Affective Social Robots

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Affective social robots: overview

- Designing social robots
- The expression of affect
- Modeling the development of affect in robots

Designing Emotions for Social Robots

Emotions for Social Artifacts

- **Conveying intentionality**
  - Coherent explanation for observed behavior
  - Emotions and personalities as sources of intentions
- **Eliciting emotions**
- Making humans **feel comfortable** about the interaction
  - Tailor interactions to meet human needs
  - Artifact more believable, "closer" to human
- **Enhanced communication**
  - Non-verbal communication
  - "deeper" understanding (what we *mean*, not what we say)

How to signal this? Face, body, behavior

EXAMPLES of useful things to signal in social interaction:

- **Happiness**:
  - Reinforcement of social bonds: produce openness towards others
  - Its expression indicates a disposition towards friendly interaction
  - Antidote against stress, “tonic”
- **Sadness**:
  - Reinforce social bonds: produce emphatic reactions, “ask for help”
  - Delay activity in motor and cognitive systems (change perspective, plan)
  - Signal that a problem is present
- **Anger**:
  - Mobilize energy
  - Direct bodily resources towards action muscles
  - Its expression can prevent aggression
- **Fear**:
  - Motivate escaping from dangerous situation
  - Its anticipation induces avoidance behavior

How to model this?

- **Desired features:**
  - Life-like impression
  - Believability, trust
  - Interactions adapted to humans

- **Problems:**
  - Which are the relevant features of emotions?
  - Choice of underlying model: categories or dimensions?
  - Complexity of expressions: caricature or portrait?
  - Mimic “surface” (“shallow”) characteristics, or is a “true” (“deep”) emotional system needed?

Life-like qualities?

- Giving the appearance of life to an observer …
- Qualities?
  – Simple features (e.g., movement)
  – Elements (e.g., faces)
  – Behavioral manifestations, e.g.:
    - Coherence
    - Personality
    - Similarity to animal/human behavior
    - Working towards survival

Some relevant features

- Impression of coherent behavior and personality (**believable**)
- **Face**:
  - Elements: mouth (lips), eyes, eyebrows, eyelids
  - Expressions: caricature, reproducing configurations of muscles (AUs)
- **Movement**: coherent, well synchronized, right timing
- Features activating the "**baby scheme**"
- Vocal **inflexion**

Design Challenges

- **Inspiration from nature?**
  - *Can we?*
  - *Should we?*
    - "Dangers" of extreme realism: over-attribution, delusion, frustrated expectations, lack of trust and believability
    - Avoid fooling people into believing an artifact is something else
    - Maybe not sensible to use same mechanisms for artifacts?
- **Human acceptance**
  - How to design artifacts accepted as social partners?
  - Key elements: believability, human is in control
  - Include individual differences, design for profiles, reflect "history" of emotional interactions

Surface or Beyond?

- When thinking of social interactions involving humans, **believability** is a big issue …
  - Is it enough to model “shallow” (observable) features?
    - Is this just “cheating”?
  - Do we need an underlying emotional system integrated in the architecture
    - More coherent long-term interactions, increased believability
- **“Shallow” modeling can teach us about e.g.:**
  - What makes us *perceive* emotional displays as believable
  - Human tendency to anthropomorphize: why, how to exploit it in our designs (designing for the human)

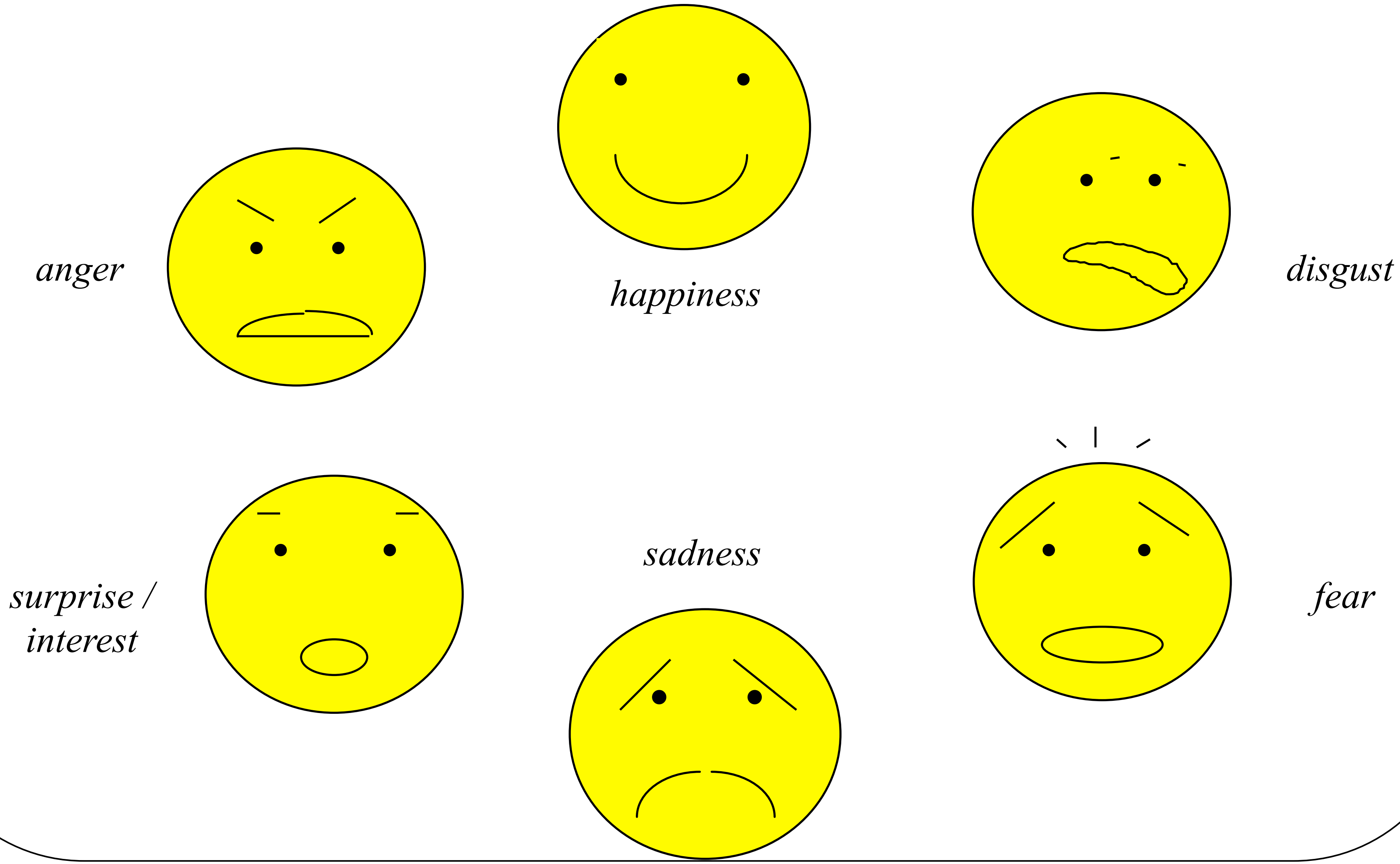
To summarize …

- **Giving artifacts emotions makes sense in many cases (not in all!)**
  - Single artifact: increase autonomy, enhance adaptation, life-like behavior
  - Social interactions: adaptation to social partner, believability, impression of life
- **"Two sides" of emotions:**
  - Monitoring system (internal and external environment)
  - Communication, social interaction
    - ➢ Design a morphology adapted to emotional and social interactions
- **Is this the same as ??**
  - Internal/"deep" emotion system vs.
  - "shallow" external features?
- **Do we need both aspects to achieve "life-like" artifacts?**

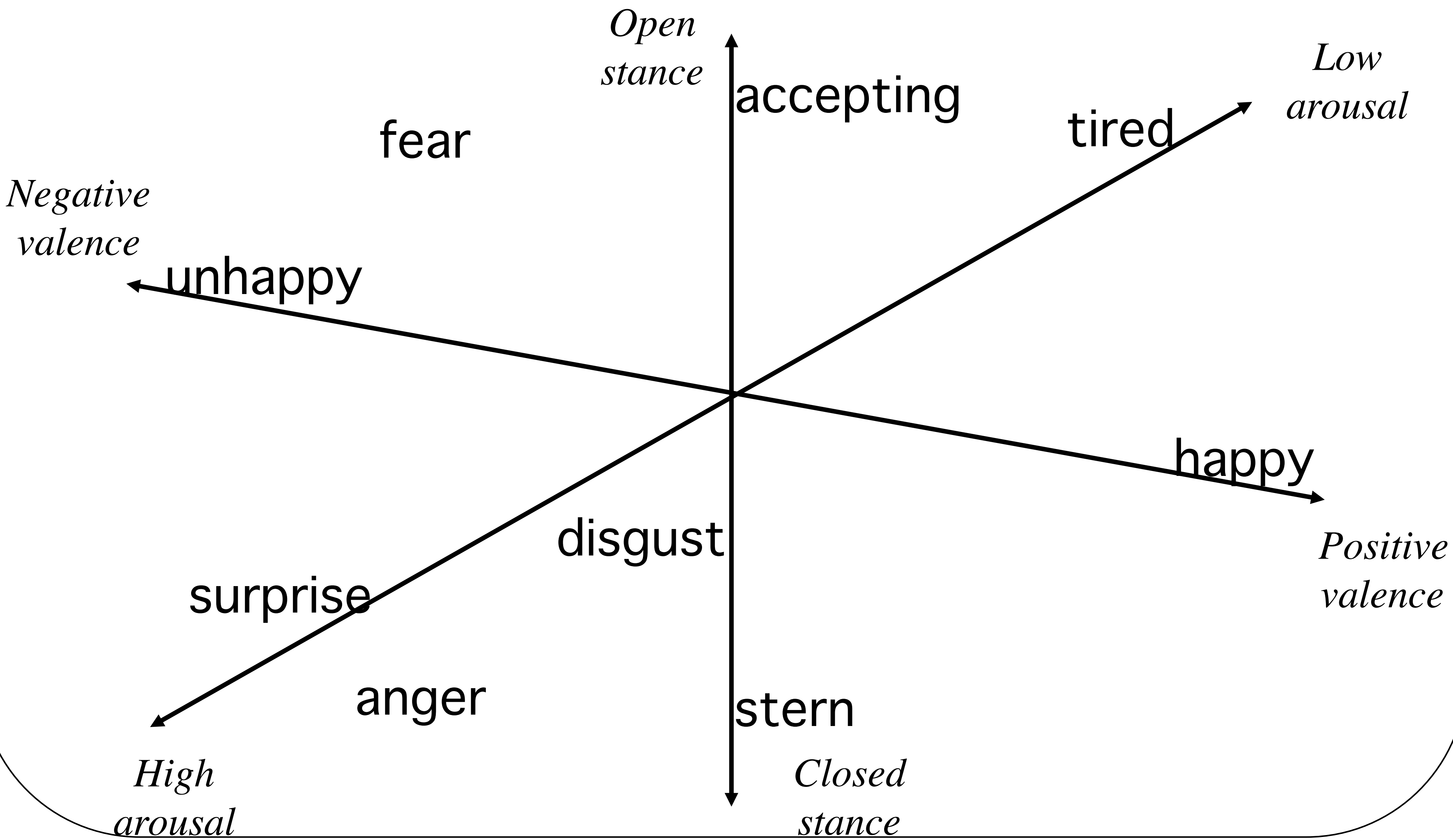
✓ ***Do not put more emotion into the system than what is required by the complexity of the system/environment interaction***

Affect Expression in Robots: robot faces and bodies

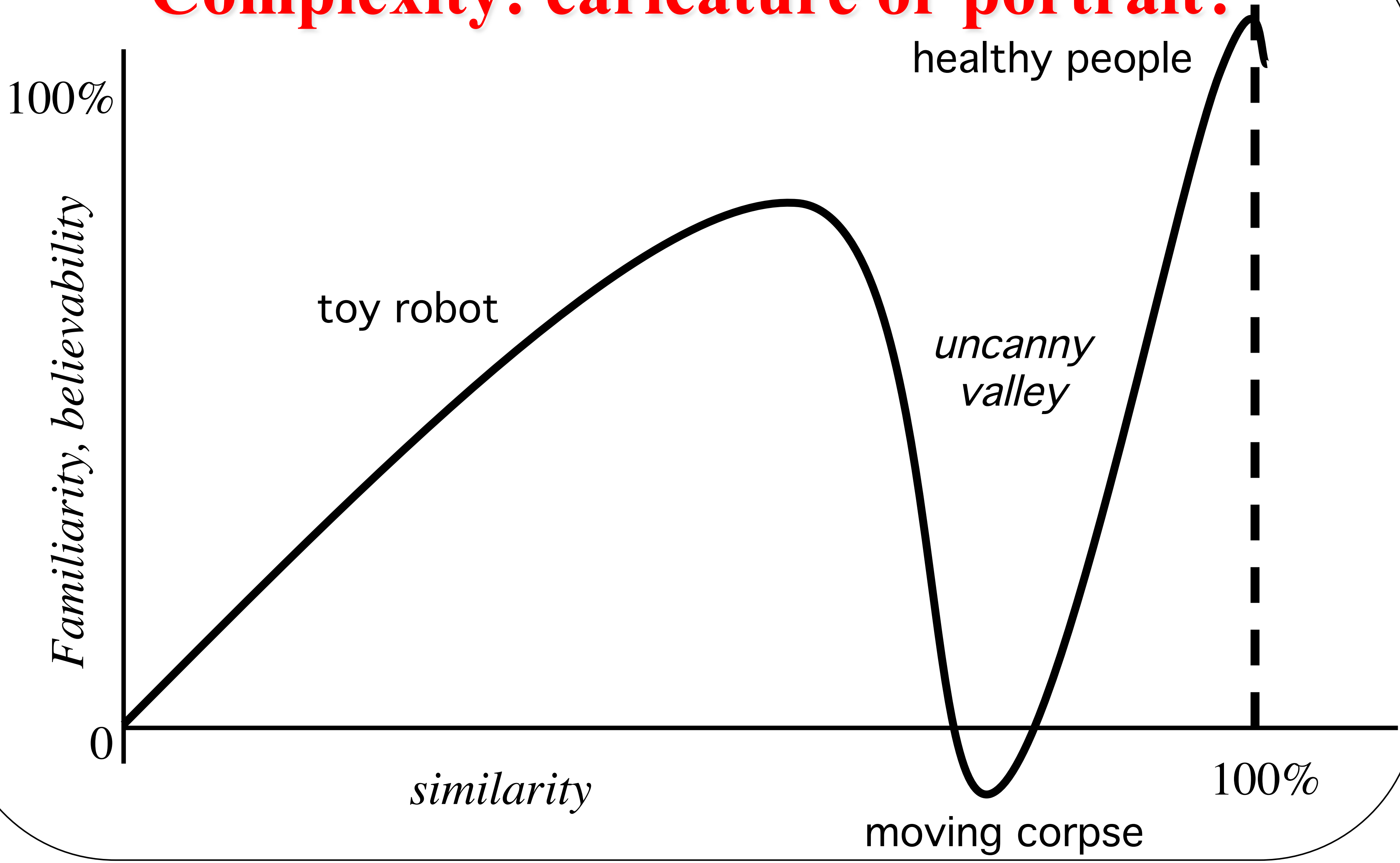
Choice of model: categories?



Choice of model: dimensions?



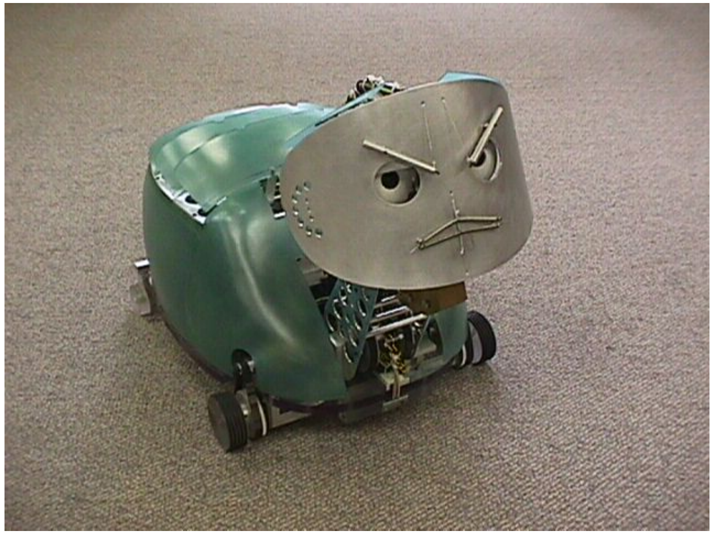
Complexity: caricature or portrait?

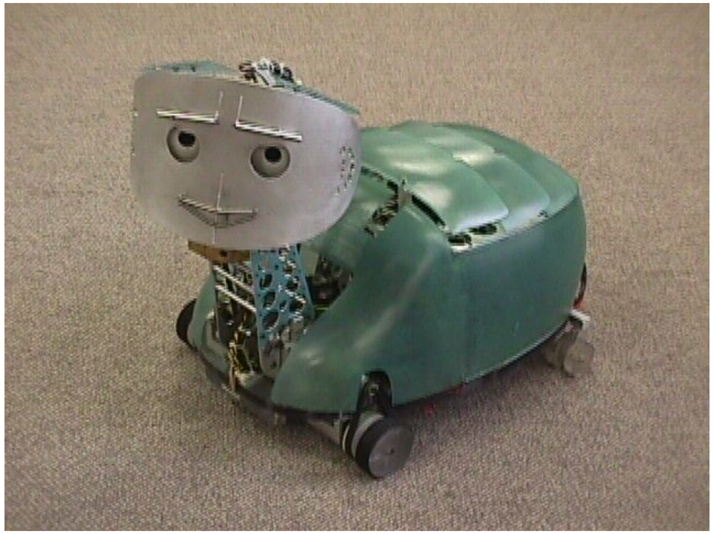


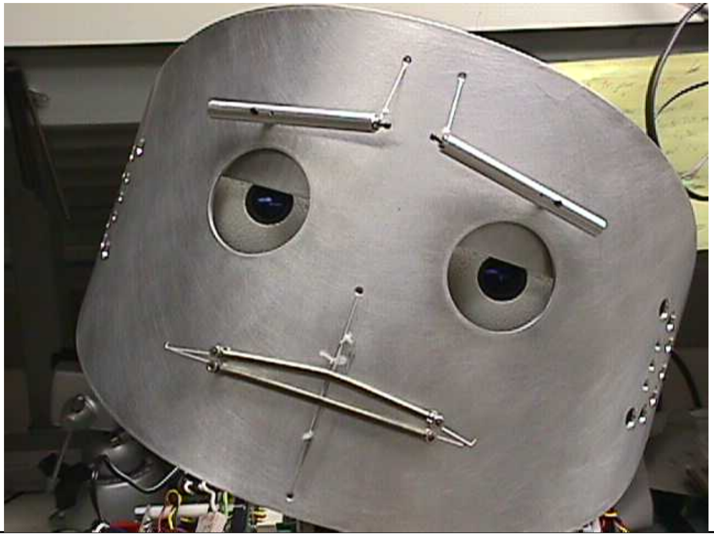
Sparky: the teleopareted robot (M. Scheeff)

- **Tele-operation** to allow for richer social interactions to emerge
- Focus on **human reactions** during interactions
- Modalities of **interaction**: tactile, sound, visual
- Modalities of **emotional expression**:
  - Face (4 DoF): 4 basic expressions
  - Vocal inflexion
  - Movement, body posture
- **Observed behaviors** (children and adults, lab and museum):
  - Touch the robot (back, face, head)
  - Talk to the robot using "pet talk"
  - Mimic the robot's movements and expressions
  - Empathic responses (not all boys!)

Sparky "in action"







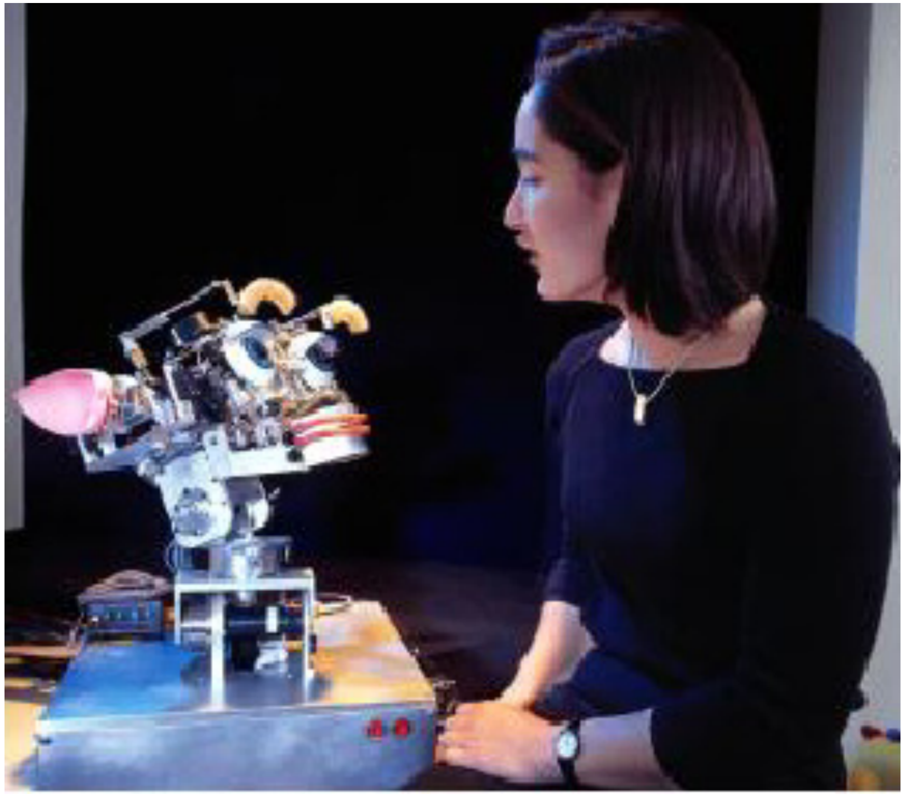
Kismet: The sophisticated head (C. Breazeal)

- "Sociable" robotic head, platform for social interactions and learning (**infant/caretaker situations**)
- High **complexity** at different levels: mechanics, architecture, facial expressions (21 DoF controlled by 18 PCs, 4 operating systems)
- Modalities of **interaction**: visual, acoustic
- Modalities of **emotional expression**:
  - Facial: expressions based on componential (dimensional) model
  - Vocal inflection (proto-language)
  - Movement, posture
- Emotions used as mechanisms to control interactions with human
- Very expressive, but "distinct" emotions not always easily recognized
- Needs more systematic testing of expressions…

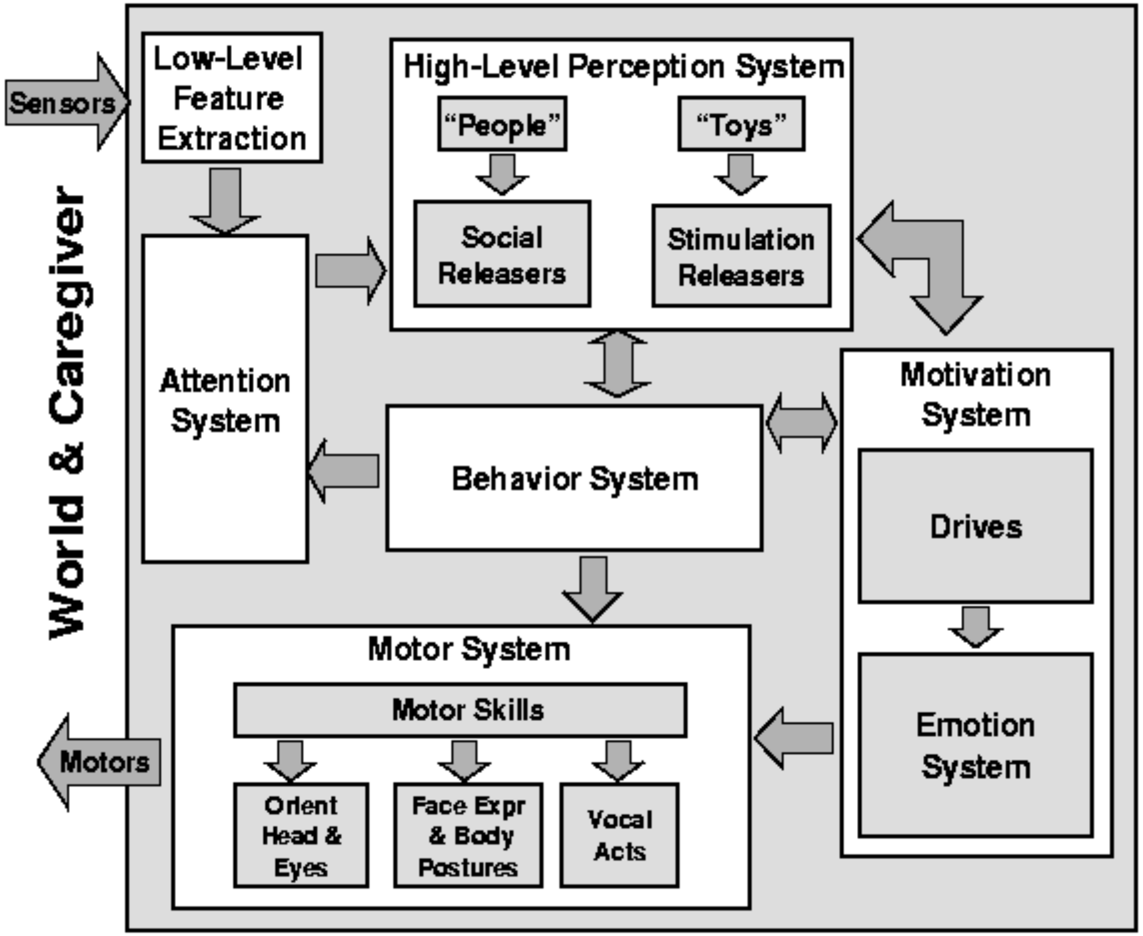
Kismet and its caregiver

Videos of Kismet:

- https://www.youtube.com/watch?v=NpbCPNoLqd0
- https://www.youtube.com/watch?v=Kw-gOmJwzuc
- https://www.youtube.com/watch?v=dKZczUDGp_I



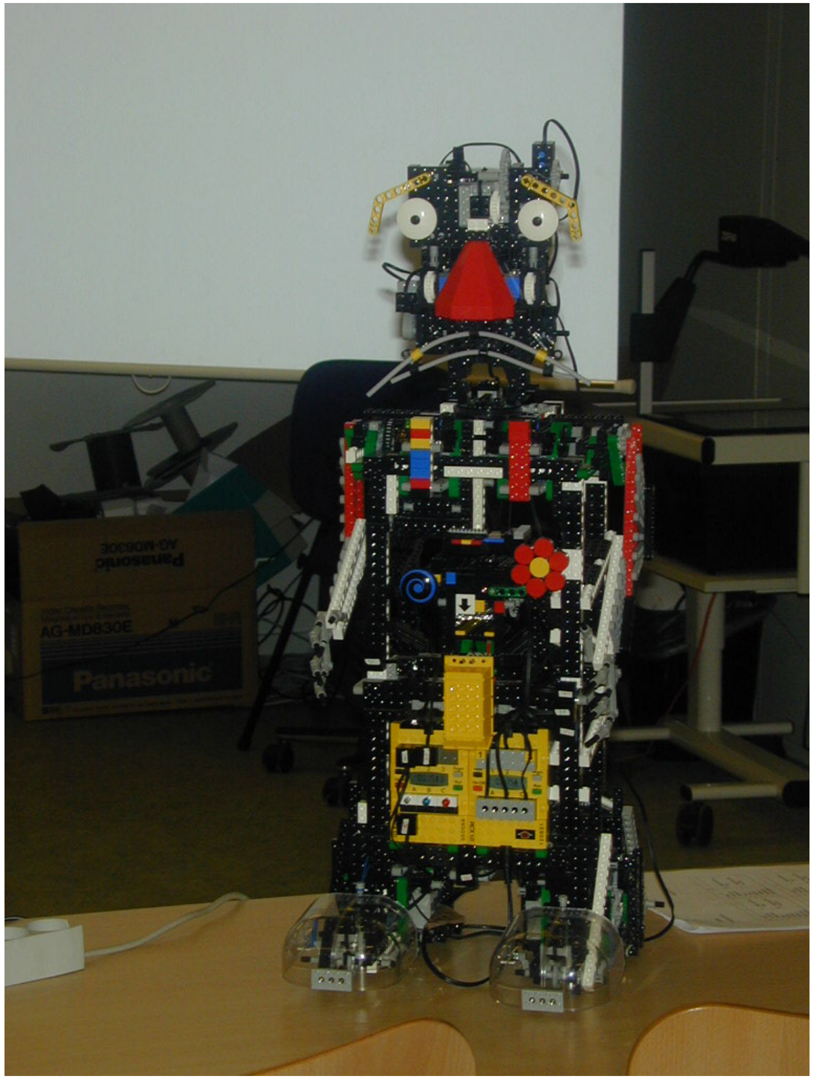
Kismet’s architecture



Feelix: A simple "humanoid" (L. Cañamero)

- **Plausible interactions with very simple LEGO robot**:
  - Focus on interaction as main functionality (not task-specific interaction)
  - Exploit the potential robots offer for physical (tactile) manipulation
  - Explore roles of different sensory modalities in social/emotional interaction
- **"Rich enough" interaction, varied emotional responses**:
  - Easily recognizable emotions: "basic" set with associated prototypical expressions
  - Minimal set of features needed for plausible emotional expression and interaction
    - > how much emotion can be recognized from the face alone?
  - Explore/exploit human tendency to anthropomorphize
- Implement and **test** psychological models using a robot

Feelix



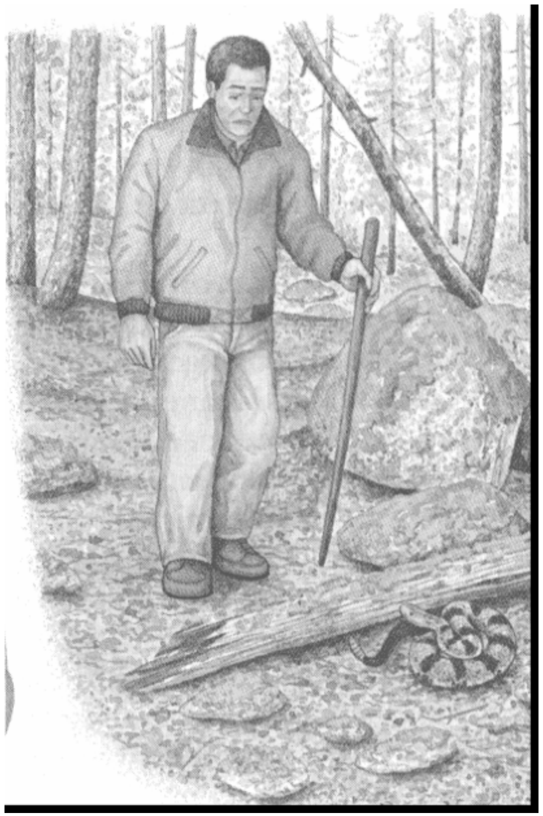
Feelix's emotion model

- **Facial expressions**:
  - Division of face in 2 halves (upper, lower), **perceptual primitives**
  - Expressive **features** (4 DoF): eyebrows, mouth (2 lips)

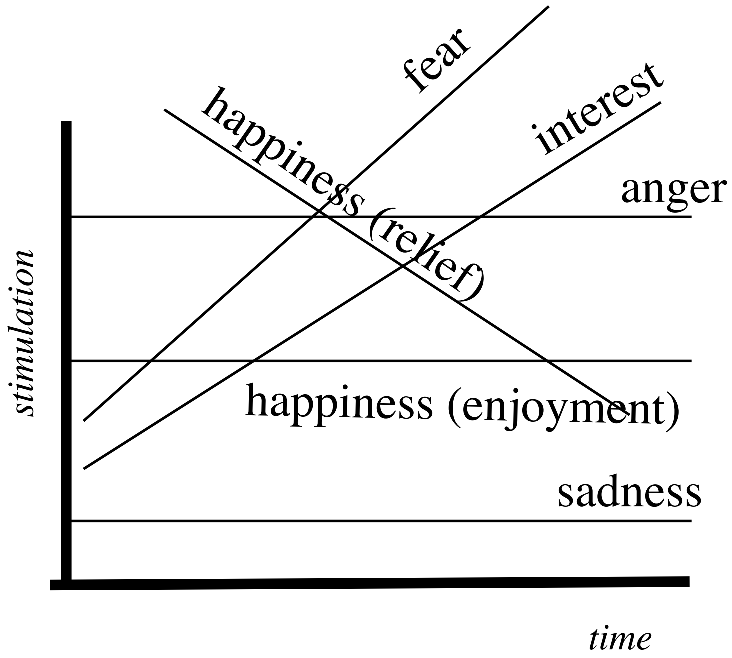
- **Emotion activation through interaction:**
  - **Tactile** stimulation: duration and frequency of presses
  - General activation **patterns**:
    - Sudden stimulation increase: ***surprise***, ***fear***
      - (very) few short and frequent presses
    - Sustained high stimulation level (over-stimulation): ***anger***
      - many short and frequent presses / very long presses
    - Moderate stimulation: ***happiness*** (enjoyment)
      - "nice" presses (not too long, not too short, not too many)
    - Sustained low stimulation level: ***sadness***
      - absence of / very few presses

Emotion activation

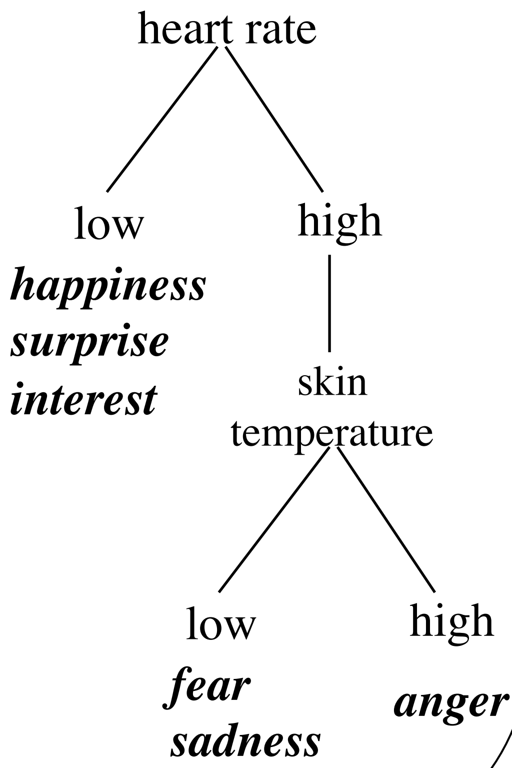
Significant event



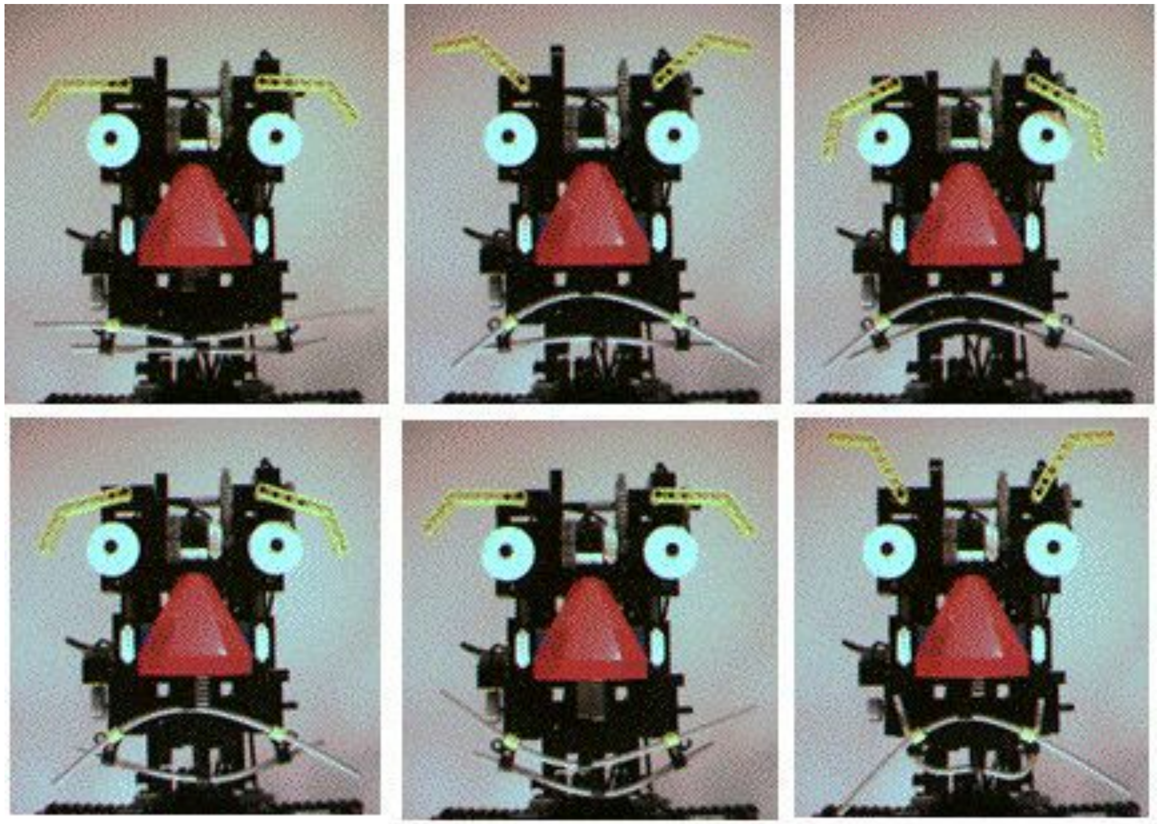
General patterns



Specific patterns



Feelix's emotional expressions



Playing the emotion game with Feelix

- **Tests on recognition of emotional expressions**
  - Three tests: (1) free; (2) multiple-choice; (3) human faces
  - Results congruent with cross-cultural studies by psychologists
- **Interesting observations!**
  - *During emotion recognition*:
    - People mimicking Feelix's face to identify the emotion
    - "Empathy": people mirroring the expression with face and vocal inflection while commenting ("Ooh, poor you", "Look, now it's happy!")
  - *During interaction with Feelix*:
    - People mirroring the emotion they wanted to elicit:
      - With their faces
      - In the nature of the presses applied to the feet

Results on emotion recognition

Subjects: 41 children, 45 adults. 3 tests: 1) free, Feelix; 2) multiple-choice, Feelix; 3) human faces

1) F-F	**Anger**	**Happiness**	**Fear**	**Sadness**	**Surprise**	*Average*
Children	64%	93%	0%	83%	17%	64% (52%)
Adults	57%	64%	2%	81%	29%	58% (47%)

2) Mc-F	**Anger**	**Happiness**	**Fear**	**Sadness**	**Surprise**	*Average*
Children	44%	57%	22%	57%	37%	49% (43%)
Adults	37%	62%	9%	84%	36%	55% (46%)

3) F-H	**Anger**	**Happiness**	**Fear**	**Sadness**	**Surprise**	**Disgust**	**Contempt**	*Average*
Children	100%	100%	64%	79%	50%	29%	0%	70% (60%)
Adults	71%	98%	62%	91%	93%	76%	0%	82% (70%)

Affect Space for bodily expression of emotions in humanoid robots (Beck et al.)

- Use of body posture and movement
- Valence, arousal, stance
- Bodily expression can convey both general arousal / valence, but also specific emotions
- Face and body can convey similar or contradictory information
- Affect Space for humanoid robots:
  - Analysis of what different expressive elements contribute to perceived emotion
  - Methods from animation used
  - Example: effect of head position on the perception of emotions?

The three main questions tested were:

(Q1) Is it possible for participants to correctly identify the key poses displayed by Nao?

(Q2) Is the effect of moving the head similar across all the key poses? In other words, is the contribution of head position independent from the rest of the expression?

(Q3) What is the effect of changing the head position on the interpretation and perceived place of a key pose in the Affect Space?

Affect Space, emotion blends: head position

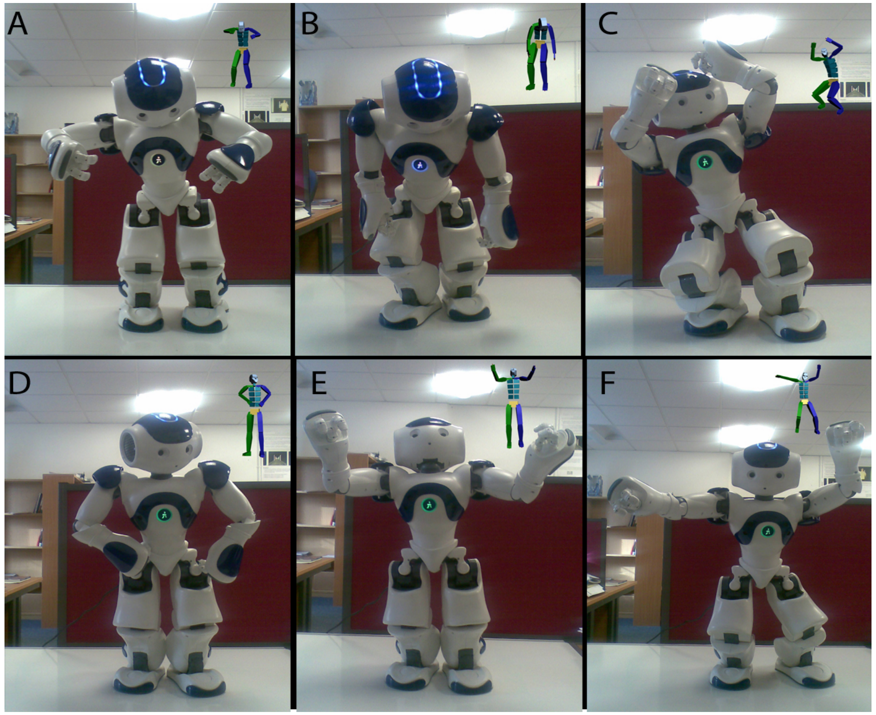
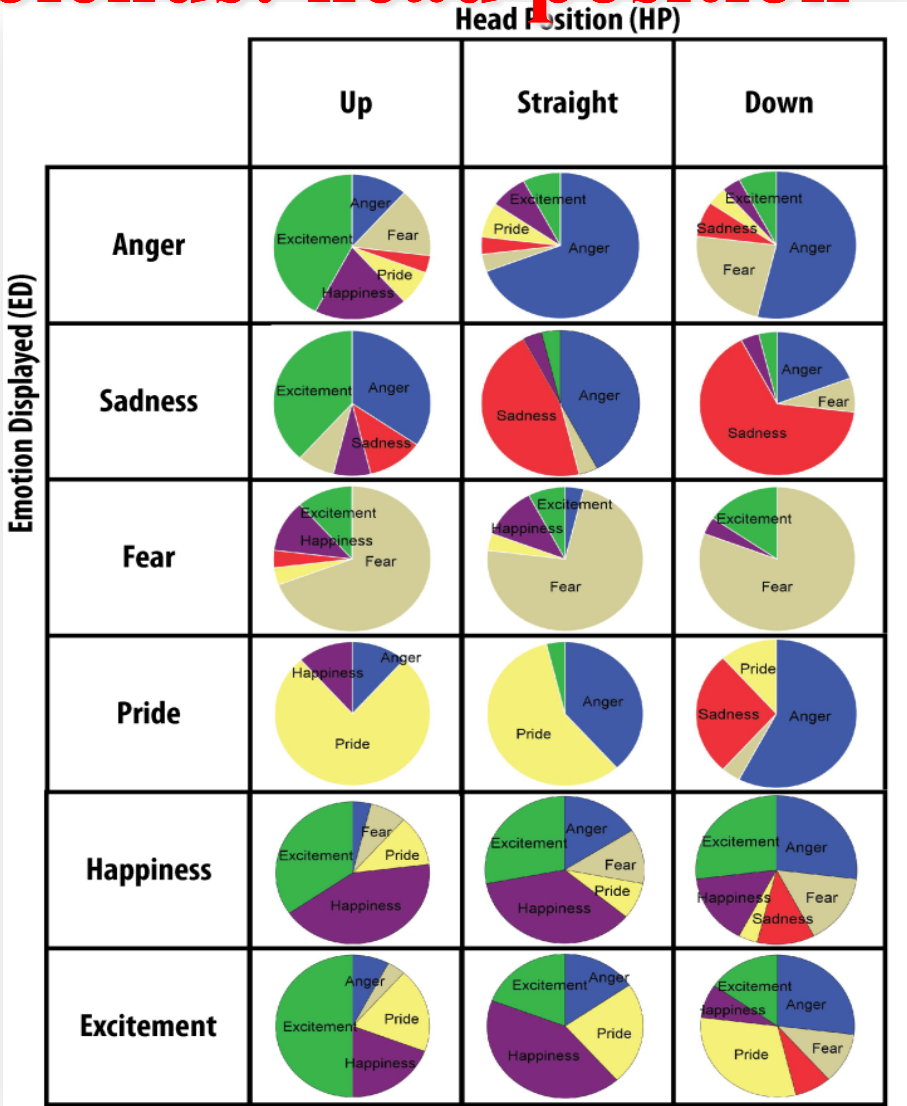


Table 1. Percentage of participants who correctly identified the emotional key pose at least once (Chance level would be 42%)

Pride	Happiness	Excitement	Fear	Sadness	Anger
100%	83%	63%	92%	92%	58%



Modeling the development of affect in robots

Development of affect in robots:

- Modeling the development of affect in robots as a method to build robots that learn from people and develop adapted to their future users
- Affective phenomena involved:
  - Imprinting
  - Dyadic coordination
  - Attachment
  - Role of caregiver
  - Role of sensorimotor experiences on affective/cognitive development (epigenetic model)
- Robotics research project on emotional development in robots:

FEELIX GROWING EU-funded project, coordinated by Lola Cañamero.

Videos:

- *Project overview*, https://www.youtube.com/watch?v=96_h79ffiJA
- *Robot nursery*, https://www.newscientist.com/article/dn16644-video-sociable-robots-learn-to-get-along-with-humans/?jwsource=cl

Attachment and social bonds

- Humans are social mammals
  - Affiliate into groups, tribes, etc.
  - Attachment and child rearing
  - Territoriality
  - Dominance hierarchies

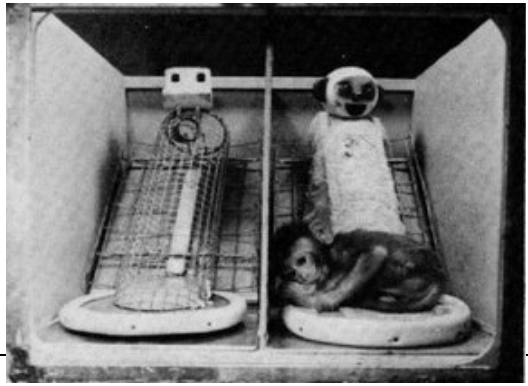
- Attachment as "drive" to maintain proximity / accessibility to a caregiver

- Most mammal species show some kind of bond between caregivers and young

- Non-human primate infants behave almost identically to human infants in most attachment experiments








Imprinting and adaptation to caregiver

- Initial imprinting to caretaker at particular distance
- Robot learns and tries to reproduce sensations associated with comfort

- History of affective interactions, + or - memory at different time scales

- Comfort facilitates learning
- Interaction driven by “comfort” / “distress” responses in robot (right interaction dynamics)
- Right balance between exploration, exploitation (depending on affect => openness to novelty)

Arnaud Blanchard’s PhD thesis (2006).
Blanchard, A. & Cañamero, L. (2005,2006). Proc. EpiRob Conferences.
Cañamero, L., Blanchard, A., Nadel, J. (2006), Intl. J. Humanoid Robotics.

Attachment: security, regulation, learning

Videos 1-4: courtesy of Kim Bard, University of Portsmouth, UK

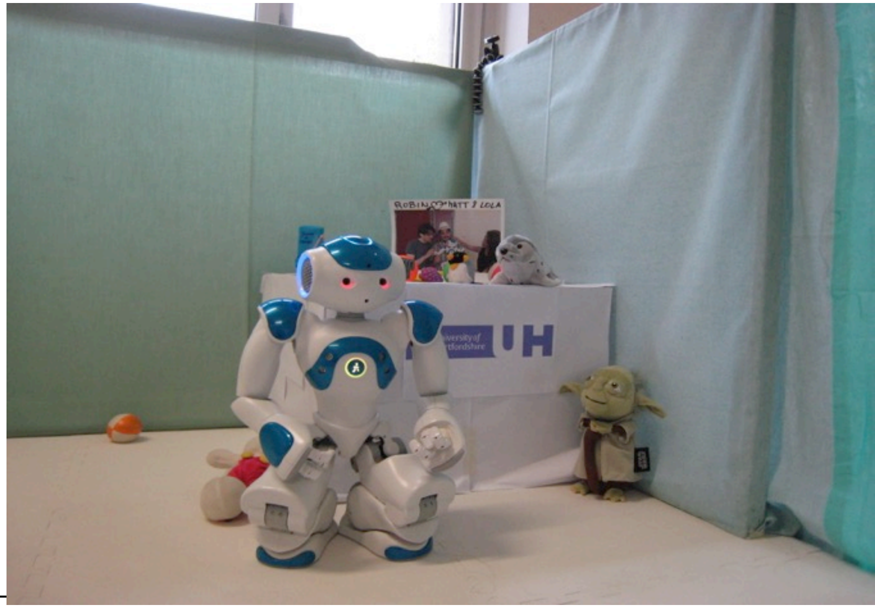
Videos 5-6: Antoine Hiolle's PhD thesis, UH (2015)

Videos:

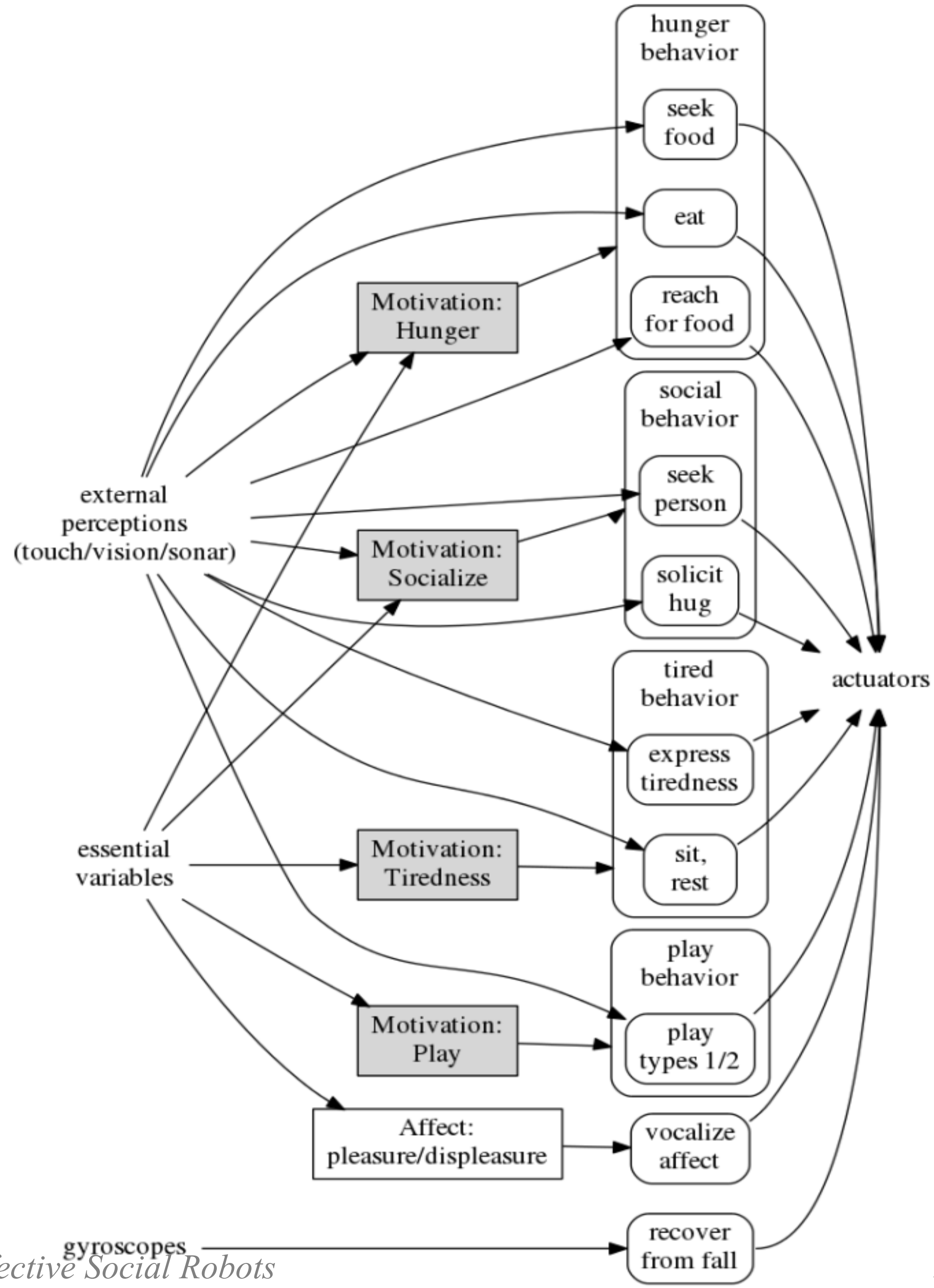
- Attachment in robots, https://www.youtube.com/watch?v=tndSnyUWqBI
- Attachment in chimpanzees, https://www.youtube.com/watch?v=pjG4PS2vJUg

An affective autonomous toddler to support self-efficacy in diabetic children

- ROBIN:
  - Like the children, has diabetes
  - Needs help from children to “manage” his diabetes, children become the “responsible grown-ups” and learn to apply their knowledge
  - Lewis & Cañamero, RO-MAN 2014; ICSR 2015; Cañamero & Lewis, Intl. J. Social Robotics, 2016
  - **Video**: https://youtu.be/ua4ppBWvajE



Robin’s Action Selection Architecture



Hormonal modulation of development

(Lones & Cañamero, ICDL-Epirob 2013; Lones, Lewis & Cañamero, ALIFE 2014, ICDL-Epirob 2014, Frontiers 2016)

Interaction with the environment

Secretion of hormones

Hormone imbalance triggers epigenetic mechanism

Potentially results in adaptive behaviour

- In biological models Cortisol and Testosterone are two of the more studied epigenetic hormone triggers:
  - Cortisol exposure leads to the emergence of an withdrawn phenotype
  - Testosterone is linked with the emergence of an outgoing phenotype
- Hormone levels trigger epigenetic change by causing up- and down-regulation of their own receptor
- These mechanisms tend to be more powerful during “critical developmental stage”

Hormonal modulation of development: Robot model

Three homeostatic variables (0<x<100)

- **Energy**, Derived from battery level
- **Health**, Decreases with physical contact
- **Temperature**, Sensed internally

Each variable has an associated hormone secreted in relation any deficits

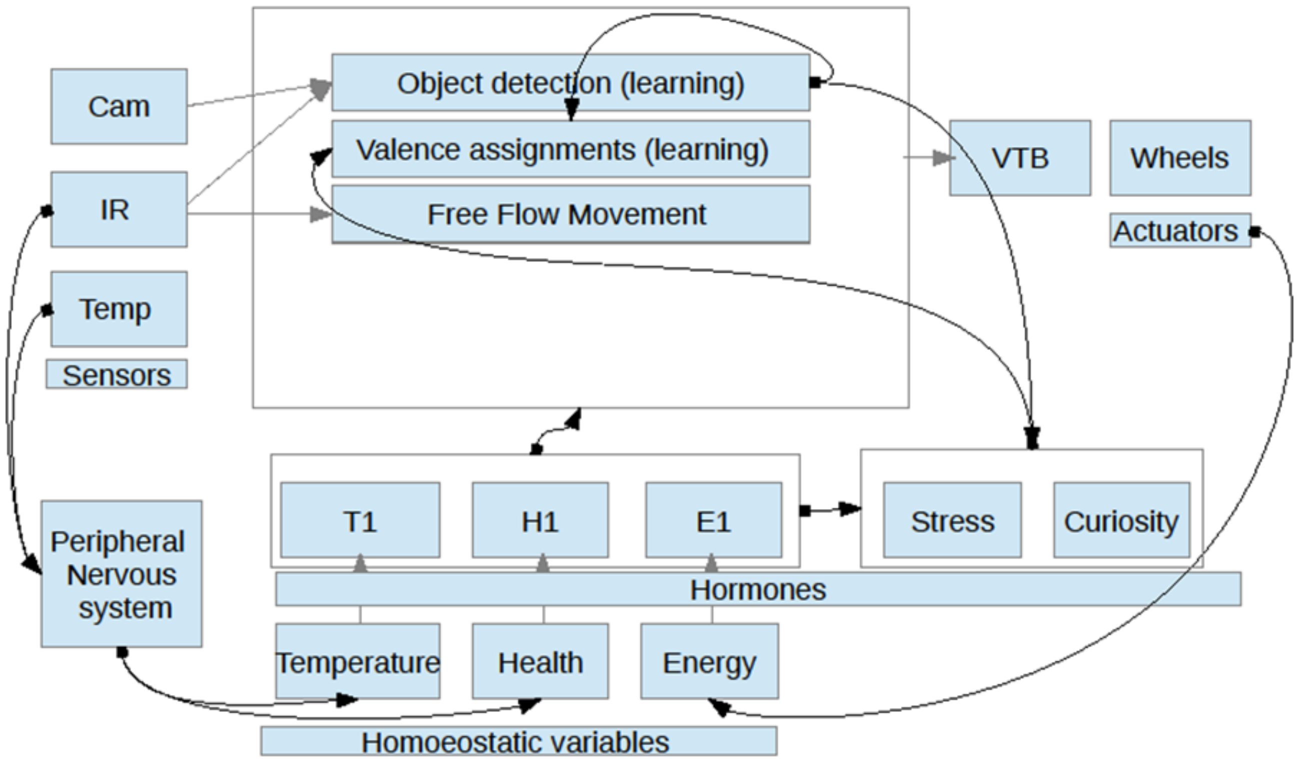
Two Neuro-Hormones

Secreted in relation to internal state and environmental conditions

Curiosity – an abstract take on Testosterone (T), secreted when homeostatic variables are high

Stress – an abstract take on Cortisol (CHT), secreted when homeostatic variables are low or robot over-stimulated

AS Architecture



Pre-trained GNN used to determine novelty

Object type	Novelty value
Smaller	Low
Same size	Medium
Larger	High
Wall	Negative
Hole/gap	Very High
Movement	Low-High

Hormone Name	Encouraged behaviour	
Curiosity	Outgoing behaviour such as Exploration, Thrill seeking, Learning	
Stress	Withdrawn behaviour such as Wall following, Avoidance	
E1 (Energy)	Recover of homeostatic deficits	Suppression of high cost modules
H1 (Health)		Increased desire of personal space
T1 (Temperature)		Reduced speed

Developing with a caregiver

Developing with a caregiver

Positive Environment	Negative Environment
Attentive to needs	Neglectful to needs
Appropriate levels stimulation	Over & under stimulation
Allow the robot to dictate the interaction	Fast, sudden movements

Video:

https://www.youtube.com/watch?v=B5UnGRsYD74&feature=youtu.be

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Link to Lola's publications: http://www.emotion-modeling.info/publications

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- Lones, J., Lewis, M., and Cañamero, L. (2018). "A Hormone-Driven Epigenetic Mechanism for Adaptation in Autonomous Robots", *IEEE Transactions on Cognitive and Developmental Systems*, vol. 10, no. 2, pp. 445–454, 2018.