Affective Computing for Game Design

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Examples of Future Trends in Affective Gaming

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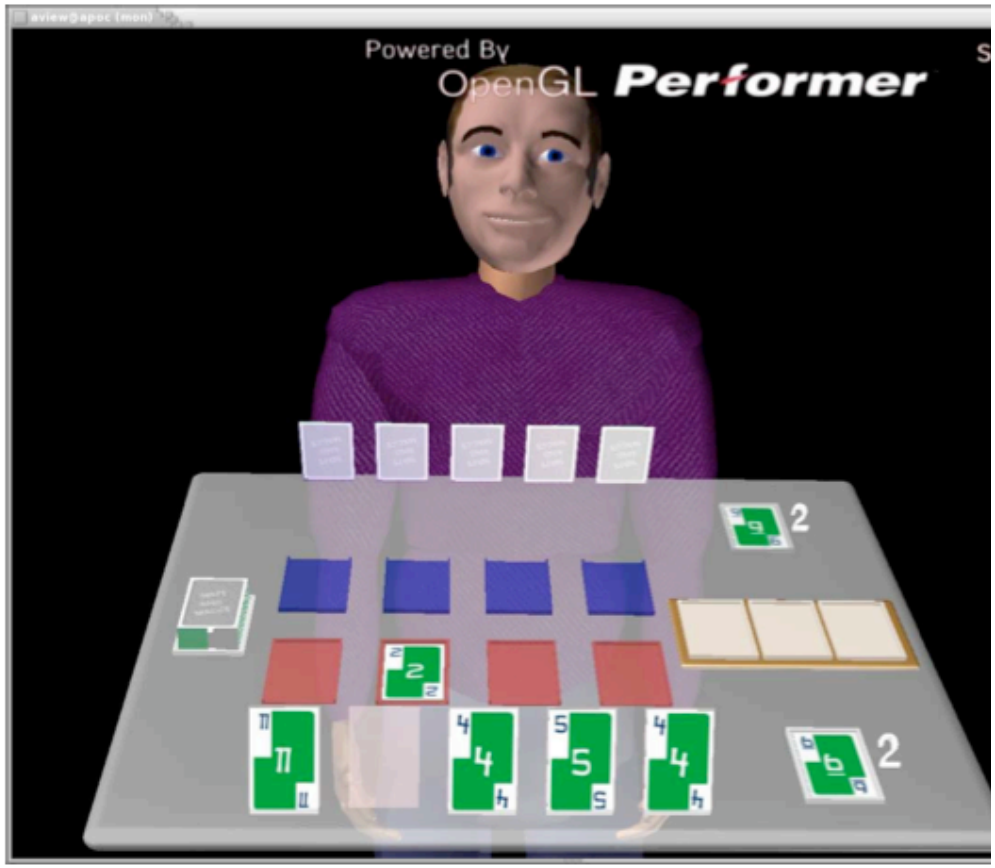
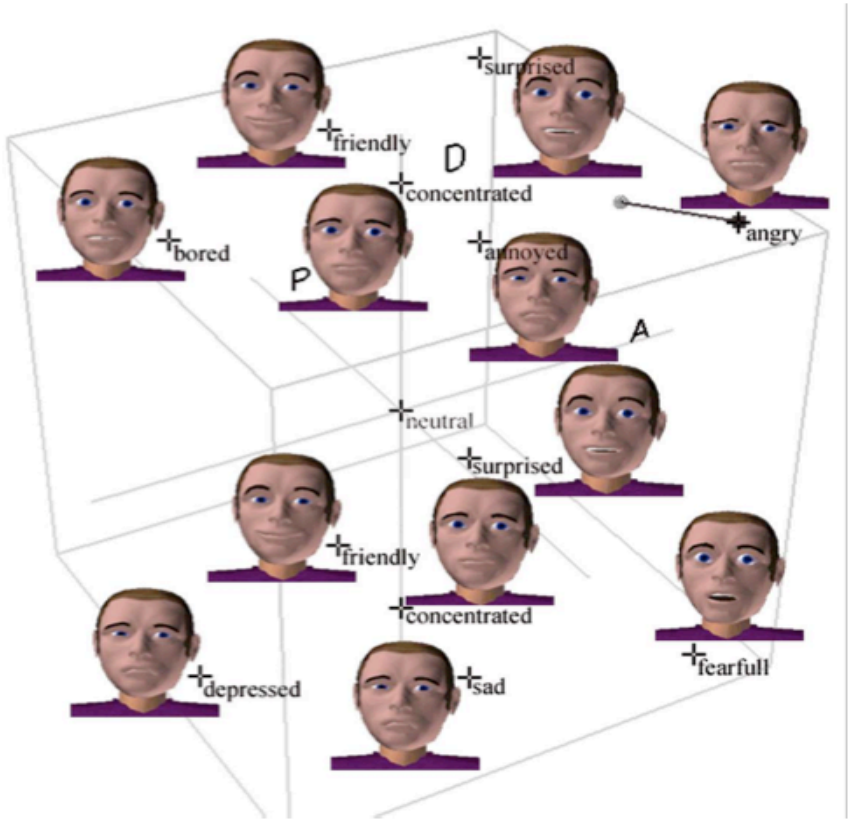
Intelligent Affective Game Characters





Affective Virtual Character - Max Becker et al., 2005

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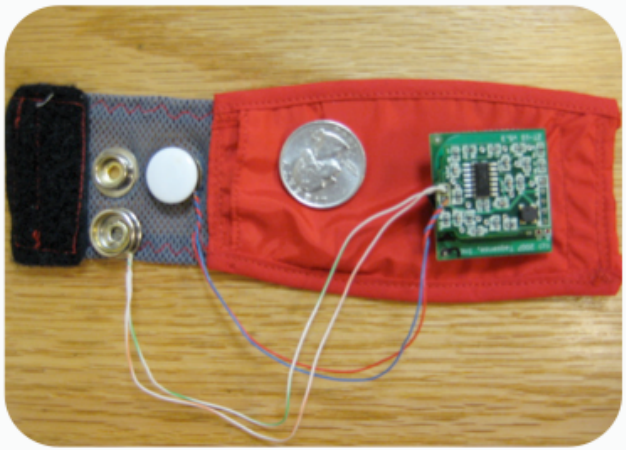
Non-Intrusive Sensors

Galvactivator sensing off the palm

Wireless sensing off the wrist



Wireless sensing of physiological signals

Picard et al., 2008

Non-Intrusive Sensors

Wireless sensor for EEG, heart rate, respiration, head motion, blink rate and skin temperature

Emsense

Non-Intrusive Sensors

Wireless EEG helmet - Emotiv Systems

Outline

- Tutorial Overview & Objectives
- Affective Gaming & Emotions in Games
- Overview of Affective Computing
- Background on Emotion Research
- Sensing & Recognition of User Affect
- Affect Expression in Game Characters
- Affective Modeling
- Evaluating the Effectiveness of Affective Games
- Summary and Conclusions

Tutorial Objectives

- Understand the Role of Emotions in Games
  - When & Where & How to Integrate Emotions in Games
- Emotion Research in Psychology & Neuroscience
- Methods & Techniques from Affective Computing
- Sensing & Recognizing User Affect
  - Emotion Signatures, Sensors, Recognition Algorithms
- Expressing Affect in Game Characters
  - Emotion Signatures, Expressive Modalities, Markup Languages
- Affective Modeling
  - Game Character & Agent Models
  - User Affective Models
- Evaluation of Affective Games
  - Can Emotion Help Evaluate Games?
- Challenges & Future Directions

Affective Gaming & Emotions in Games

"Assist Me,
Challenge Me,
Emote Me" (Gilleade et al., 2005)

What Is Affective Gaming?

- Current meanings:
  - **"Games where player's emotional state is used to manipulate gameplay" (Gilleaede et al., 2005)**
  - **"In order to have an affective videogame, both player & videogame have to be responsive to the affective signals of the other." (Gilleaede et al., 2005)**
  - **"where both player & game are affected by the actions of the other"**
  - **"Affective *gaming* is concerned with the application of affective computing techniques to the domain of digital games. Affective gaming involves both the 'evocation' of emotions, as well as the detection of player emotion." (Sykes, 2004)**

What Is Affective Gaming?

- Expanded definition:

Games where emotions of the players, and the simulated emotions of the game characters, play a key role in the gameplay, game objectives & the user experience.

Why Affective Gaming?

- Emotion plays a key role in:
  - Engagement
  - Learning (memory, problem-solving, attention)
  - Motivation

  …. all these are elements of successful games

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Affective Gaming

Recognize Player Emotions

…to adapt to player's needs

…to control the gameplay

Gameplay Control

Evoke Player Emotions

Affective Gaming

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•Adapt game content
•…game strategy
•…criteria for success
•…music & visuals
•…game events
•…game character behavior

…to adapt to player's needs

Recognize Player Emotions

Gameplay Control

…to control the gameplay

Evoke Player Emotions

•…game events
•…avatar behavior
•…game character behavior
•…environment

•Game character behavior
•Music
•Visuals
•Game narrative
•Game events

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Affective Usability Evaluation

- Use player affect to evaluate game effectiveness
- …degree of engagement
- …achievement of training goals
- …progress in therapeutic goals

…to adapt to player's needs

Recognize Player Emotions

Gameplay Control

…to control the gameplay

Evoke Player Emotions

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Affect-Focused Game Design: Objectives

- Focus on emotion as a key component of a successful game experience
- Understand when emotion is important & when it can safely be ignored
- Know which emotions are most important..& when
- Know how to use player emotions to achieve game objectives

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Affect-Focused Game Design: Methods & Tools

- Sense & recognize player emotions
  - To adapt game to player's changing state
  - To predict player behavior
  - To communicate player's state to other players
  - To use player's emotions as direct means of controlling game
  - To use player's emotions to evaluate game effectiveness
- Express affective behavior in game characters & player avatars
  - To evoke desired emotions in the player
    - To maximize player enjoyment
    - To achieve training or therapeutic objectives
  - To communicate player's state to other players

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Affect-Focused Game Design: Methods & Tools (cont.)

- Model player's emotions
  - To help recognize player emotions in real-time
  - To develop better game adaptations
- Model game characters' emotions
  - To generate realistic character behavior and believable affective expressions
  - … responsive to dynamically-evolving game scenario & player behavior
  - … in real-time

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State-of-the-Art in Affect-Adaptive Gaming

- Exploratory systems - not commercially available
- Affect-mediated game control
  - Zen Warrior, Relax-to-Win
- What can be detected?
  - Arousal (GSR, heart rate, game controls, pupils)
  - Valence (facial EMG muscles)
  - Frustration (combination of signals)
  - Boredom & Interest (combination of signals)
  - Confusion (combination of signals)

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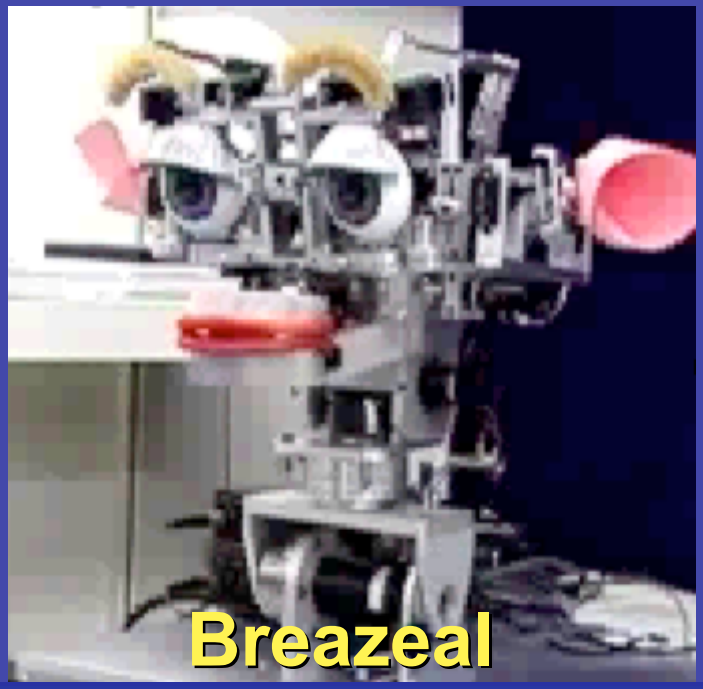
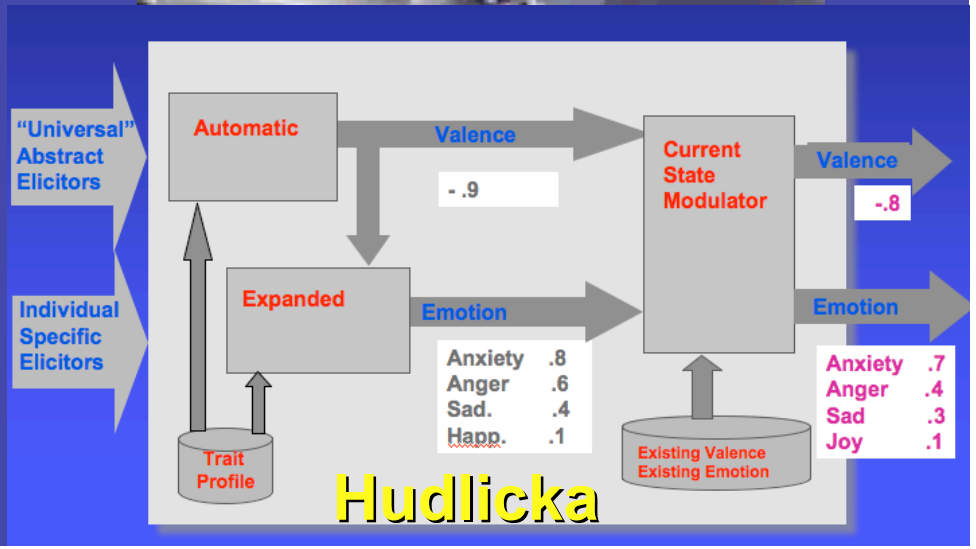
Overview of Affective Computing

MAX (Becker, Prendinger et al.)



Breazeal

De Rosis



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Affective Computing

- Broad area of interdisciplinary research and practice relating computers and affect
  - "Anything that combines computing and emotions"
- Term coined by Rosalind Picard (MIT Media Lab)
  - 1997 book "Affective Computing" (MIT Press)
  - "How can emotions be generated in computers, be recognized by computers, and be expressed by computers?"
    (Picard, Affective Computing, '97)

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Emotion Sensing & Recognition

OR?

"Emotion" Expression

Affective User Model / Cognitive-Affective Architecture

GRETA, Fiorella de Rosis, U. Bari

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Affective Computing Includes…

- Emotion sensing and recognition
  - via a variety of sensors from multiple modalities
- Generation of 'affective' behaviors in machines
  - Facial expressions in agents and robots
  - Affective synthetic speech
  - Affect-induced behavioral variation in robots and agents
- Computational models of emotion and affective phenomena
  - Emotion generation (via appraisal)
  - Emotion effects on cognition & behavior
  - Affective user models
- Cognitive-affective architectures
  - Generic requirements for modeling emotion
  - Characterizing emotion in computational terms

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Applications of Affective Computing

- Agents and robots
  - Emotionally and socially intelligent agents and avatars
- Training & tutoring & decision-support systems
  - More effective & realistic interaction
  - User modeling
  - Affect-adaptive interfaces and affective HCI
- Therapy
  - Agents & robots to help autistic children
  - Agents & robots for psychotherapy (social skills & social phobias)
- Arts & Entertainment
  - Interactive games

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Methods & Techniques Relevant for Affect-Focused Game Design

- Player emotion sensing & recognition
- Expression of emotions in game characters & player avatars
- Models of emotion generation & emotion effects in game characters
- Affective models of players

Background on Emotion Research

Definition(s) of Emotions

- (See: roles & characteristics of emotions…)
- Most definitions involve descriptions of:
  - Characteristics
    - Fast, (undifferentiated?) evaluative judgments
  - Roles & functions
    - Coordinate multiple systems: physio, cognitive, motor
    - Manage goals in uncertain environments
    - Motivate behavior
    - Trigger patterns of desired behavior - “action tendencies”
    - Communicative mechanisms facilitating social interaction

So What ARE Emotions?

- Evaluative judgments of the
  - World
  - Others
  - Self

  - … in light of agent's goals and beliefs

- …motivating and coordinating adaptive behavior

- “emotion is about motivation”
  - Positive & negative feelings, readiness or tendency to cope, cues for cognition & action

- “cognition is about knowledge”
  - Learning, memory, symbol manipulation, thinking and language”

(Izard, 1993, p. 75)

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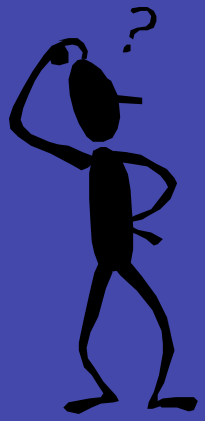
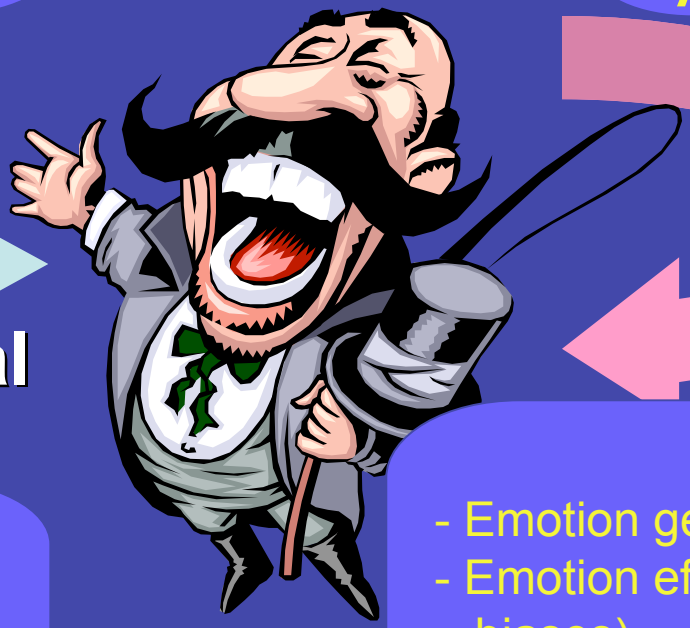
Roles of Emotions

WHAT?
*** Social coordination**
*** Rapid communication of behavioral intent;**

WHAT?
*** Motivation**
*** Homeostasis**
*** Adaptive behavior**



Interpersonal



Intrapsychic

HOW?
Express emotions via:
-Facial expression
-Speech (content & properties)
-Gesture, Posture
-Specific actions

HOW?
- Emotion generation (appraisal)
- Emotion effects (processing biases)
- Global interrupt system
- Goal management
- Prepare for coordinated actions

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How Do We Recognize an Emotion if We See One?

- Manifested across multiple, *interacting* modalities:
  - **Somatic / Physiological** (neuroendocrine - e.g., heart rate, GSR)
  - **Cognitive / Interpretive** ("Nothing is good or bad but thinking makes it so…")
  - **Behavioral / Motivational** (action oriented, expressive, 'visible')
  - **Experiential / Subjective** ("that special feeling…", consciousness)

- Much terminological confusion can be attributed to a lack of consideration of these multiple modalities of emotions
  - e.g., Is emotion a feeling or a thought? - It's both

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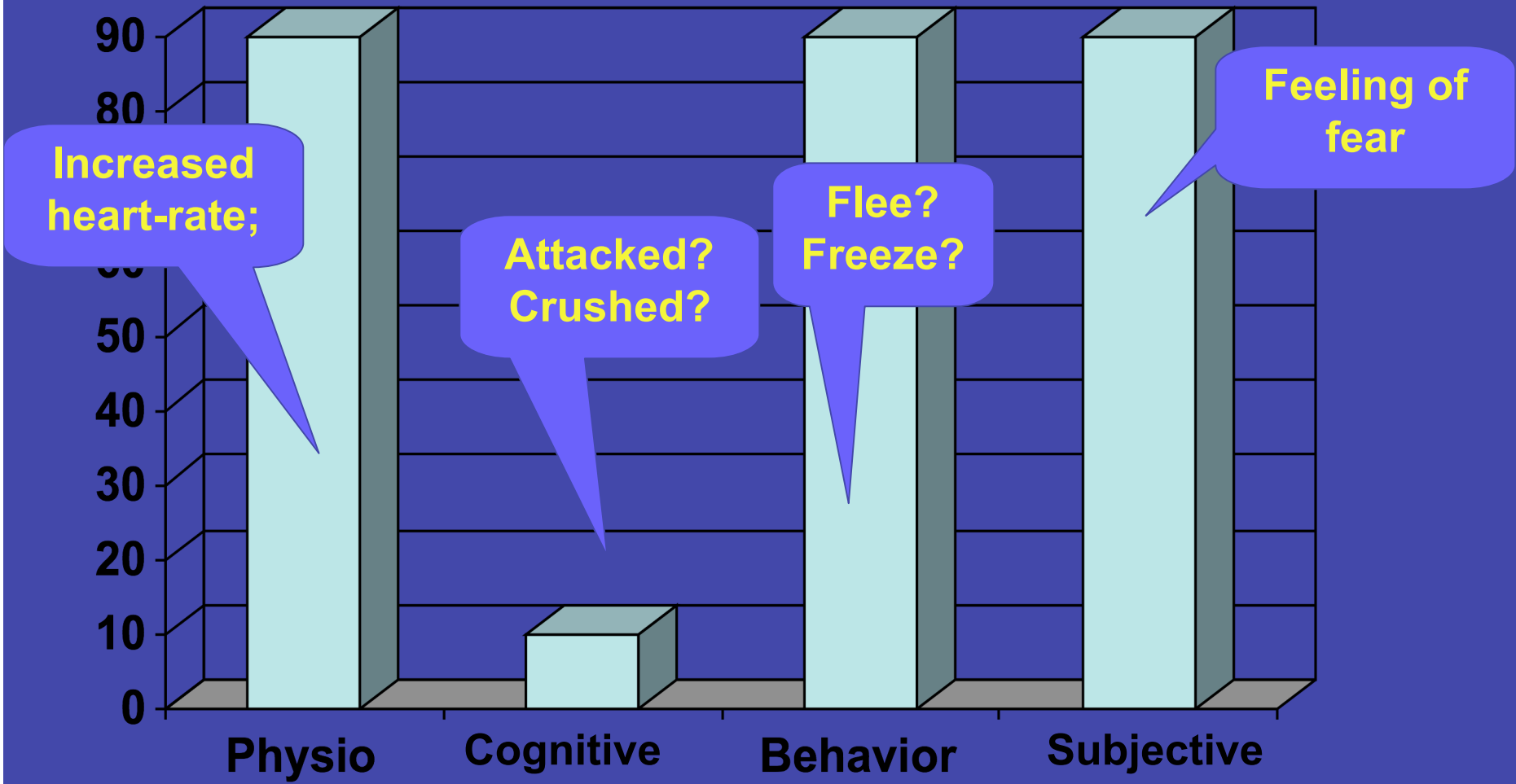
Simple Fear "Signature": Large, Approaching Object



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Do Different Emotions Have Unique Signatures Across these Modalities?

- Cognitive
  - Positive emotions: positive self, world, and others assessments
  - Negative emotions: negative self, world, and others assessments
  - Fear / anxiety: threat focus, attention focus
- Physiological
  - There are differences, but physiology alone unlikely to differentiate among all emotions
  - Jury is still out on even the 'basic' emotions – but it appears that SOME may be distinguishable via ANS signatures
  - More ANS differences among negative than positive emotions
    - "just sit back and relax" does not require much metabolic support
    - + emotions as 'undoers' of ANS activation produced by - emotions (Levenson, 1994)
- Behavioral
  - Positive emotions → approach tendencies
  - Negative emotions → withdraw tendencies… but also fight for anger - an approach behavior
- Subjective
  - Yes – but difficult to characterize objectively

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Anger

- Trigger:
  - Progress toward a goal hindered… esp. by other agent
- Cognitive:
  - Focus attention (very strong effect)
  - Assign blame to the perceived causal agent (typically another agent)
  - Overestimate chances of own success
  - Try alternate strategies
- Physiological – mobilize and sustain high energy levels:
  - Higher diastolic blood pressure (than fear)
  - Greater peripheral resistance (than fear)
  - Larger increase in heart rate (than disgust)
  - Larger heart rate acceleration (than happiness)
  - Larger increase in finger temperature (than fear)
- Behavioral:
  - Eagerness to act
  - Fight & aggression
  - Social: prevent (or facilitate) aggression

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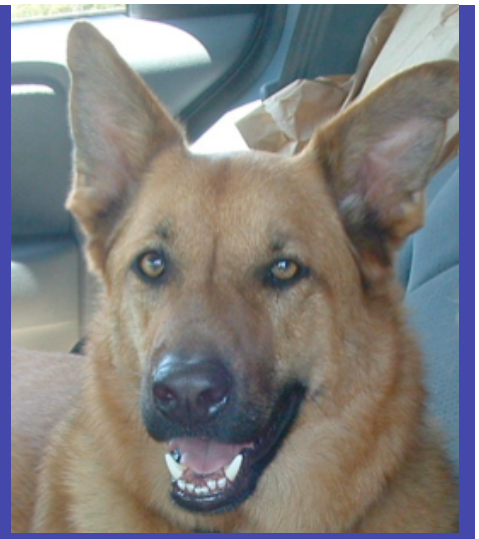
Joy / Happiness



- Trigger:
  - Goal achievement
- Cognitive:
  - Faster, more global processing
  - Use of heuristics (because things are basically ok) (vs. in-depth analysis required when there is a problem)
- Physiological:
  - Relaxation, recuperation
- Behavioral:
  - Approach tendencies
  - Social: Signals readiness for friendly interactions
  - Stimulates more ‘open’ attitudes towards experiences and social situations

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Fear

- Trigger:
  - Perceived danger to important self- or other-protective goals
- Cognitive:
  - “Tunnel vision” (attentional narrowing focusing on source of threat)
- Physiological – mobilize energy level ‘spike’
  - Lower diastolic BP (than anger)
  - Larger heart rate acceleration (than happiness)
  - Decreased finger temperature
  - Larger skin conductance increase (than happiness)
- Behavioral:
  - Motivate flight & avoidance (and sometimes freeze)
  - Motivate protective behavior

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Sadness / Depression

- Trigger:
  - Loss or inability to achieve an important goal
- Cognitive:
  - Focus on negative evaluations of situation / self (past, present, future)
  - Slower, more deliberate and analytical processing… to prepare for alternative strategies
- Physiological:
  - Larger increase in heart-rate (than disgust)
  - Greater peripheral vascular dilation (than other negative emotions)
- Behavioral:
  - Avoidance / withdrawal (resource conservation following (repeated) failure or adverse event)
  - Slower motor reactions
  - Social: Communicate need for help (can strengthen social bonds)

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Emotions Are Not All Created Equal

- Different elicitors and behaviors.. Of course

- BUT also vary in:
  - Consistency of elicitors & responses
  - Diversity in elicitors & responses
  - Sustainability & decay
    - Anger decays most slowly after initial trigger
  - Infusive potential - generalization over time to events / actors schemas
    - Anger is very high
  - Contradictory effects
    - Fear: flee or freeze?
  - Relative frequency
    - E.g., anger most frequently experienced… in the US (Lerner & Tiedmus, 2006)
  - Ability to capture attention
    - Anger highest
  - Accurate recognition (facial expression)
    - Anger most accurately recognized

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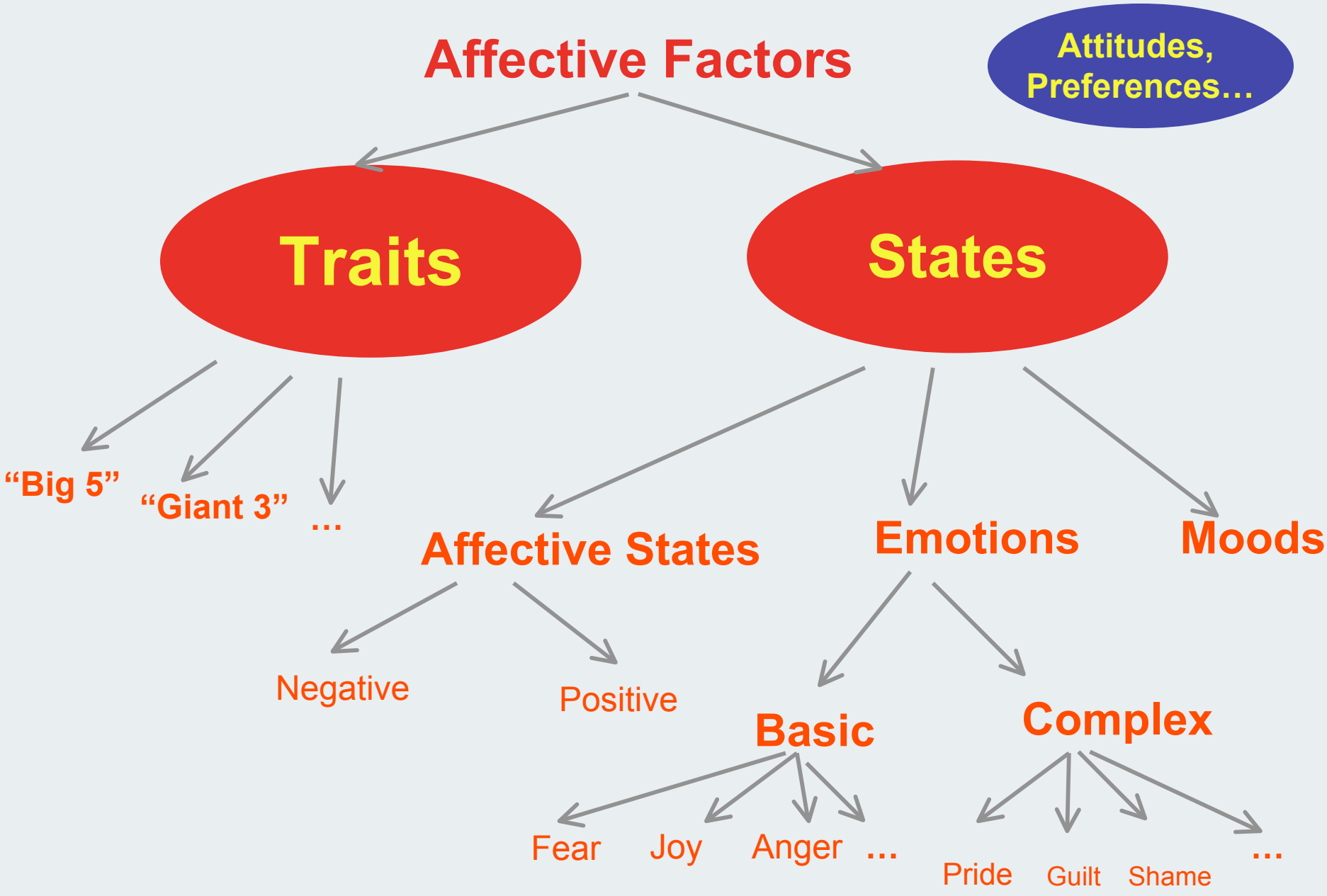
A Taxonomy of Affective Factors



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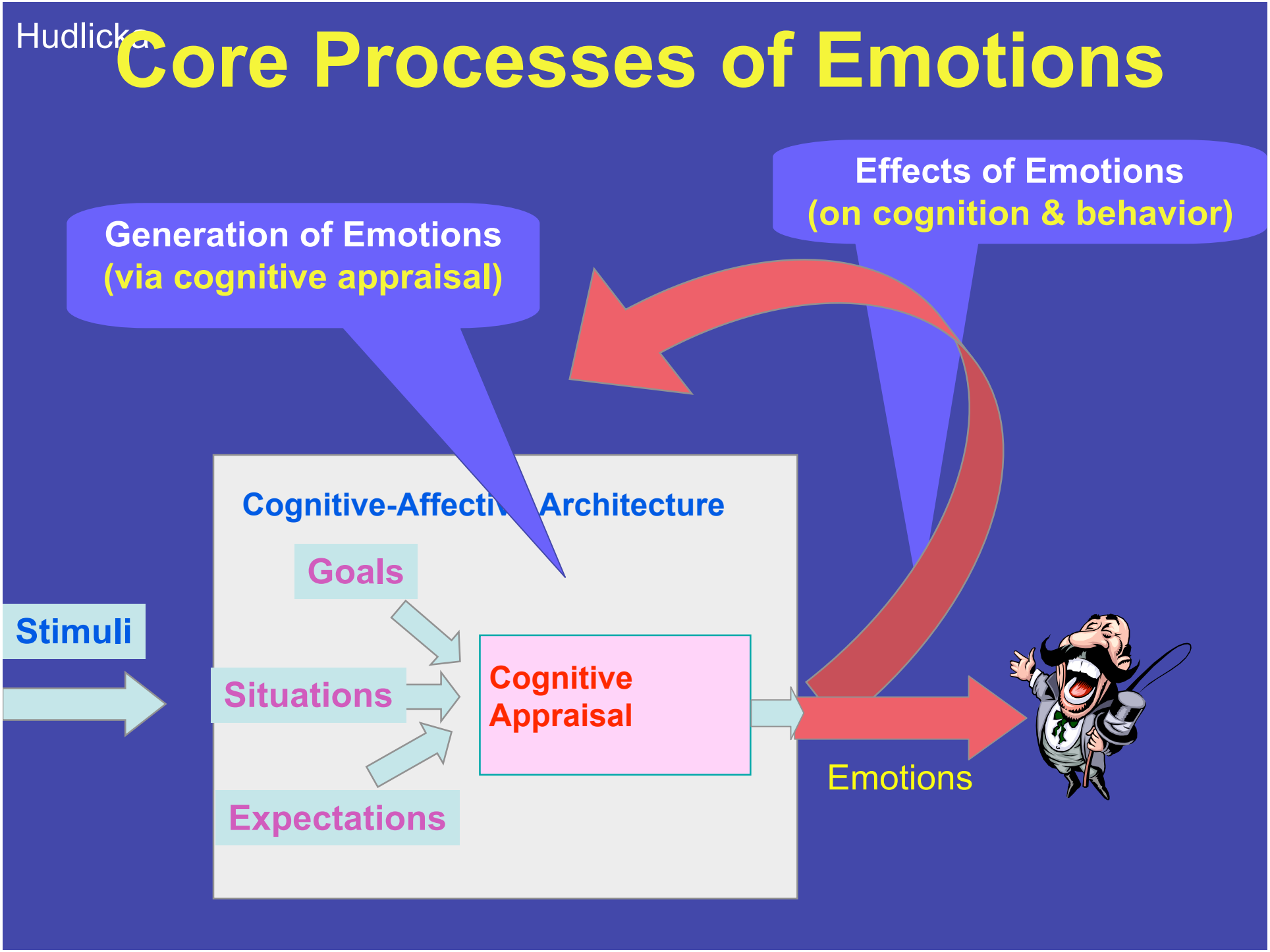
Core Processes of Emotions



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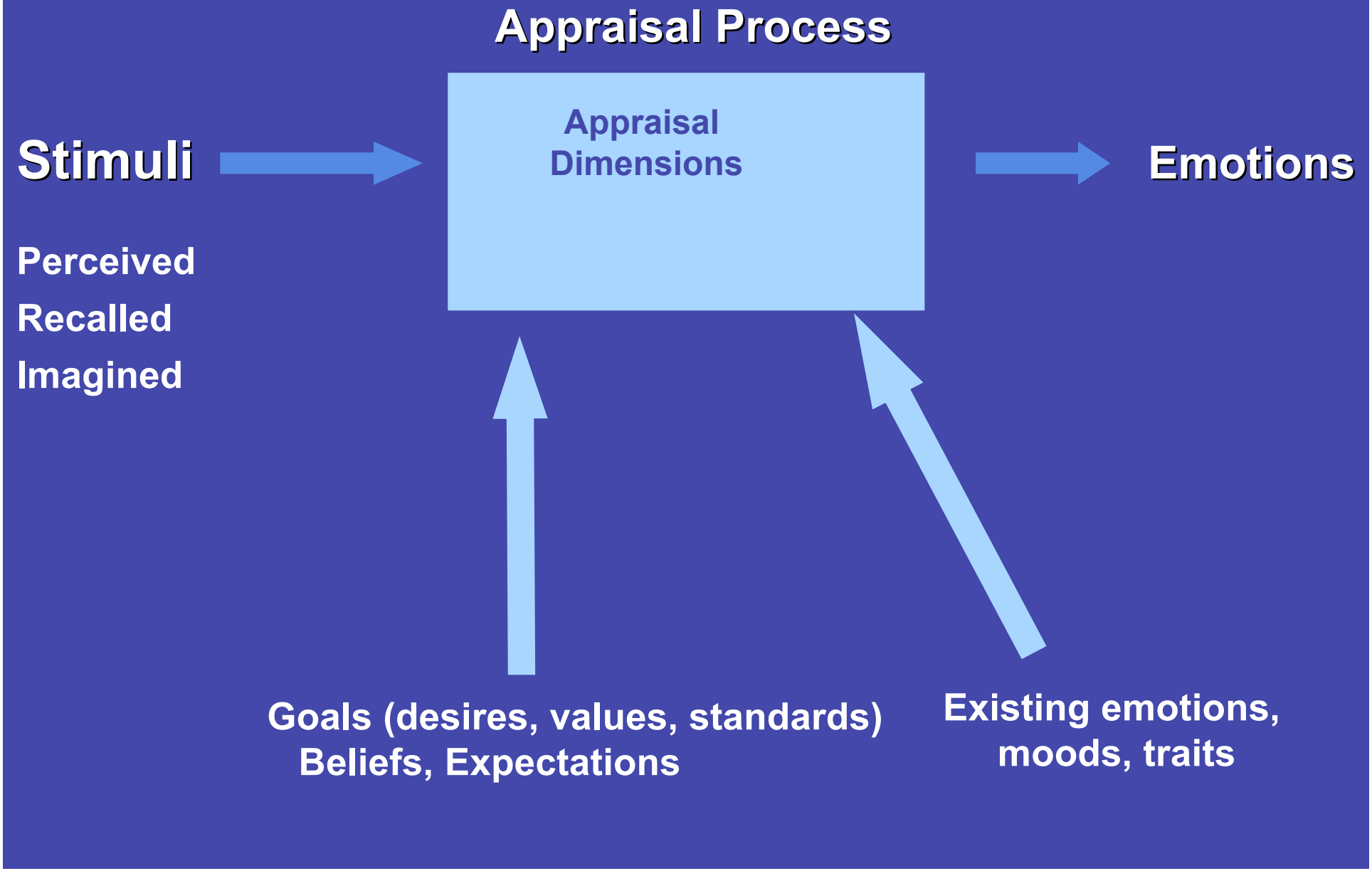
Emotion Generation via Appraisal



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Emotion Generation via Appraisal

Appraisal Process

Stimuli

Appraisal Dimensions

Emotions

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Emotion Generation via Appraisal

Appraisal Process

Stimuli

Appraisal Dimensions

Emotions

Goals (desires, values, standards)
Beliefs, Expectations

Existing emotions, moods, traits

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Emotion Generation via Appraisal

Appraisal Process

Stimuli → **Appraisal Dimensions** → **Emotions**

Domain-Independent Appraisal Dimensions

Novelty
Valence
Goal / Need relevance
Goal congruence
Agency
Coping potential
Social and self norms and values

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STIMULI

FEAR

Novelty	*high*
Valence	*low*
Goal relevance	*high*
Agency	*other*
Outcome probability	*high*
Goal congruence	*low*
Urgency	*v. high*
Coping potential	*low*
Norms	

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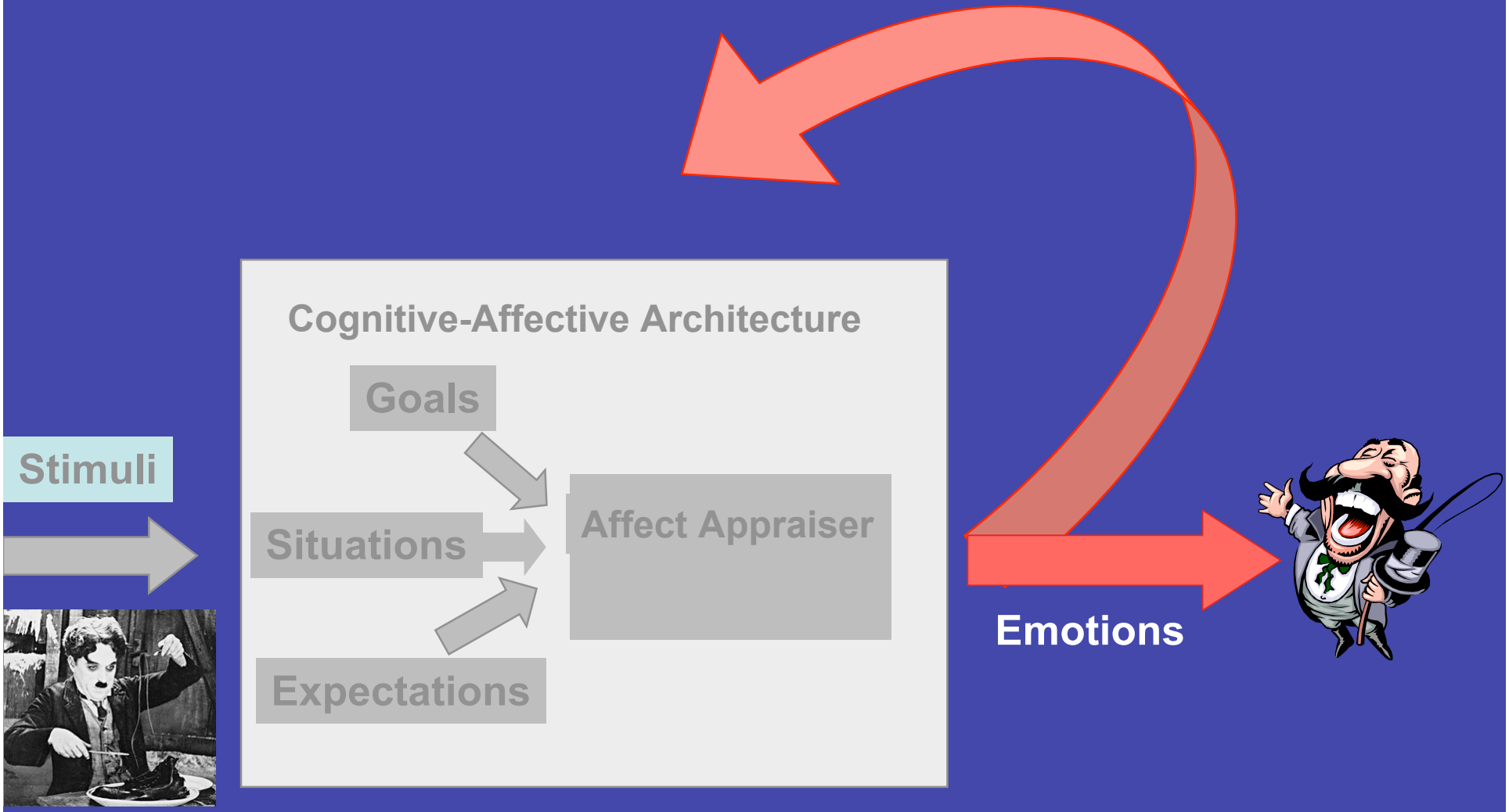
Emotion Effects on Behavior & Cognition



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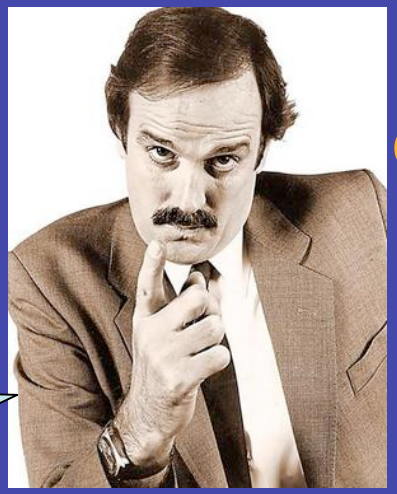
Emotion Effects on Behavior

Emotion



Facial expression

Gestures

Posture

Behavior

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Emotion Effects on Cognition

- Emotion and cognition function as closely-coupled information processing systems
- Emotions influence fundamental processes mediating high-level cognition:
  - Attention speed and capacity
  - Working memory speed and capacity
  - Long-term memory recall and encoding
- Influences on processing & contents and structure
  - Transient biases influence processing
  - Long-term biases result in differences in long-term memory content & structure

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Examples of Affective Biases

- Anxiety
  - Narrows attentional focus
  - Reduces working memory capacity
  - Biases towards detection of threatening stimuli
  - Biases towards interpretation of ambiguous stimuli as threatening
  - Promotes self-focus

- Happiness
  - Increase estimates of degree of control
  - Overestimate of likelihood of positive events
  - Promotes variety seeking
  - Promote creative problem-solving (breadth & flexibility of thought)
  - Promotes ‘big picture’ thinking - focus on ‘the forest’
  - Promotes fast, heuristic processing

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Examples of Affective Biases

- Sadness (Williams et al., 1997; Gasper & Clore, 2002)
  - Use of simpler decision strategies
  - Reliance of standard, well-practiced procedures
  - Decreased search for behavior alternatives
  - Faster but less-discriminate use of information
  - Better choice accuracy on easy tasks – worse on difficult tasks
  - Simpler decisions and more polarized judgments
  - Increased self-monitoring
  - Promotes focus on details (focus on “the trees”)

- Anger (Lerner & Tiedmus, 2006..and others)
  - Facilitates automatic, superficial, heuristic processing
  - Biases towards anger-based processing (anger stimuli, anger SA…))
  - High sense of certainty
  - Reduced assessment of future risk
  - Overestimate chances of own success
  - Eagerness to act
  - Attribution of hostile motives in others

Examples of Affective Biases

- Mood and Memory (Bower, 1981; Bower, 1986)
  - Mood-congruent recall
- Obsessiveness and Performance
  (Persons and Foa, 1984; Sher et al., 1989)
  - Delayed decision-making
  - Reduced ability to recall recent activities
  - Reduced confidence distinguishing btw actual and imagined actions / events
- Biases can be adaptive or maladaptive, depending on context

Theories

- Fewer theories exist than for appraisal
- Specific mechanisms of emotion effects not as well developed
- Some available theories:
  - Spreading activation & priming (Bower, 1984; Derryberry, 1988)
    - "Network theory of Affect"
  - Distinct *modes* of processing associated with different emotions (Oatley & Johnson-Laird, 1987)
  - Emotions as patterns of parameters modulating processing (Fellous, Matthews, Ortony et al., Hudlicka, Ritter…)

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Emotion and Cognition

- Two interdependent systems
  - Both essential in biological agents
  - Each capable of information processing
  - …Influencing each other

- Affective system precedes cognitive system in phylogeny & ontogeny

- Why do people get so emotional about emotion?
  - Difficult to characterize & investigate
  - Historical focus on pathology, lack of control ("Oh you're so emotional")

- BUT - rarely: "Oh you're so cognitive"

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Sensing & Recognition of Player Emotions

Sensing & Recognizing Emotions

- Inherently difficult due to:
  - Frequently subtle nature of emotions
  - Variability across individuals
  - Variability within individuals across time… situations
- Data / signals available from multiple modalities
- Which of the emotion modalities are most suitable?
  - Cognitive / Interpretive
  - Somatic / Physiological
  - Motivational / Behavioral
  - Experiential / Subjective

Most Frequently Modalities Used for Sensing & Recognition

- ***Somatic and physiological manifestations***
  - Heart rate
  - Galvanic skin response
  - Respiration rate
  - Blood volume pressure
  - Blood chemistry
- ***Observable behavioural manifestations***
  - Facial expressions
  - Posture
  - Gestures and movements
  - Speech (prosody and content)
  - Behavioural choices

Other Emotion Modalities Can Also Be Used for Emotion Recognition

- Cognitive & Interpretive
  - Assessed via diagnostic tasks
    - Ranging in complexity: simple -→ VR
  - Assessed via self-reports
- Subjective / Feeling
  - Assessed via self-reports

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Theoretical & Practical Limits

- With respect to recognition and expression, all emotions were not created equal

- The simpler (basic) emotions:
  - Share more universal triggers (e.g., large approaching objects for fear)
  - Share behavioural response patterns, across and within individuals, and even cultures
  - Are more readily recognized, by humans and by machines
  - (e.g., fear, anger, joy, sadness, surprise, and disgust)

- More complex emotions have:
  - Larger cognitive component,… leading to
  - More individual variability… leading to
  - Increased difficulty of recognition and expression
  - (e.g., pride, shame, guilt)

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Requirements for Emotion Recognition

- Requires integration of:
  - Hardware (sensors)
  - Mathematical methods for data enhancement and filtering
  - Pattern recognition and classification algorithms
- Use of multiple signals from multiple modalities (emotion components)
- Identification of the best signals for recognizing particular emotion
  - Unique emotion ‘signatures’ across signals and modalities
- Use data from multiple time frames

Identifying Unique Signatures for Particular Emotions

- Particular emotions may be more strongly manifested:
  - Within a specific subset of these modalities and via particular signals
    - positive valence detected from facial expressions
    - arousal correlates with heart rate
  - This has implications for selecting particular:
    - Modality / sensors for sensing & recognition
    - Modality / output devices for expression

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Generic Requirements for Emotion Recognition

- Diagnosticity – Unique emotion 'signatures'
  - Identify specific patterns of signals across modalities (e.g., behavioral) & channels (e.g., facial expression) for a particular emotion
  - Different emotions may have different 'optimal' signatures across modalities & and particular channels within each modality
- Semantics – Vocabulary of 'primitives' for each relevant modality & channel
  - Associate each emotion with a particular configuration of 'primitives' (zygomatic muscle ->smile ->happiness")
  - Facial Action Coding system (Ekman & Friesen, 78)
  - Speech acoustic signal features – median, max, min intensity; pitch
- Sensors & 'Input Devices' – Develop sensors for required signals
  - E.g., heart rate monitor for HR, camera or EMG for facial expressions
  - Variability in: training requirements & ease of use, intrusiveness, expense, data quality, post-processing requirements, ease of feature extraction
- Data Filtering Algorithms – Select appropriate filtering methods
  - Variability in data requirements, algorithm complexity, output quality
- Pattern Recognition Algorithms – Select best PR methods
  - Variability as above
  - Artificial neural nets, clustering algorithms, hidden Markov models
  - Learning: supervised, unsupervised

Modalities Considered

- Facial expressions
- Physiological signals
- Speech
- Gestures and movements
- Body posture

Facial Expressions

- To what extent do facial expressions indicate distinct emotions?
- What is the best way of sensing facial expression?
  - Electrodes sensing muscle movement?
  - Visual data?
    - Still data
    - Video data
- What is the best means of encoding the facial expression data?

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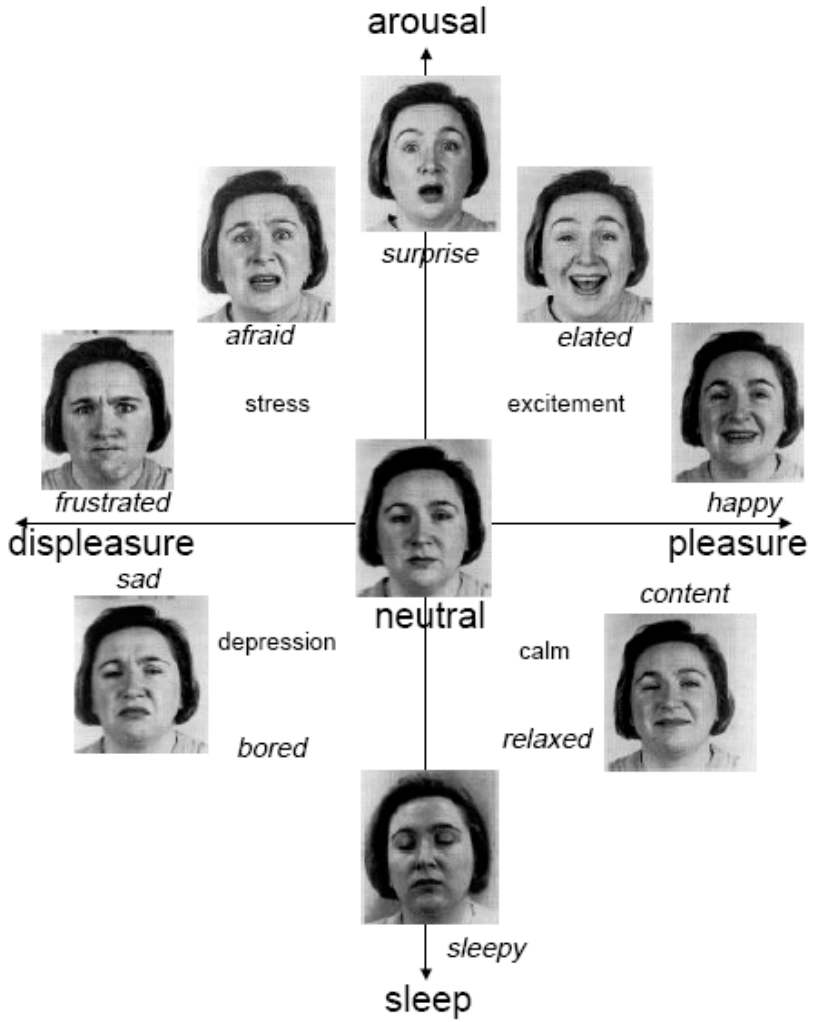

Figure 2: Russell's pleasure-arousal space for facial expression. Adapted from Russell (1997).

(Breazeal, 2003)

Facial expressions

- Facial expressions are one of the most obvious manifestations of emotion
- Basic emotions are readily recognized from facial expressions
- Extensive literature exists in psychology on emotion expression (Cacioppo et al., 1992; Ekman & Friesen, 2003)
- Much progress has been made in machine emotion recognition via facial expression (Cohn & Ekman, 2003; Essa & Pentland, 1997; Fasel & Luettin, 2003)

Diagnosticity

- To what extent do facial expressions indicate distinct emotions?
- ‘Basic emotions’ are reflected in the face via characteristic configurations of the facial muscular ‘vocabulary’, controlled by a variety of facial muscles
  - Shape of lips
  - Shape of eyebrows
  - Narrowing of eyes
  - Raising cheeks
- Happiness / joy:
  - Raising of the lip corners (controlled by the zygomatic major)
  - Narrowing of the eyelids, causing the characteristic ‘crowsfeet’ wrinkles
  - Raising of the upper cheek areas

Diagnosticity (cont.)

- Note: frequently seen ‘fake’ smiles can be identified by lacking some of these components (e.g., the narrowing of the eyelids, ‘crowsfeet’), and including other components (e.g., tense broadening of the mouth)
- Emotions associated with characteristic patterns are:
  - Happiness / joy
  - Sadness / distress
  - Anger
  - Fear
  - Disgust
- With the possible exception of happiness, most emotions “cannot be identified by the activity of a single muscle” (Cohn & Ekman, 2003)

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Facial Features of Emotions

	Facial Action							
Meaning	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		↓	↓			↓		

(Breazeal, 2003)

Semantics

- Emotion expressions have been extensively analyzed to identify units of analysis most suitable for effectively describing the variety of observed facial expressions
- Most extensively used coding and analysis system is Ekman and Friesen's Facial Action Coding System (FACS) (Ekman & Friesen, 1978)
- FACS represents an example of a mature semantic vocabulary extensively used in machine recognition of emotion
  - … using variety of data

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Semantics (cont.) FACS

- Identifies characteristic position of facial muscles in terms of a number of unique “action units”
- Each “action unit” describes a particular configuration of a particular facial muscle
- For example:
  - ‘AU6’ refers to the muscle controlling the eye shape (orbicularis occuli)
  - AU12 refers to the zygomaticus major, which controls the upward movement of lip corners, characteristic of smiling
  - AU24 refers to a lip ‘tightening’, characteristic of anger

Sensors

- Two options exist for obtaining facial expression data:
  - Facial electromyography (EMG)
  - Computer vision approaches

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Facial EMG

- Direct sensing of the muscle movements via surface or needle electrodes
- Sensors need to provide three types of information about the facial ‘actions’:
  - Action type (e.g., which muscle is doing what)
  - Intensity
  - Timing (onset, apex, offset)
- Both still images and videos are used
  - Videos are better
- Pros:
  - More established
  - High temporal resolution
- Cons
  - Intrusive (electrodes)
  - … but – expression glasses (less intrusive) (Picard, 2000)
  - Interpretation can be challenging because muscle fibers are intertwined
  - Difficult to establish that a particular signal corresponds to a specific muscle rather than a combined muscle group

Computer Vision

- Automatic analysis of face images (Cohn & Ekman, 2003)
  - Enhanced with markers (Kaiser & Wehrle, 1992), such as Vicom™ and Peak Performance™
  - “Markerless” (less intrusive)
- Much recent progress
- Also uses FACS

Data Filtering

- Many data filtering and feature extraction methods are available
- Four of the most commonly used for facial image analysis, singly or in combination (Cohn & Ekman, 2003)
  - Difference imaging
  - Principal components analysis (PCA)
  - Optical flow
  - Edge detection

Pattern Recognition Algorithms

- Once the key features are detected, a number of classifier algorithms and methods can be used to identify particular expressions
- Typically data are divided into a training set, used to train the classifier, and a testing set, used to validate its effectiveness (Cohn & Ekmanm, 2003)
- Most frequently used methods are:
  - Artificial neural networks
  - Hidden Markov models, the latter using temporal information (Cohn & Ekmanm, 2003)
  - Variety of other classifiers have been explored (see Bartlett et al., 2004 for a review)

Summary

- Specific success rates for emotion recognition via facial expressions vary
- Average = 85% accuracy in recognizing the 'basic' emotions
- Riseback & Picard report ability of EMG-based approaches to discriminate between interest & surprise, and confusion & frowning with 85-100% accuracy (N=6)
- Valence is most readily assessed, with rates close to 90 %
- Facial EMG is effective in discriminating between positive and negative emotion (Cacioppo et al., 1986)
- Computer vision methods capable of forced-choice differentiation among anger, disgust, surprise, happiness, and neutral, up to 98% (N=8) **(Essa & Pentland, 97; Yacoob & Davis, 96)**
- Both the EMG and computer vision approaches are expensive, labor intensive and require special training to use effectively

Recognition Success Rates

- Computer systems beginning to approach human success rates in emotion recognition:
  - for many of the basic emotions
  - … under forced-choice conditions
- Example of machine recognition accuracy rates:
  - Facial expressions
    - Avg. accuracy 85% for basic emotions
    - Computer vision accuracy: up to 98%
  - Physiological signals
    - ~81% - multiple signals, forced-choice, basic emotions
  - Speech
    - ~ 70% for forced-choice, basic emotions, speaker-dependent
    - Anger easiest, then sadness, then happiness, then fear…

Conclusions

- The bad news:
  - Emotion recognition is inherently difficult due to:
    - Frequently subtle nature of emotions
    - Variability across individuals
    - Variability within individuals across time… situations
- The good news:
  - Data available from multiple modalities
    - Facial expressions, speech, physiological signals, gestures…
  - Data available from multiple time-frames
  - Sensors are improving
    - Smaller, less intrusive, wireless, wearable…
  - Vocabularies of features are being developed
  - Recognition algorithms are improving