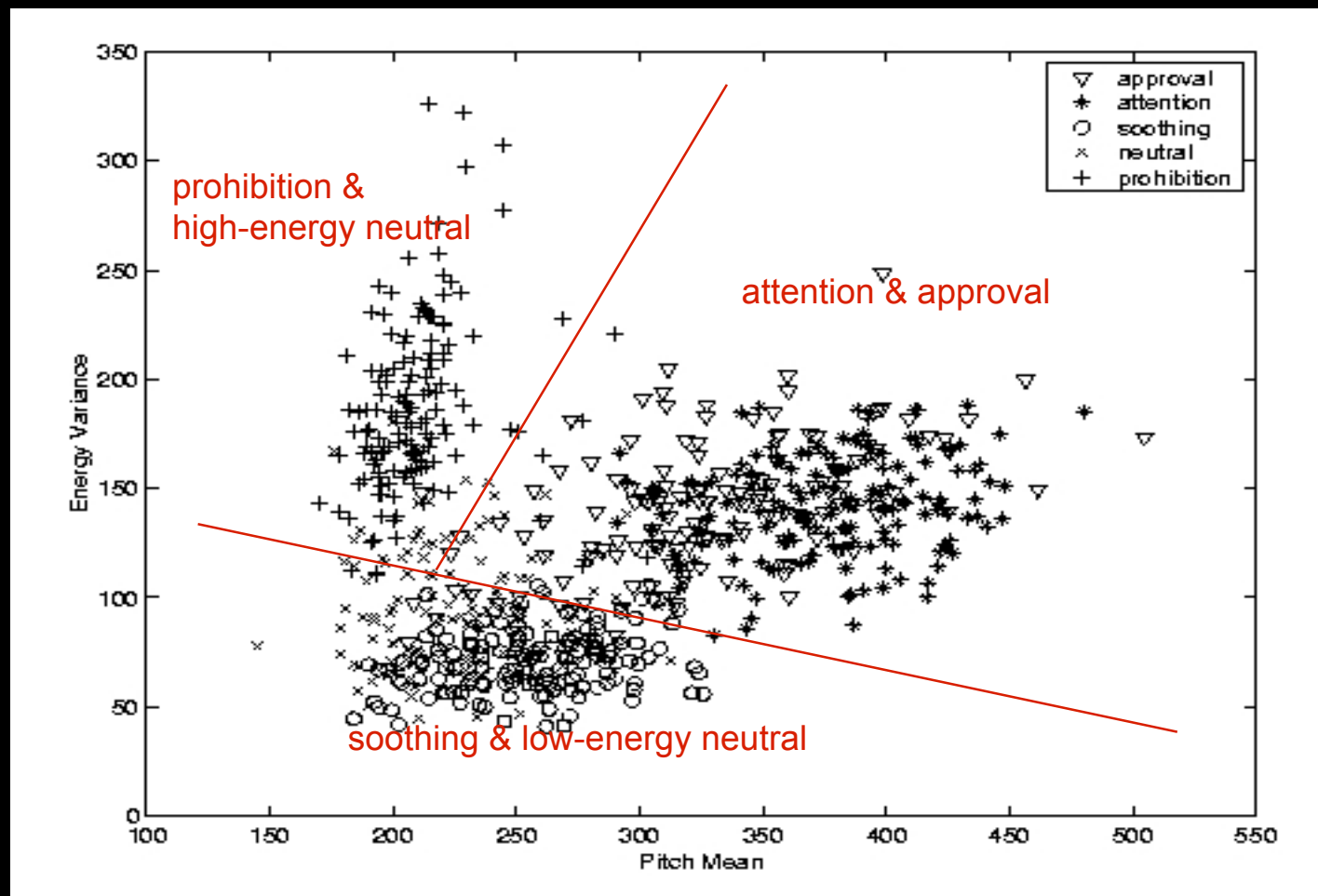
Multi-Stage Classifier Model
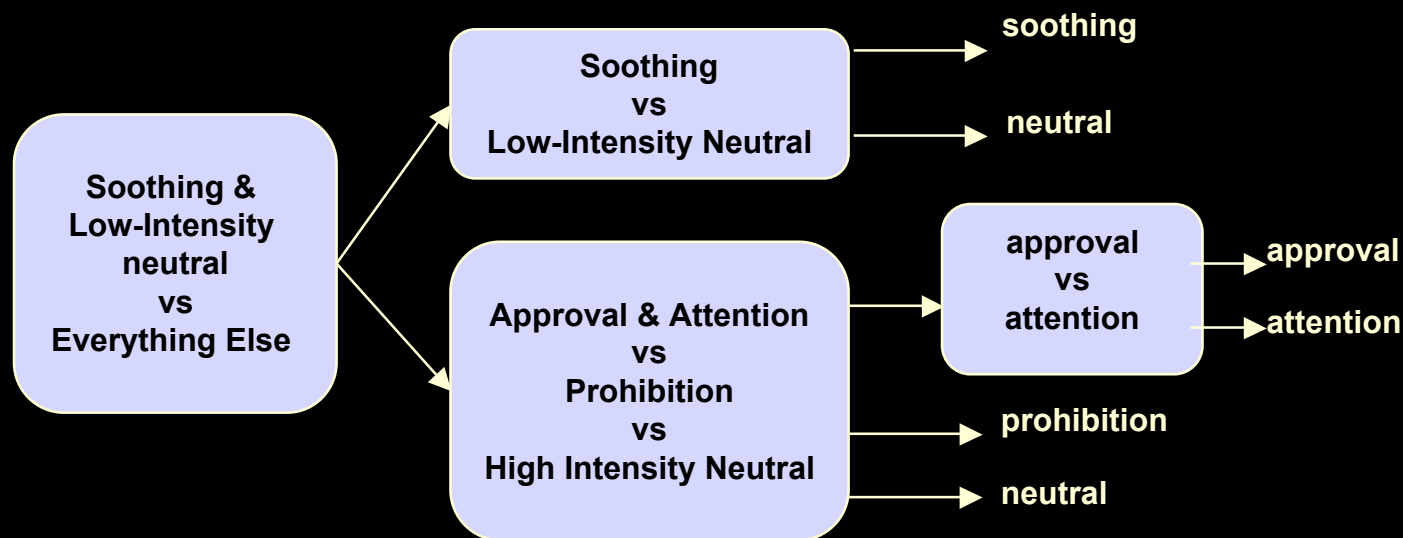
- **Each stage is simple for real-time performance**
- **Later stages use more Fernald contour characteristics**
- **Off-the-shelf learning mechanism for the stages (Mixture of Gaussian with EM)**

Results, Multiple Languages

Test set	Strength	Class	Test Size	Classification Result					% Correctly Classified
				Approval	Attention	Prohibition	Soothing	Neutral	
Caregivers		Approval	84	64	15	0	5	0	76.19
		Attention	77	21	55	0	0	1	74.32
		Prohibition	80	0	1	78	0	1	97.5
		Soothing	68	0	0	0	55	13	80.88
		Neutral	62	3	4	0	3	52	83.87
Naive speakers	Strong	Approval	18	14	4	0	0	0	72.2
		Attention	20	10	8	1	0	1	40
		Prohibition	23	0	1	20	0	2	86.96
		Soothing	26	0	1	0	16	10	61.54
	Medium	Approval	20	8	6	0	1	5	40
		Attention	24	10	14	0	0	0	58.33
		Prohibition	36	0	5	12	0	18	33.33
		Soothing	16	0	0	0	8	8	50
	Weak	Approval	14	1	3	0	0	10	7.14
		Attention	16	7	7	0	0	2	43.75
		Prohibition	20	0	4	6	0	10	30
		Soothing	4	0	0	0	0	4	0
		Neutral	29	0	1	0	4	24	82.76

Plutchik's Behavioral Homeostasis

Prototype	Function of the Associated Behavior	Emotion Associated	Activation Conditions for Kismet
Incorporation	Accept environmental stimulus	acceptance	Acceptance of a desired stimulus
Rejection	Get rid of something harmful already accepted	disgust	Attend to a salient but *undesired* stimulus
Protection	**Avoid being destroyed**	**fear**	Appearance of a threatening, overwhelming stimulus
Deprivation	React against important loss	sorrow	Loss of a desired stimulus
Orientation	React to a new or strange object	interest	Appearance of new, *salient* stimulus
Exploration	Explore environment	boredom	Need of a desired yet absent stimulus
Reward	Reinforce beneficial behavior	joy	Success in achieving goal of active behavior
Destruction	Remove barrier to achieve some need	anger, frustration	Delay in achieving goal of active behavior

Example of Protective Response

Top Level Behavior
satiate stimulation

Drive
stimulation

Behavioral context: desired vs. undesired stimulus

perceptual contribution to behavioral relevance

quality=intense nature=toy

Perceptions
large amounts of color and motion

Releasing Mechanisms
desired but intense toy

Behavioral Response
avoid toy

avoidance motor response

"tag" percepts with affective info (arousal, valence)

Somatic Markers
high arousal negative valence

Emotion Processes
"fear"

affective contribution to behavioral relevance

behavioral contribution to affective state

"fearful" Facial Expression, Voice quality

Emotive Facial Expressions
Russell, Smith & Scott

arousal

surprise

afraid

angry

elated

stress

excitement

frustrated

happy

displeasure — pleasure

neutral

sad

content

depression

calm

fatigued

relaxed

bored

sleepy

sleep
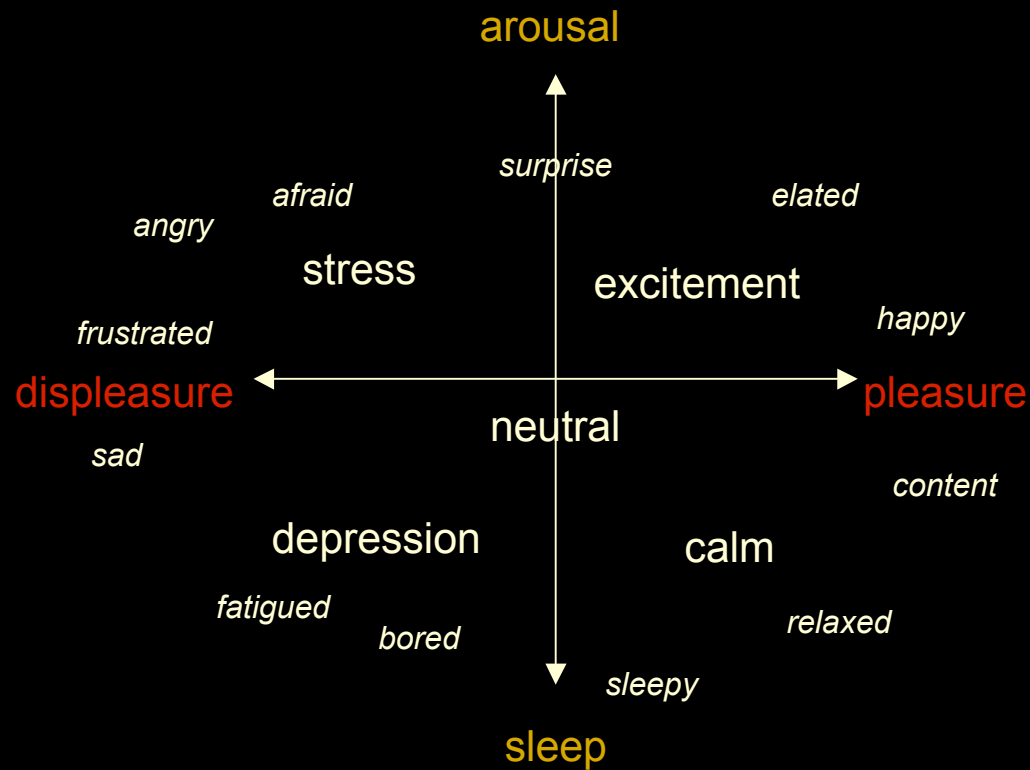
Face movement correlates to dimensions

Meaning	Facial Action							
	Eyebrow Frown	Raise Eyebrows	Raise upper Eyelid	Raise Lower Eyelid	Up Turn Lip Corners	Open Mouth	Tighten Mouth	Raise Chin
Pleasantness	↓				↑	↑	↑	↓
Goal Obstacle/Discrepancy	↑							
Anticipated Effort	↑							
Attentional Activity		↑	↑					
Certainty		↓		↑		↑		
Novelty		↑	↑					
Personal Agency/Control		↓	↓			↓		

Facial Expressions & Affective Assessment

Open stance

fear

Low arousal

Negative valence

accepting

tired

unhappy

content

surprise

disgust

Positive valence

High arousal

anger

stern

Closed stance
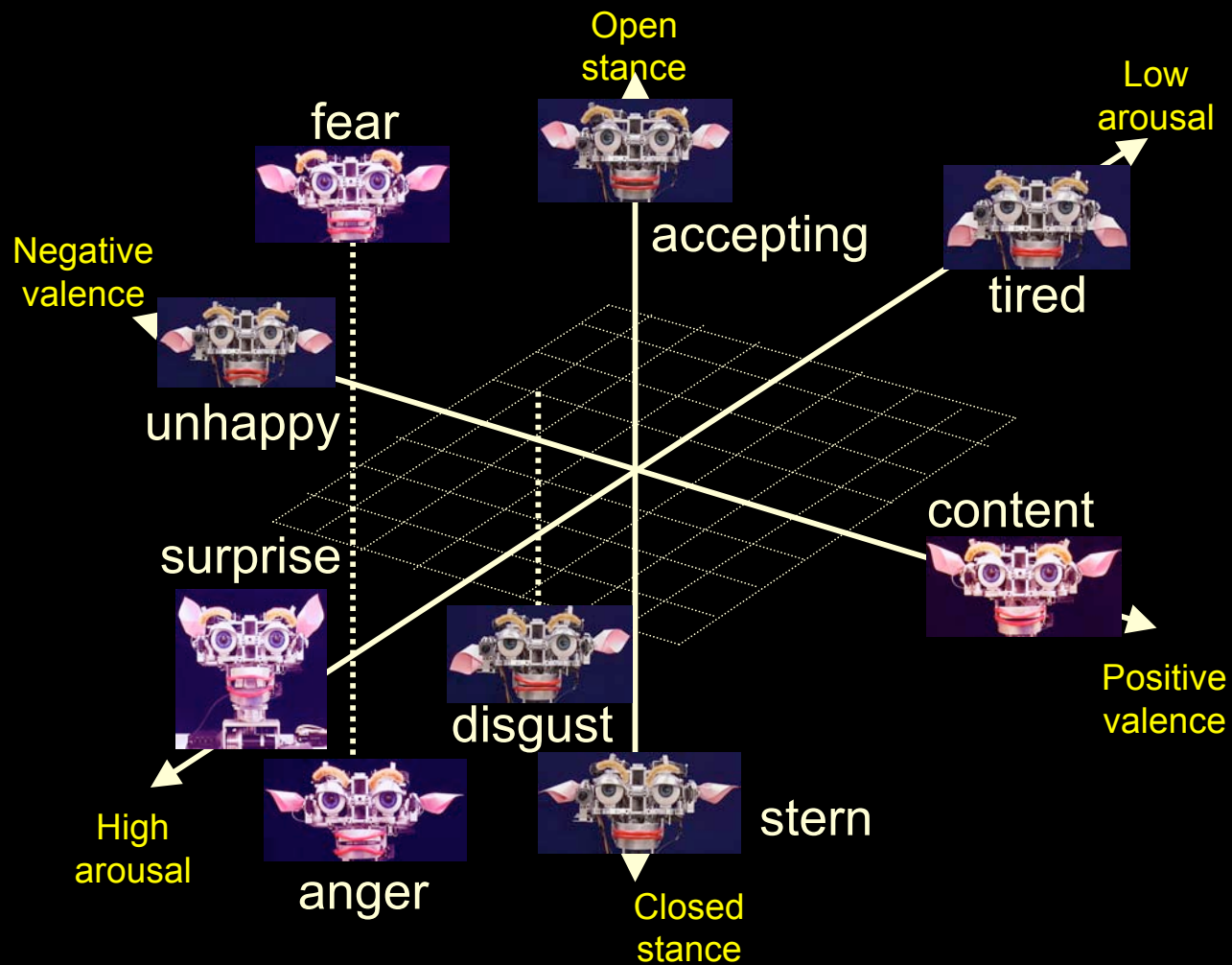
Multi-Modal Expression

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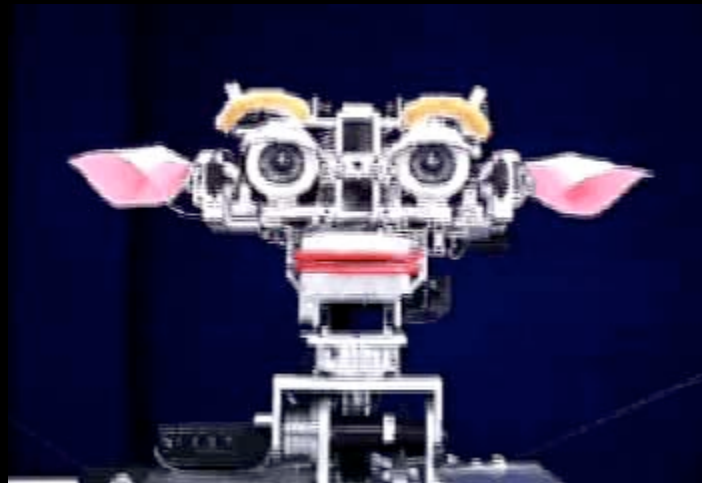
Evaluation of Emotive Expressions
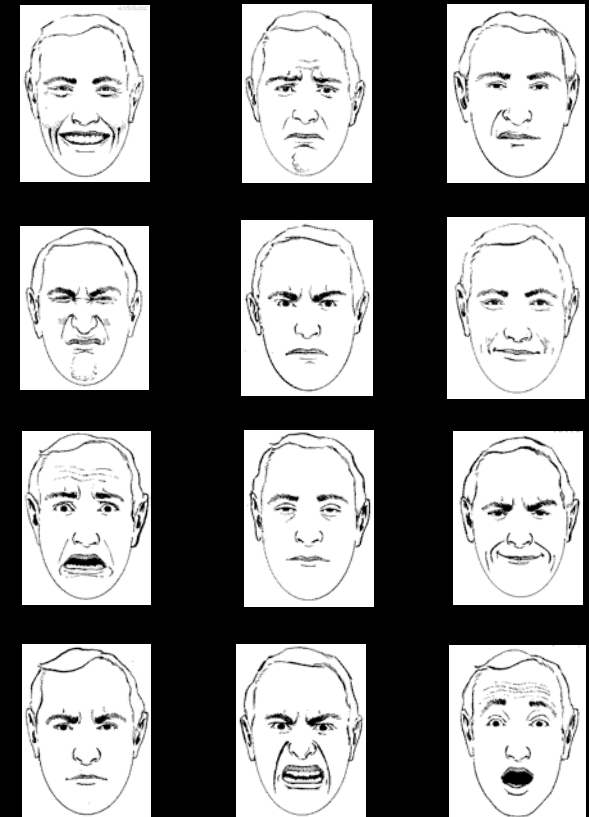
	most similar	%	comments
anger	anger	100%	shape of mouth and eyebrows are strongest reported cues
disgust	disgust	80%	shape of mouth is strongest reported cue
	sly grin	20%	described as "sneering"
fear	fear	70%	shape of mouth and eyes are strongest reported cues. Mouth open "aghast"
	surprise	10%	subject associates look of "shock" with sketch of "surprise" over "fear"
	happy	20%	lip mechanics cause lips to turn up at ends, sometimes confused with a weak smile
joy	happy	70%	report lips and eyes are strongest cues. Ears may provide arousal cue to lend intensity
	content	10%	report lips used as strongest cue
	repulsion	10%	lip mechanics turn lips up at end, causing shape reminiscent of lips in repulsion sketch
	surprise	10%	perked ears, wide eyes lend high arousal. sometimes associated with a pleasant surprise
sorrow	sad	90%	lips reported as strongest cue. Low ears may lend to low arousal.
	repulsion	10%	lip mechanics turn lips up and end, causing shape reminiscent of repulsion sketch
surprise	surprise	90%	reported open mouth, raised brows, wide eyes and elevated ears all lend to high arousal
	happy	10%	subject remarks on similarity of eyes, but not mouth
pleased	content	90%	reported relaxed smile, ears, and eyes lend low arousal and positive valence
	sly grin	10%	subject reports the robot exhibiting a reserved pleasure. Associated with the "sly grin" sketch
sly grin	sly grin	50%	lips and eyebrows reported as strongest cues
	content	30%	subjects use robot's grin as the primary cue
	stern	10%	subject report's the robot looking "serious", which is associated with "sly grin" sketch
	repulsion	10%	lip mechanics curve lips up at end. Subject sees similarity with lips in "repulsion" sketch
stern	stern	60%	lips and eyebrows are reported as strongest cues
	mad	10%	subject reports robot looking "slightly cross". Cue on robot's eyebrows and pressed lips
	tired	20%	subjects may cue in on robot's pressed lips, low ears, lowered eyelids
	sly grin	10%	subject reports similarity in brows.

random chance = 8%

Emotive Communication
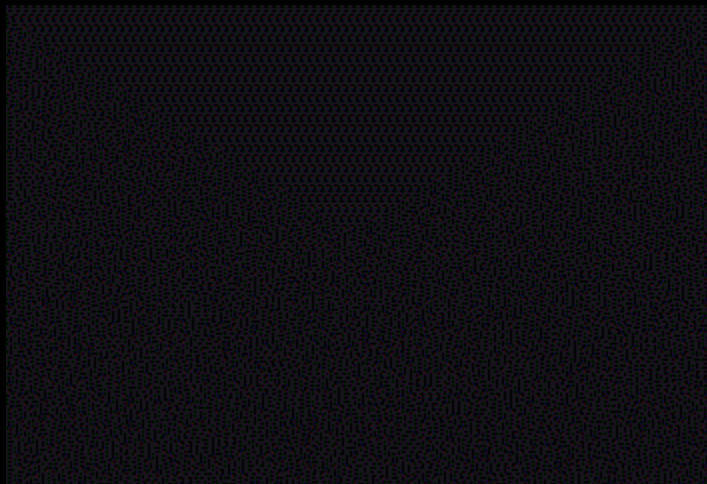
Movie of affective interaction

- All female subjects (n=5)
- 22-54 years of age
- Multiple languages
  - French, German, Indonesian, English, Russian
- Video recorded

Annotation of observable measures

Observable Measures for Communication of Affective Intent		
Cue	*Reading*	*Annotation*
Utterance	*utterance*	"*utter*"
Prosody	*pitch, energy, tempo*	Pr:
Body Posture	*neutral, erect, forward, away*	Bd:
Head Tilt	*neutral, up, down*	Hd:
Gaze Direction	*eye contact, glance/stare-down, glance/stare-up, glance/stare-right, glance/stare-left*	Gz:
Facial Expr	*neutral, relax, happy, sad alert, comforting, other*	Fc:
Ear Pose	*neutral, perk up, droop, fallen*	Er:
Lip Shape	*neutral, rounded, smile, frown*	Lp:
Acknowledge		*ack*
Sequential (across turns)		$\Longrightarrow, \Longleftarrow$
Sequential (within turn)		$\rightarrow$
Simultaneous		$\Longleftrightarrow$

Sample annotated interaction

Praising Intent Issued by Subject A

Trial	Utterance		Human		Robot
1	"Great job Kismet"	⟺	Bd:fwd, Fc:happy, Hd:up, Gz:eye-ct	⟺	Er:perk-up, Fc:neu, Hd/Bd:neu, Gz:eye-ct
2	"Way to go"			⟹	Gz:glance-up, Er:perk-up
3	"You're a smart robot"		Fc:happy	⟹	Gz:eye-ct, Lp:grin →, Fc:relax →, Fc:happy
4	ack				
5	"You're a cute robot"	⟺	Bd:fwd, Fc:happy, Hd:up, Gz:eye-ct	⟹	Lp:curve-up, Bd/Hd:neu, Gz:eye-ct
	(small gasp)	⟺	Bd:erect	⟸	
6	"You're so smart"	⟺	Bd:fwd, Lp:smile, Hd:up	⟹	Lp:curve-up, Gz:glance-up, Hd:up
7	"What beautiful eyes"	⟺	Fc:happy, Hd:up	⟺	Fc:happy, Hd:up
8	ack				
9	"Good job"	⟺	Bd:fwd, Hd:up, Gz:eye-ct, Fc:happy	⟹	Fc:neu, Hd/Bd:neu, Gz:look-right
10	"Good job"	⟹	Gz:stare-down		
11	"That was ingenious"	⟺	Bd:far-fwd, Gz:eye-ct	⟺	Bd:fwd, Gz:eye-ct
12	"What are you looking at? Great"		Body:fwd, Hd:up, Bd:sit-back	⟺, ⟹	Head:up, Er:perk-up, Gz:eye-ct
13	"Who's the pretty robot"	⟺	Bd:fwd	⟹	Fc:sad, Hd:down
14	"Oh no"	⟺	Bd:sit-back, Pr:soft,low, Fc:neu	⟸	
15	"You're great"	⟺	Pr:excited,high, Bd:far-fwd, Hd:up, Bd:sit-back	⟹, ⟸	Hd:up, Lp:smile, Er:perk-up

Prohibition Intent Issued by Subject C...continued

| Trial	Utterance		Human		Robot
3	"Bad robot"	⟺	Bd:fwd, Hd:far-dwn	⟹	Hd:far-dwn, Gz:hold-dwn, Bd:fwd
4	ack				
5	"Bad job"	⟺	Fc:stern, Hd:dwn, Gz:eye-ct, Bd:neu, Bd:sit-back	⟹, ⟸	Bd:lean-back, Fc/Hd:neu, Gz:eye-ct
6	"Don't take over the humans"			⟹	Er:drop, Hd:dwn
7	ack				
8	"No Kismet"	⟺	Pr:loud,deep	⟹	Hd:dwn, Gz:dwn, Er:drop →, Fc:sad
9	ack				
10	"That was so bad of you"	⟺	Bd:fwd, Fc:stern, Gz:eye-ct	⟺	Hd:bit-dwn, Gz:eye-ct, Er:bit-dwn
11	"Did you make potty on the rug" ("Oh sorry")	⟺	Bd:far-fwd, Hd:dwn, Pr:deeper,louder	⟺, ⟸	Gz:dwn, Hd:dwn→, Ers:fallen, Face:sad
12	ack				
13	"Kismet"	⟺	Face:stern, Hd:dwn	⟺	Gz:eye-ct, Hd:dwn, Er:drop
14	"Bad robot"	⟺	Hd:dwn, Pr:deeper, Hd:dwn	⟺	Gz:dwn, Fc:sad, Hd:dwn
15	ack				
16	"Dont do that to me"	⟺	Hd:dwn	⟹	Hd:dwn
17	"Dont look at me like that"	⟺	Pr:deeper, Hd:dwn	⟹, ⟸	Hd:up→, Hd:dwn, Gz:dwn, Er:drop
	ack				

Interaction Findings

- **Ready and effective use of expressive feedback in communication**
  - To acknowledge understanding
  - modulate intensity of their response
  - modulate intensity of robot's response to them
- **Internal states shared albeit not identical** (e.g., humans & dogs)
  - Empathic reactions
  - Affective mirroring
- **Natural, intuitive, understandable, enjoyable for human**
  - Design based on natural analogs

Functional Perspective
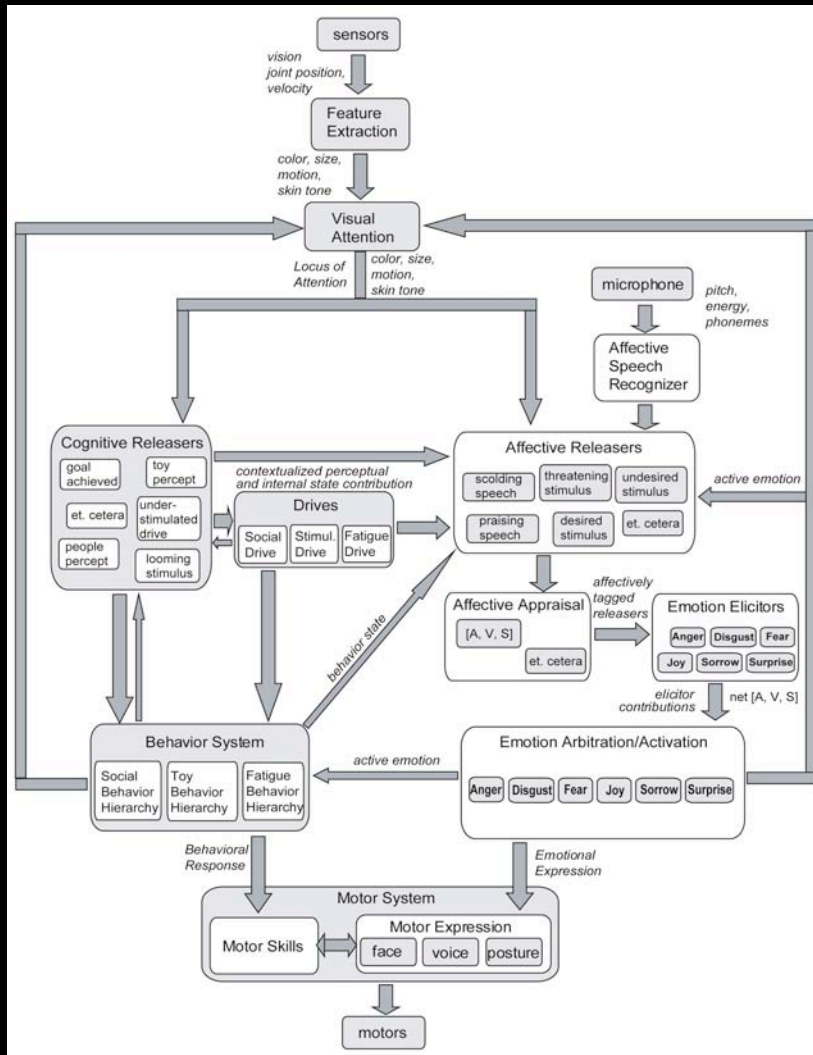
- **Performance perspective on "robot emotion"**
    - More opportunistic behavior
    - Appropriate persistence of behavior
    - Improved goal prioritization
    - Relevant saliency and attention
    - Better communication with human
    - …over cognitive system alone

Summary

- **Socially interactive robots**
  - Applied to entertainment and beyond
  - Personal robots that have appeal to humans for diverse applications
  - Take "emotion" seriously
- **Emotion & Design**
  - Impacts human Performance (car example)
  - Impacts Adoption of technology (wheelchair example)
- **Emotion & Intelligence**
  - In Humans
  - Principles, models, theories applied to robots

Robots in the World with People