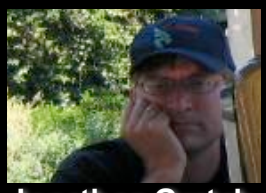
Computational Models of Emotion



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Outline

- Motivation
  - Why model emotion?
  - Key Themes
- Applications
- Theoretical & Empirical Desiderata
  - Emotion, cognition and behavior
- Computational models
  - Breadth & Scope
  - Specific examples
- Empirical Evaluation
  - Range of questions

What is Emotion

Cognitive

Emotion is a mental phenomena

- Arises from physiological & cognitive processes
- Associated with key cognitive functions
  - Focusing mental, sensory resources
  - Influencing beliefs
  - Priortorize goals
  - Informing/Biasing decision-making
  - Preparing action and reaction
  - Maintain Homeostasis
  - Learning and long-term adaptation
- Relevant to traditional AI

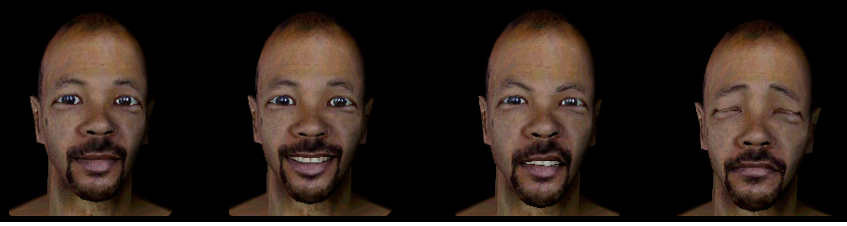
What is Emotion

Cognitive

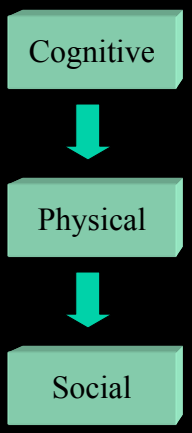
Physical

Emotion is a physical phenomenon

- Mind expressed
- Emotion processes associated with specific physical behaviors
  - Facial expression
  - Body language and posture
  - Voice
  - Word choice
  - Behavioral dynamics
- Relates to HCI



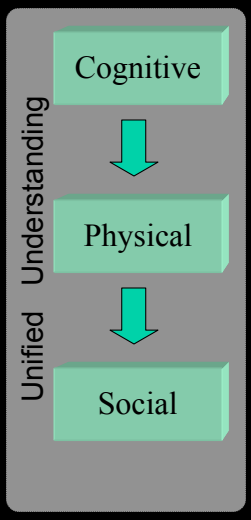
What is Emotion



Emotion is a social phenomenon

- Emotion is a signal that influences the behavior of others
  - Emotional contagion
  - Social referencing
- Relates to multi-agent teamwork

What is Emotion?



The integration of

- Cognitive, physical and social
  - Collect and coordinate resources
  - Balance Reactive and Deliberative

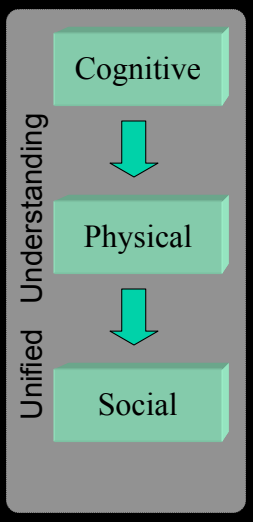
Linkage of Cognitive, Physical and Social

- **Claim: Emotion plays crucial interpersonal function to facilitate coordinated activities:**
  - Cognitive (felt) emotions motivate pro-social behavior
    - Provides intrinsic rewards for cooperation
    - Provides intrinsic punishments for non-cooperation
  - Physical displays communicate socially relevant mental states
    - Automatic and rapid means of communication
  - Social effects depend on tight coupling between feeling & display
    - You display what you feel

Example: Anger

- Cognitive
  - Arises from perception of injustice
  - Informs self about *quality* of the interaction (Keltner&Haidt99)
  - Heightens sensitivity to injustices of others
- Physical
  - Associated with characteristic bodily responses
    - Facial displays
    - Shift of blood from internal organs toward hands and arms (Keltner & Haidt 99)
    - Physical action
- Social
  - Elicits fear-related responses (Dimberg&Ohman96)
  - Serves as demand for someone to change course of interaction (Emde, Gaensbaur&Harmon76)

Why our we interested?



Goal is to develop computational framework for modeling, simulating, explaining and exploiting these phenomena

- To inform intelligent system design
  - By drawing on insights from emotion's cognitive/social function
  - Not a new idea in (Simon/Minsky)
- To inform emotion theory
  - By concretizing/transforming theory and developing methodological tools
- To drive applications
  - Education, Training and Health Interventions

AI & Emotion Research

- AI arose from narrow view of intelligence
  - Cognitive Psychology, Logic, Decision Theory
- Emotion psychology considers different phenomena
  - Social psychology, motivation, drives

Traditional Perspective	Emotion Perspective
Emphasizes individual problem solving	Cognition embedded in a social and cultural context
Single goal	Multiple problem-solving styles
Single optimal solution	Juggling multiple goals
Short-term interactions	Long term adaptation

- Study of emotion can enrich and complement AI

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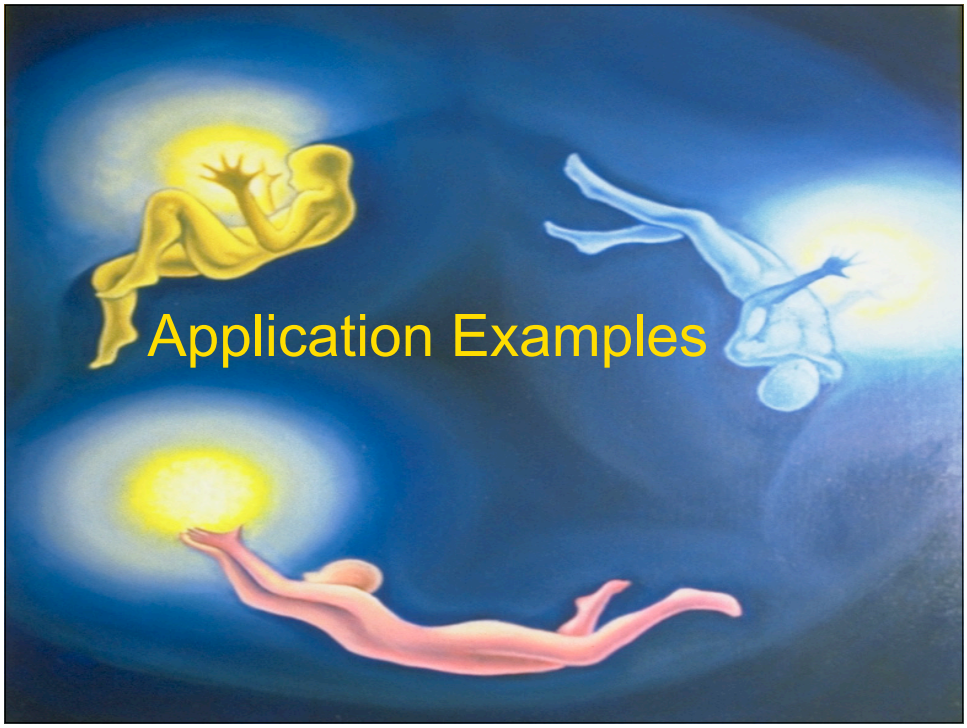


Applications

- Growing interest in systems that exploit emotions
  - HCI: Speech & non-verbal recognition and generation
  - User and human behavior modeling
  - Believability/Entertainment

Education

– Tutoring systems	[evaluative feedback]	(Lester)

Health Interventions

– Coping with stress	[explore emotional state]	(Marsella)
– Bullying	[evoke empathy]	(Paiva)
– Safe sex training	[induce emotional state]	(Miller)
– Social phobias	[provoke social stress]	
– Post-Traumatic Stress		

Law enforcement

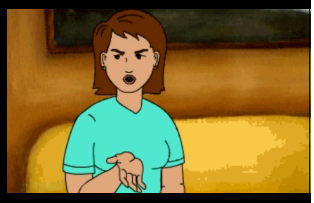
– "Shoot/no-shoot" training	[model reality]	(Institute of Justice)
– Evacuation training	[induce trust]	(Isbister)

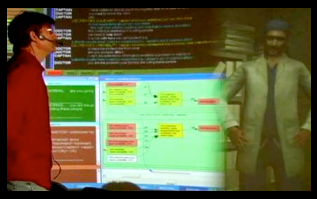
Social Learning Environments

Explore emotionally charged social interactions in safety of VR

Virtual Role Play

Learner interacts with Virtual Humans





Virtual Humans

- Users interact with virtual humans
  - Computer-generated simulations of humans
  - Playing mentors, teammates, adversaries, etc.
- Communicate in natural language
  - Coordinated gestures and non-verbal communication
- Behaviors not pre-scripted
  - Behave by understanding social situation
  - Reason about possible responses to events
- Respond emotionally to situation
  - Affects the way they perform tasks & interact socially
  - Affects gaze, face, gestures, posture

Carmen's Bright IDEAS
(Marsella, Johnson, LaBore 2000/2003)

Teaches emotion coping skills to parents of pediatric cancer patients

Multi-agent system
- Therapist and Parent
- Agents have model of emotion
- Users can influence parent agent's goals to mirror their own concerns

Emotions influence agent decisions and behavior displays

Emotions designed to be accurate

Gina and Carmen talk

VICTEC

Aylett, Paiva, Woods et al

- Teaches children skills to deal with school bullying
- Multi-agent system
  - Bully, Victim, Observer
  - Agents have model of emotion
  - Children asked to help one of the characters with their problems
  - Emotions influence agent decisions and behavior displays
  - Emotions designed to create empathy

VICTEC/FearNot!

- Goal: Reduce bullying in school
- FearNot!: Children learn to cope with bullying
- Child interacts with **emotion**-driven virtual characters
- Paiva, Aylett, Dias, Woods, Hall, Dautenhahn, et al.
- Status: eCircus

SASO: Dealing with Doctors

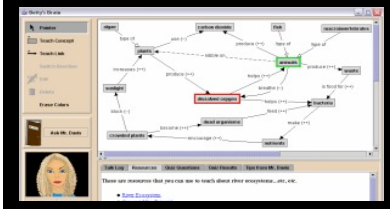
- ***Pedagogy:*** Training Negotiation Skills under high stress, emotional conditions
- ***Background:*** Operations are planned in area of NGO clinic
- ***Goal:*** Persuade doctor to re-locate clinic

Intended as integrated research prototype, not full training system

Work with Bill Swartout, Jon Gratch, Ed Hovy, Shri Narayanan, David Traum

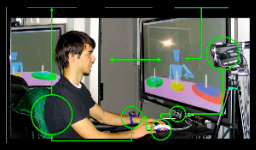
Tutoring Systems

Cosmo / Herman the Bug (Lester et al)
- Uses emotional displays for tutorial impact



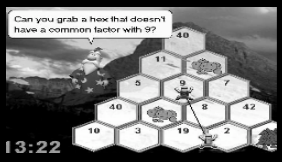
Betty's Brain (Biswas et al)
- Learning by teaching paradigm
- Uses virtual character to induce empathy

Models to mediate HCI/ITS



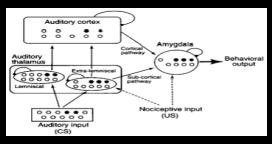
Affective Learning Companion (Burleson & Picard)
• Uses emotionally intelligent agent for tutorial impact

AutoTutor (D'Mello, Graesser et al)
• Affect sensitive intelligent tutoring



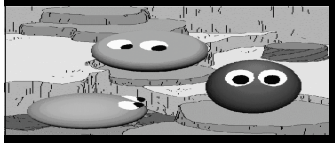
Prime Climb (Zhou & Conati)
• Assessing learner affect

Other Uses



Armony et al
• Methodological Tool
• Used computational model based on anatomical data to study conditioned fear response

PETEEI (El-Nasr et al.)
• Pet with Evolving Emotional Intelligence



Believable Emotional Agents (Neal Reilly)
• Interactive Drama

Key Themes

- Capturing Dynamics
  - Linkage with cognitive and behavioral processes
  - Modeling the phenomena AND the process flow
- Evaluation/Validation
- Evaluation of dynamics

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Emotion Dynamics

Emotional Dynamics

Surprise

Fear

Anger
(Aggressive)

Empathy

Humor/Relief

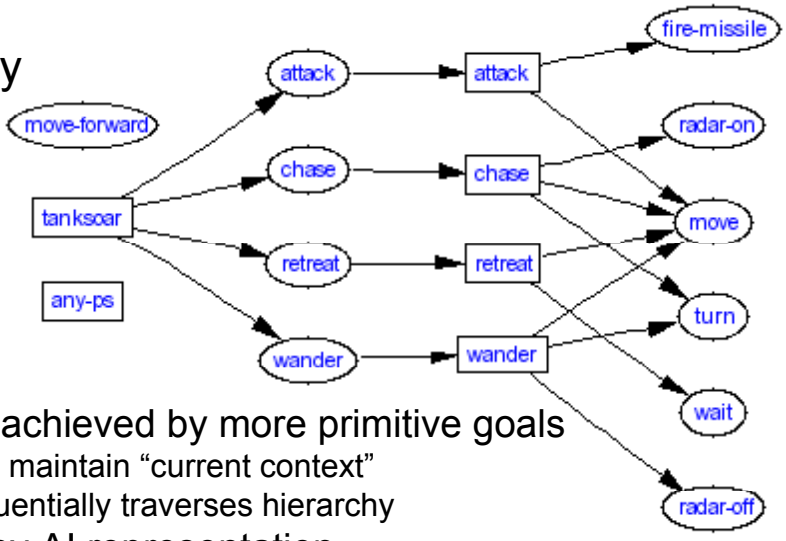
The phenomena

- **What does emotion do to cognition**
  - **Review key findings on emotions**
  - **Discuss in relationship to classical (rational) reasoning models**
  - **Are these "distortions" in fact "rational"?**

Herb Simon
Motivational and Emotional Controls of Cognition, Psych. Rev. 74(1) 1967, pp.29-39

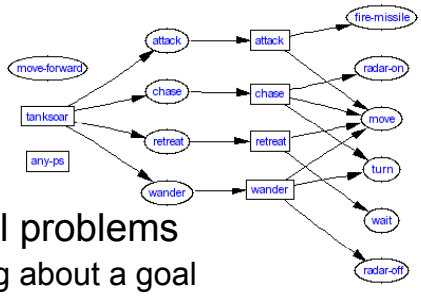
- First to integrate emotion with information processing view of cognition
  - Emotion plays controlling influence over cognition
  - Emotion is an interrupt system that sets aside ongoing activities when high-priority needs encountered
- Emotion "logically necessary" given Simon's assumptions about the nature of cognition
  - Cognition operates serially
  - Cognition organized around "tightly organized hierarchy of goals"

Goal Hierarchy



- Abstract goals achieved by more primitive goals
  - Abstract goals maintain "current context"
  - Cognition sequentially traverses hierarchy
- Influenced many AI representation
  - Hierarchical Task Networks (HTN)
  - Means-ends Planning
  - Reactive Planning
- Problems
  - Great if you just have 1 goal → enforces persistence
  - Not so great if you have to juggle multiple goals

Goal Hierarchy



- This view foregrounds certain control problems
  - Termination: When should I stop thinking about a goal
    - when is goal achieved satisfactorily (satisficing)
    - when is it taking too long too long to achieve it
  - Multiple goals: How do I multitask
    - Sequentially – one after another
- Simon's Claim: emotion is interrupt mechanism that addresses these control problems
  - Interrupts current goal processing
  - Shifts focus to more immediately important goal
  - Allows processor to respond to urgent needs in real time

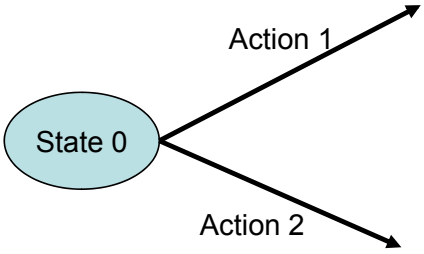
*NOTE: This view still adopted by most AI systems

Importance of emotion in understanding cognition

- Evidence of tight coupling of emotion and cognition
  - Even incidental affect (unrelated to decision at hand) has systematic and pervasive impact on judgment (e.g. Clore et al. 01)
  - Emotional deficits – both natural (Damasio94) or experimentally induced (Wilson et al93) degrade the quality of decision making
  - Incorporating the influence of affect greatly increases explanatory power of models of human decision making (Lopez87;Mellers et al. 97)
- What are some of the impacts?
- Are they functional?
  - e.g. support multitasking a la Simon?

Influences of Emotion on decision-making

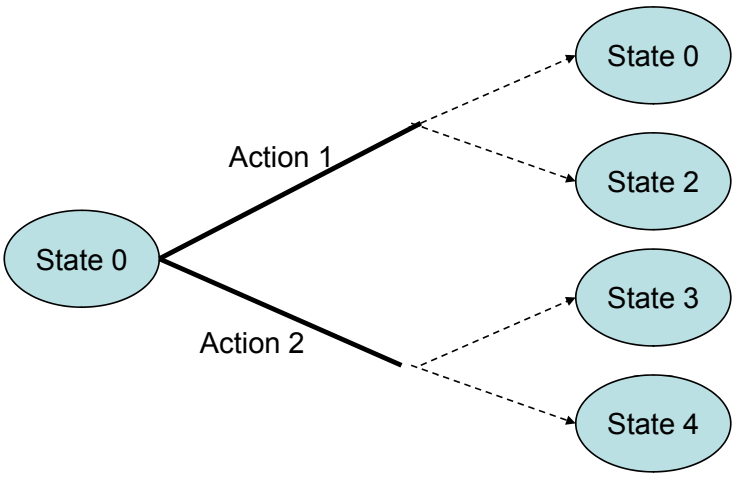
- Start by looking at decision making
  - The most mature research
  - Contrast “emotional decisions” with classical model
    - Decision Theory: dominant model of human (and agent) decision making



Classical formalism:

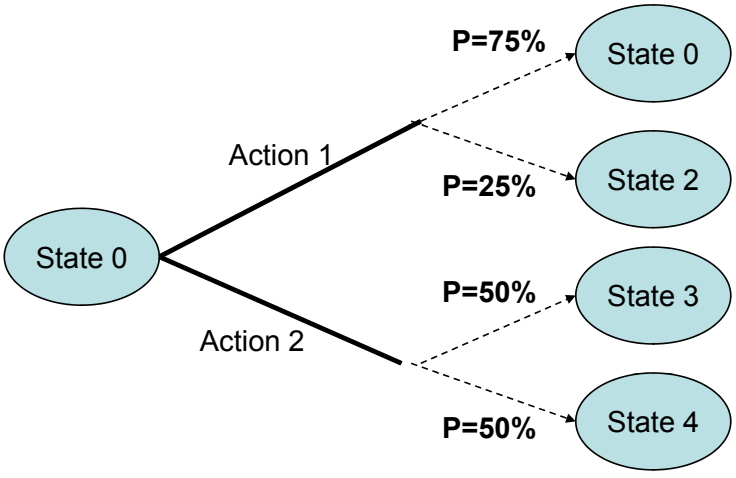
Decision making formalized as choice between alternative (actions, plans, objects, etc)

Influences of Emotion on decision-making



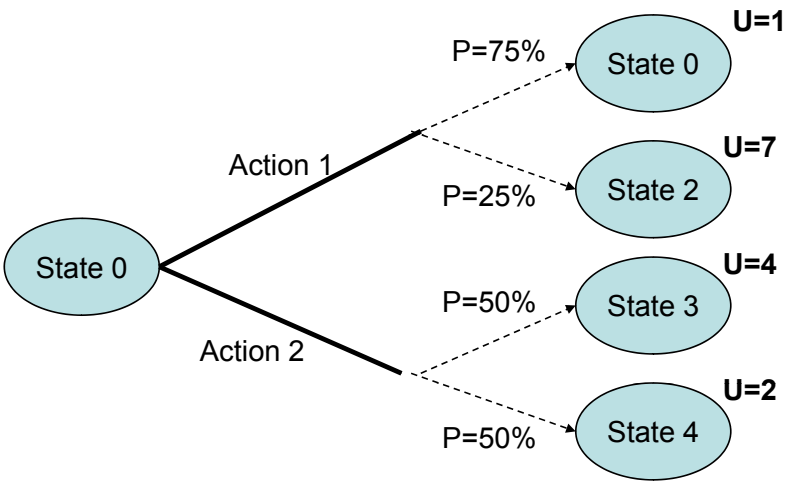
Actions have uncertain outcomes

Influences of Emotion on decision-making



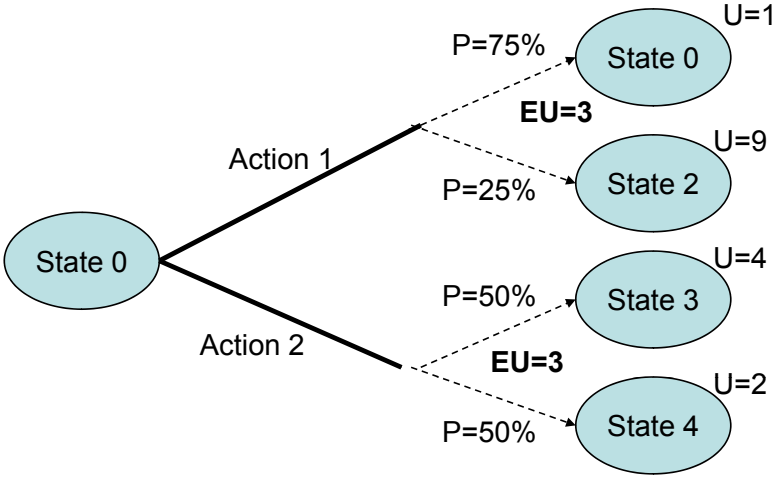
Formalize uncertainty as probability distribution over possible outcomes of actions

Influences of Emotion on decision-making



Formalize **Value** of outcome by a number called **utility**

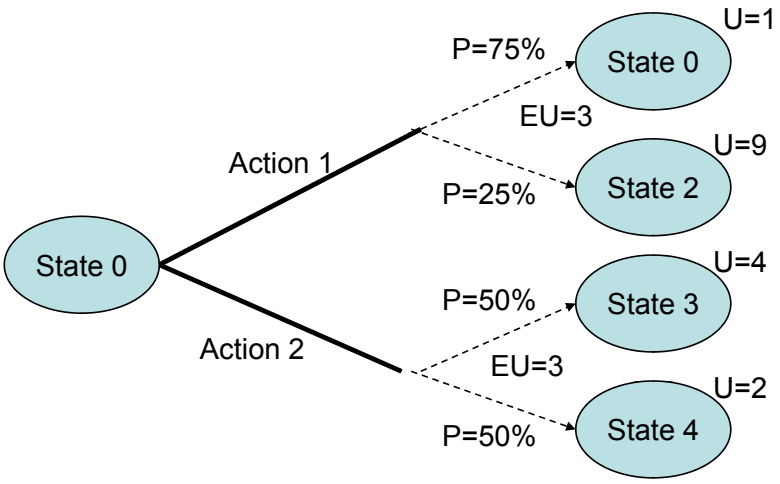
Influences of Emotion on decision-making



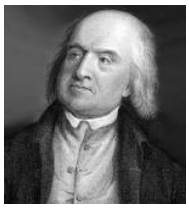
"Best" decision is to maximize **expected utility**

Influences of Emotion on decision-making

- Reconciling emotion and decision making
  - First cut: Emotion = Utility
    - Utility is subjective hedonic experience (pain and pleasure), not objective value (Bentham, 1789)
  - Decide based on "Expected Emotion"
    - Do what you think will make you feel best



David Hume

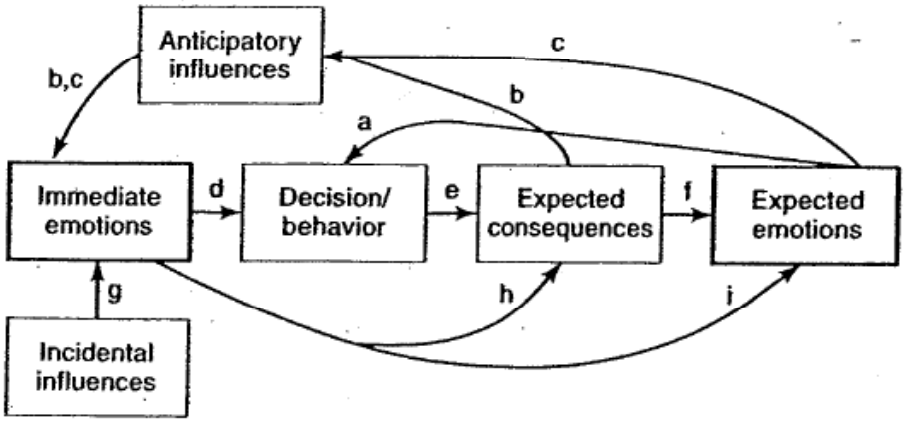


Jeremy Bentham

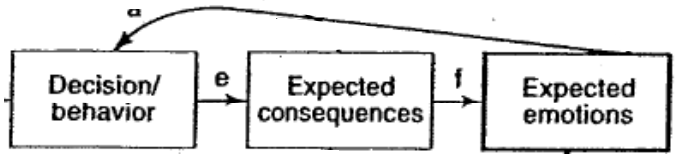
Influences of Emotion on decision-making

(Loewenstein and Lerner. 2003)

- Observation: similarities between classical decision theory and emotional decision-making, but also important distances

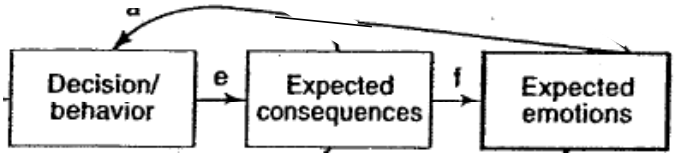


Expected emotion ≠ expected utility

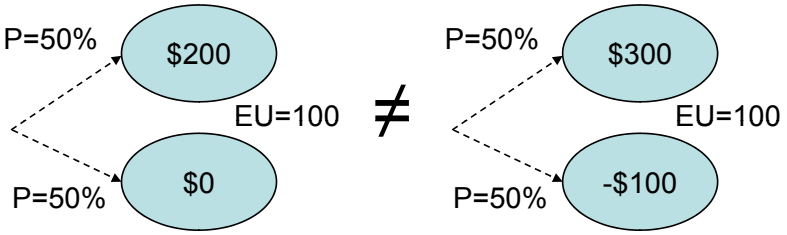


- Emotions arise from thinking about expected consequences
- These emotions act like utilities
  - i.e. Emotion is a form of utility
- But there are important differences from classical decision theory

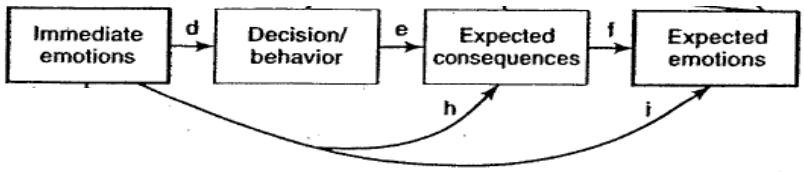
Expected Emotion



- Intensity of emotion (i.e., expected utility) depends on relative rather than absolute consequences of decisions (Markowitz, 1952)
- Intensity of emotion depends on counterfactual scenarios
  - What would have if I acted differently (Kahneman & Miller, 1986)
- Leads to regret effects (Medvec, Madley, and Golvoch95)
  - Olympic *bronze* medalists happier than *silver* medalists
    Argue because they make different comparisons
    - Bronze: At least I got a medal
    - Silver: I could have won
  - People avoid decisions they might regret afterwards



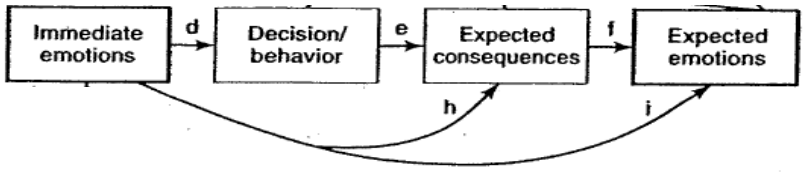
Immediate Emotion



Current emotions impact decision process in predictable ways

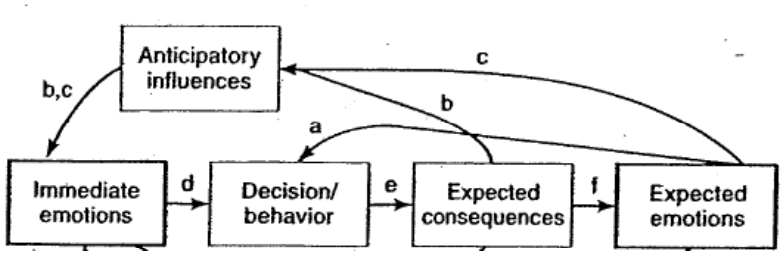
- Carry forward effects: carry current feelings into future expectations
  - Likelihood judgments: Positive emotions → downplay likelihood of risk
  - Value judgments: Positive emotions → downplay negative consequences
- Nature of Processing
  - Negative emotions narrow intentional focus (on potential threats) and deeper processing of threats
    - Narrow/deep processing, particularly of possible things that could go wrong
    - Question pre-conceptions, second guessing
    - Slower decision making
  - Positive emotions broaden attentional focus
    - Shallow processing, quick decisions
    - Uncritically accept initial judgments/stereotypes

Immediate Emotion



- Intensity Effects
  - Low intensity emotions
    - Inform cognition (Affect as information: Clore, et al. 2001)
    - Only influence decisions for which present feelings highly relevant
      - What movie to see, Yes
      - Using Java or C++, Not (as consequences not affectively charged)
    - Effects easily suppressed/overcome if aware of them
      - How do you feel on rainy vs. sunny day (Clore)
  - High intensity emotions
    - Greater influence on behavior
    - Can overwhelm cognition. People report being “out of control”
    - Eg. Phobias. People report there is nothing to fear but are helpless to act on that awareness
      - This is why IRB’s rarely, if ever, allow research on intense emotion

Anticipatory Influences



- Thinking about the future changes immediate emotions thus indirectly influencing decisions
  - Ruminating on bad consequences puts you in bad mood
  - Seems to be a "high road" and a "low road" to such influences
    - Some future expectations are "emotionally accurate" (path C)
      - Consistent with Damasio's somatic marker hypothesis: we simulate consequences using low-level neural circuits and evoke true emotion
    - Some future expectations are "inaccurate" (path B)
      - involve reasoning about emotion (I expect I would feel this way)
      - The later subject to "Morning after effects"

Anger

Lerner&Tiedens06: Portrait of the angry decision maker

Response tendency	Study	Impact of emotion
Attributions of causality and responsibility	Keltner et al. (1993)[b] (Study 1 and 2)	Relative to sad people, angry people regarded dispositional attributions as more likely and dispositional forces more responsible for an ambiguous social event.
	Quigley and Tedeschi (1996)[b]	Feelings of anger and thoughts of blame regarding a situation where someone harmed the participant escalated in a recursive loop where the more anger one experienced, the more blame placed on the perpetrator and vice versa.
	Goldberg et al. (1999)[b]	Relative to neutral emotion, anger activated more punitive attributional heuristics for inferring responsibility of harm but only when the original source of the person's anger went unpunished (i.e., people relied on their own anger from normatively unrelated events when punishing a defendant in fictional tort cases).
Evaluations and attitudes	Mackie et al. (2000)[a] (Study 1 and 2)	Relative to fear, when the ingroup was considered strong, anger towards outgroup members increased as well as the desire to take action toward outgroup members.
	DeSteno et al. (2004)[b]	Relative to sadness and neutral emotion, angry participants were slower to associate positive traits than negative traits with members of an outgroup.
	Dunn and Schweitzer (2005)[b]	Relative to sadness, guilt, gratitude, and pride, angry participants were less likely to trust others.
Perceptions of risk	Lerner and Keltner (2000)[a]	Relative to fear, anger was associated with optimistic perceptions of future risk regarding the number of yearly deaths in the United States across various events (e.g., brain cancer, strokes, floods).
	Lerner and Keltner (2001)[a] (Study 1 and 2)	Relative to fearful people, angry people were more likely to make risk-seeking choices. In contrast to fearful people, happy and angry people held optimistic beliefs about experiencing future life events (e.g., heart attack at 50, developed gum problems, married someone wealthy).

Attention effects	DeSteno et al. (2000)[b] (Study 1)	Relative to sadness, anger increased likelihood estimates of angering events (e.g., intentionally being sold a "lemon" by a used car dealer) but not saddening events (e.g., a best friend moving away).
	DeSteno et al. (2004)[b]	Relative to sadness, anger activated perceptions that angry arguments (e.g., increased traffic delays) regarding an appeal to increase the city sales tax were more persuasive than sad arguments (e.g.. suffering of special-needs infants).
Depth of processing	Bodenhausen et al. (1994)[b]	Relative to sadness and neutral emotion, anger activated heuristic processing (e.g., more stereotypic judgments, less attention to the quality of the arguments, and more attention to the superficial cues of the message).
	Lerner et al. (1998)[b]	Relative to neutral emotion, anger activated more punitive attributions (e.g., amount of blame,), harsher punishment, and heuristic processing (i.e., a reduction in the number of diagnostic cues used) in fictional tort cases.
	Tiedens (2001b)[b]	Relative to sadness, happiness and neutral emotion, anger activated heuristic processing (e.g., use of chronically accessible scripts) and hostile inferences for aggressive (but not nonaggressive) participants.
	Tiedens and Linton (2001)[b] (Study 2)	Relative to worry, anger activated heuristic processing (e.g., greater reliance on the superficial cues of the message and less attention to the argument quality).
	Small and Lerner (2005)[b]	Relative to sadness and neutral emotion, anger activated decisions to provide less public welfare assistance to welfare recipients unless participants were under cognitive load—when no difference between sadness and anger emerged.

Functional view of emotion

(Keltner & Haidt 99; Levenson; Isard; Frank; Damasio)

- Emotion plays crucial interpersonal and cognitive functions

Social Function of Emotion

- Inform self about *quality* of social interaction (Keltner&Haidt99; Clore05)
- Prepares the body for social responses
  - Anger Shifts blood from internal organs towards the hands & arms (Keltner & Haidt 99)
- Motivate formation of group bonds, loyalty, identity, norms
  - Trusting others feels good (Zak, 2004),
  - Harming others feels bad (Barrett 1995, Izard et al 98)
- Elicits adaptive social responses from others
  - Anger elicits fear-related responses (even subliminal presentation) (Dimberg&Ohman96)
  - Distress elicits sympathy (Eisenberg et al89)
- Transmit coordinating information (Spoor&Kelly04, Parkinson01)
  - Facial expressions, emotional contagion, social referencing
- Emotions motivate social sharing
  - Seek social support (Carver, Weintraub, & Scheier, 1989; Stober, 2004; Dukel-Schetter,)
  - As part of a need to "search for meaning" (Luminet, et al., 2000; Rimé, Mesquita, Philippot, & Boca, 1992)
  - As part of a "reality negotiation" to mitigate the negative impact of a possible transgression, through the use of excuses (Snyder, 1989; Snyder & Higgins, 1997)

Cognitive Function of Emotion

- Homeostasis/goal prioritization
  - Sometime cognition shouldn't be allowed to be in charge. Certain goals, food, bathroom, should interrupt cognition
- Focus of attention/Depth of processing (Bless, Schwarz& Kemmelmeier96)
  - It is important to pay attention to threats
  - If feeling good, you must be making good decisions. No need to think deeply or question prior beliefs
- Learning/Salience/Retrieval (Bower91)
  - If in danger, probably useful to remember prior time you were in danger
- Belief formation (Mele01)
  - Sometimes perceptual evidence should be discounted by desire
  - If child accused of crime, may be "rational" to maintain his innocence given the cost of wrong accusing him

General takeaway:

Study of emotion can enrich and complement AI

- AI arose from narrow view of intelligence
  - Cognitive Psychology, Logic, Decision Theory
- Emotion psychology considers different phenomena
  - Social psychology, motivation, drives

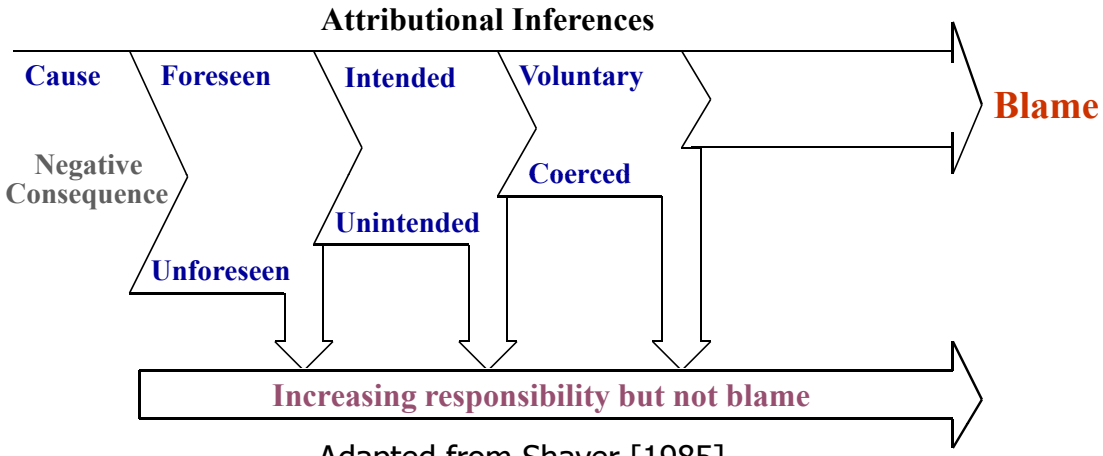
Traditional Perspective	Emotion Perspective
Emphasizes individual problem solving	Cognition embedded in a social and cultural context
Single goal	Multiple problem-solving styles
Single optimal solution	Juggling multiple goals
Short-term interactions	Long term adaptation

To survive, organisms must be able to appropriately focus on external events, characterize how they relate to their internal needs (e.g., is this an opportunity or a threat?), consider potential responses (e.g., fight, flight or plan) and recruit the cognitive, physical and social resources needed to adaptively respond. Emotion plays a central role in this process.

Wenji

Social Appraisal (Mao&Gratch2003,2005)

Some appraisals require social inferences (theory of mind)
e.g., Causal attribution involved in Anger



Adapted from Shaver [1985]

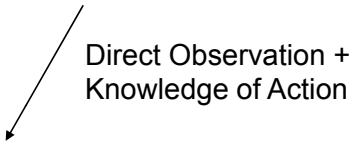
Firing squad

- An officer orders two marksmen to shoot a man. They strenuously object but the officer insists. The marksmen take careful aim, shoot the man and he dies.

Negative Consequence

Firing squad

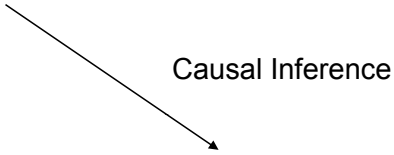
- An officer orders two marksmen to shoot a man. They strenuously object but the officer insists. The marksmen take careful aim, shoot the man and he dies.



Marksmen: Cause

Firing squad

- An officer orders two marksmen to shoot a man. They strenuously object but the officer insists. The marksmen take careful aim, shoot the man and he dies.



Marksmen: Cause → Intent

Firing squad

- An officer orders two marksmen to shoot a man. They strenuously object but the officer insists. The marksmen take careful aim, shoot the man and he dies.

Dialogue Inference

Marksmen: Cause → Intent → ¬Voluntary → Blame

Firing squad

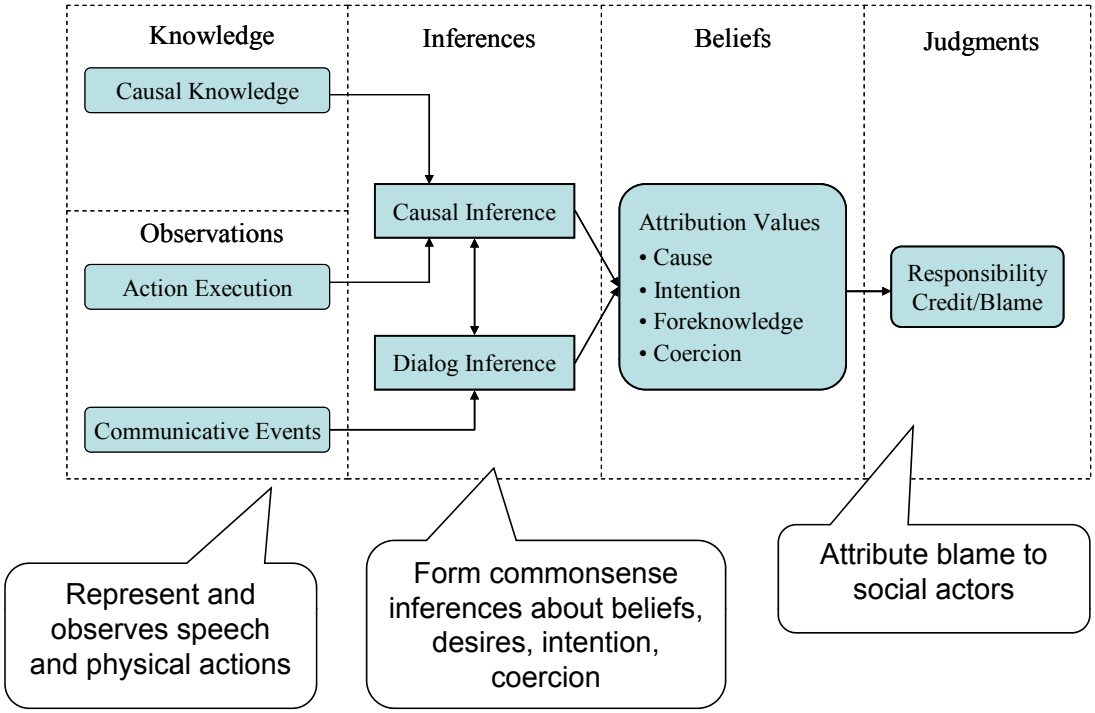
- An officer orders two marksmen to shoot a man. They strenuously object but the officer insists. The marksmen take careful aim, shoot the man and he dies.

Marksmen: Cause → Intent → ¬Voluntary

Officer: Cause → Intent → Voluntary? → Excuse?

Blame depends on further judgments: was his decision was coerced, was the killing justified

Model of causal attribution (Mao, 2006)



Models

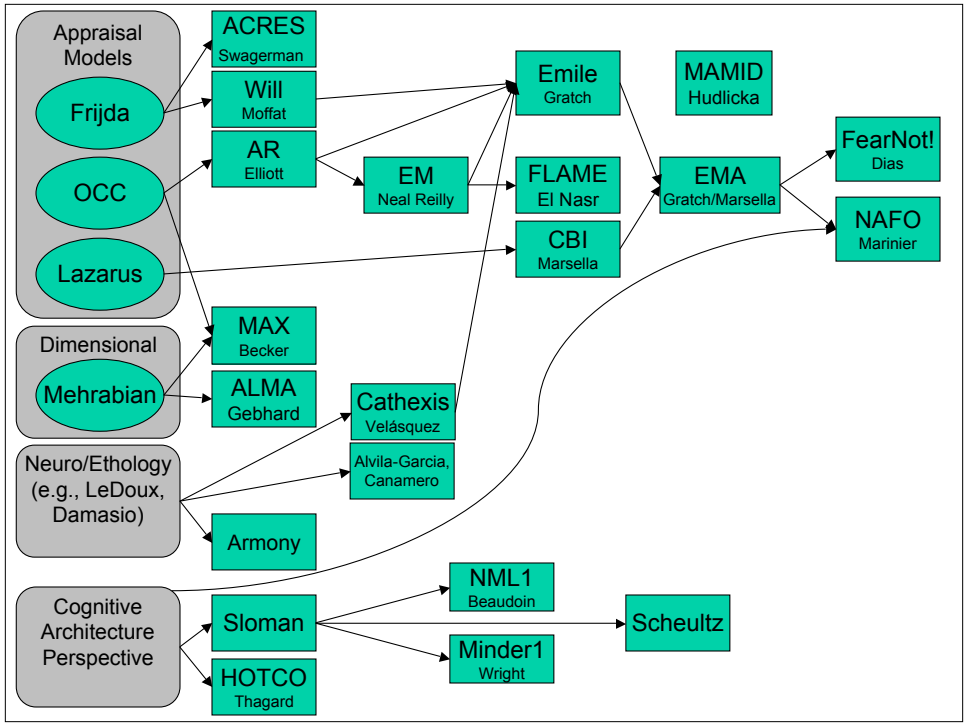

Appraisal Models
Frijda
OCC
Lazarus
Dimensional
Mehrabian
Neuro/Ethology (e.g., LeDoux, Damasio)
Cognitive Architecture Perspective
ACRES
Swagerman
Will
Moffat
AR
Elliott
MAX
Becker
ALMA
Gebhard
Armony
Sloman
HOTCO
Thagard
EM
Neal Reilly
Cathexis
Velásquez
Alvila-Garcia, Canamero
Emile
Gratch
FLAME
El Nasr
CBI
Marsella
NML1
Beaudoin
Minder1
Wright
MAMID
Hudlicka
EMA
Gratch/Marsella
Scheultz
FearNot!
Dias
NAFO
Marinier

Diagram comments

- Draw on Different Theories
  - Grounded in different experimental techniques
  - Appraisal Theories dominant
- Creating models from particular theories versus pulling from different theories
- Models of specific affective phenomena versus more general models
- Built for different Applications
- Different computational techniques
- Lineage

Modeling Appraisal Theory

Theoretical perspective

Magda Arnold

- Top down theories
  - Cognition influences emotion
  - Appraisal Theory (Arnold, Lazarus, Frijda, Scherer)

    Emotion arises from an *evolving subjective interpretation* of person's relation to their environment and informs cognitive and physical acts
  - Constructive theory

    Model the cognitive processes that inform / are informed by emotion

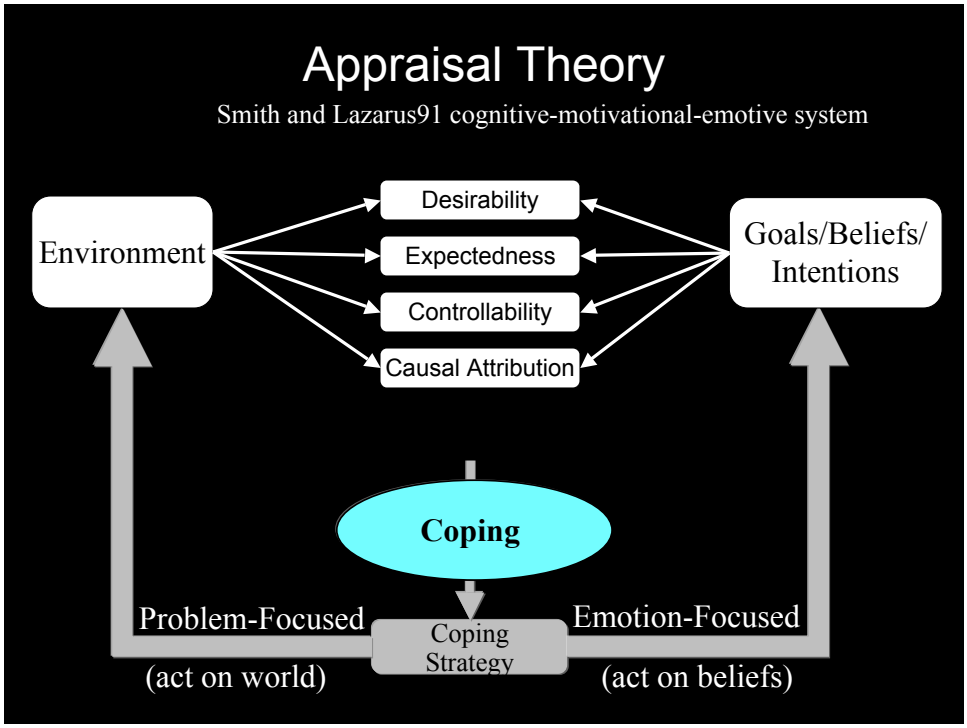
Theoretical Perspective

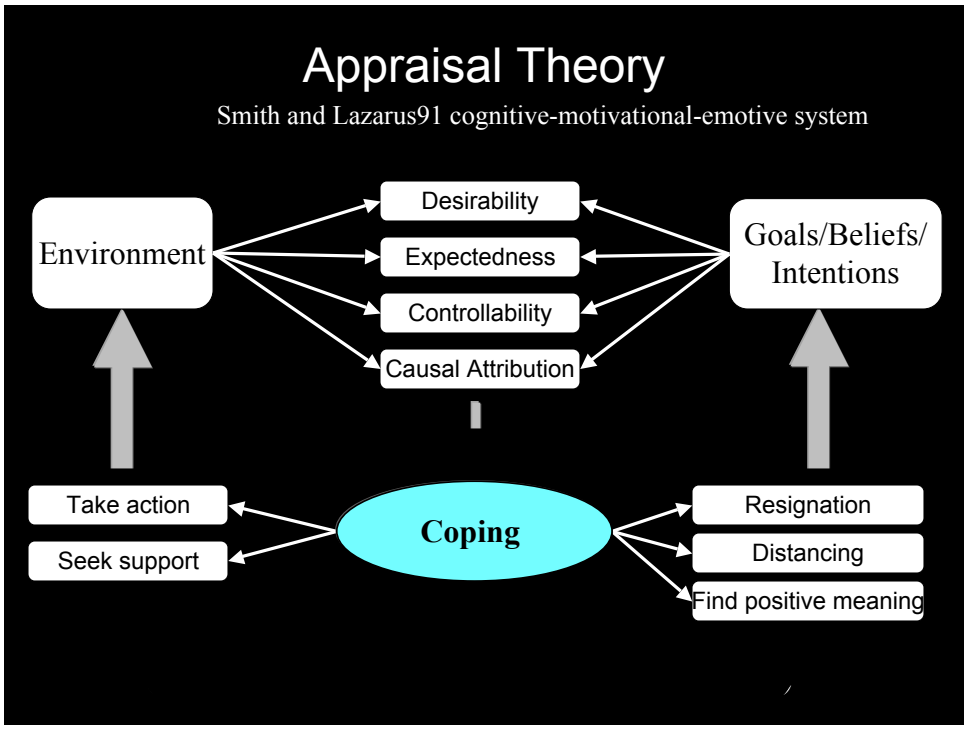
- Appraisal Theory (Arnold, Lazarus, Frijda, Scherer)

  Emotion arises from an *evolving subjective interpretation* of person's relation to their environment and informs cognitive and physical acts
  - Leventhal & Scherer's *Conceptual Level* of processing

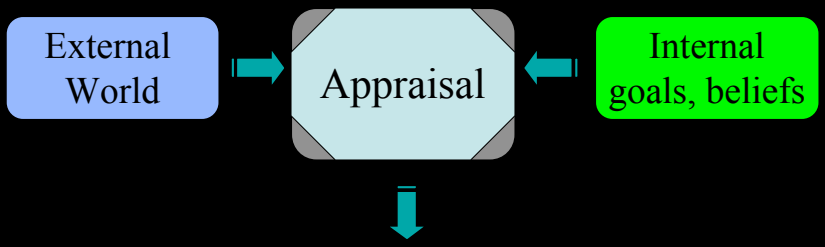
    (e.g. planning, social attributions, language)
  - Constructive theory
    - Model the cognitive processes that inform / are informed by emotion

  Emotion epiphenomena: what matters are appraisals and the responses they evoke


Appraisal Theory
Smith and Lazarus91 cognitive-motivational-emotive system
Environment
Desirability
Expectedness
Controllability
Causal Attribution
Goals/Beliefs/
Intentions
Coping
Problem-Focused
Coping
Strategy
Emotion-Focused
(act on world)
(act on beliefs)


Appraisal Theory
Smith and Lazarus91 cognitive-motivational-emotive system
Environment
Desirability
Expectedness
Controllability
Causal Attribution
Goals/Beliefs/
Intentions
Take action
Seek support
Coping
Resignation
Distancing
Find positive meaning

Appraisal



- Appraisal = Situation assessment
  - Compare beliefs, desires and intentions with external circumstances

9/10/07

Appraisal

- Characterize via *appraisal variables*
  - Desirability
    - Does this event help/hurt my goals
  - Likelihood
    - How likely is it that this event will occur
  - Unexpectedness
    - Was this event expected
  - Causal attribution (causality, agency, blame/credit)
    - Who deserves blame for causing the event
  - Coping potential (controllability, adaptability)
    - What chance do I have for dealing with this event
- Superset of criteria considered by intelligent systems
  - Decision theory: desirability, likelihood
  - Scheduling: desirability, urgency

9/10/07

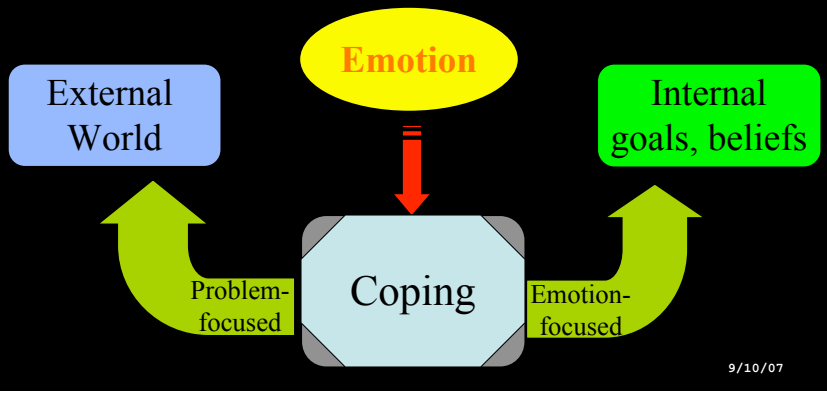
Appraisal

- Emotions defined in terms of configurations of appraisal variables
  - Undesirable, Uncertain → Fear
  - Desirable, Certain → Joy
  - Undesirable, Caused-by(Other) → Anger-at(Other)

9/10/07

Coping Strategies

- Coping = Response strategy
  - Characterized by ontology of coping strategies



9/10/07

Coping Strategies

- Problem-focused (act on the world)
  - Action execution
  - Planning
  - Seek instrumental social support
- Analogous to:
  - Deliberative or reactive problem solving
  - Team negotiation

9/10/07

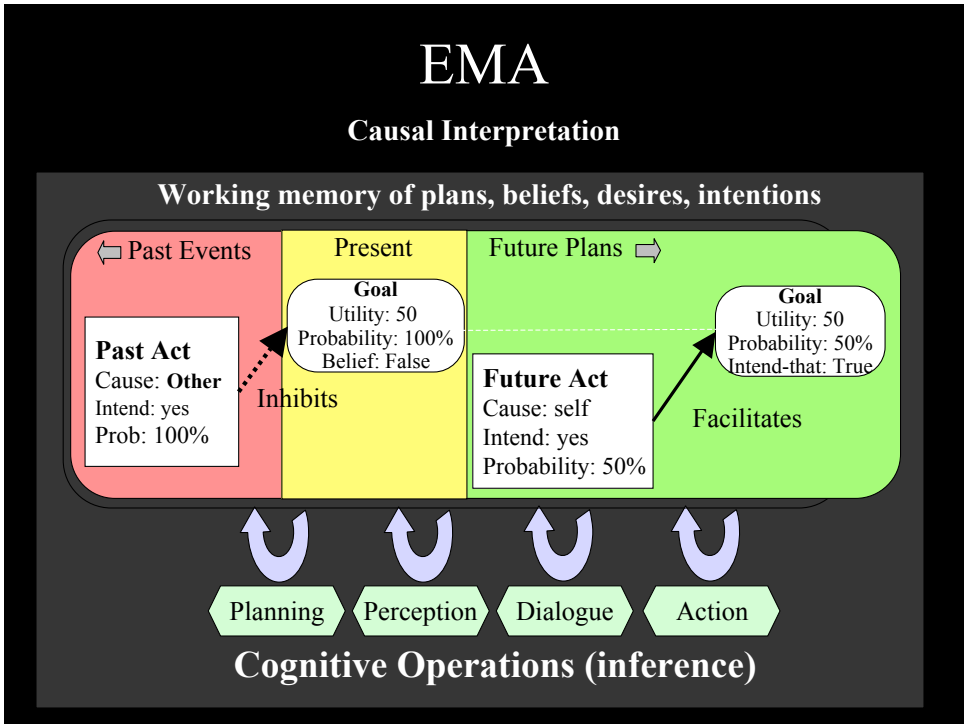
Coping Strategies

- Emotion-focused (act on belief)
  - Denial
  - Find positive meaning
  - Resignation
  - Shift blame
  - Distancing
- Not typically considered by intelligent systems
  - More than a decision (e.g. abandon current plan)
    - Provides self-justification for why
    - Related to motivational / explanatory coherence
    - Leads to persistent change in behavior

9/10/07

Appraisal Theory as architectural specification

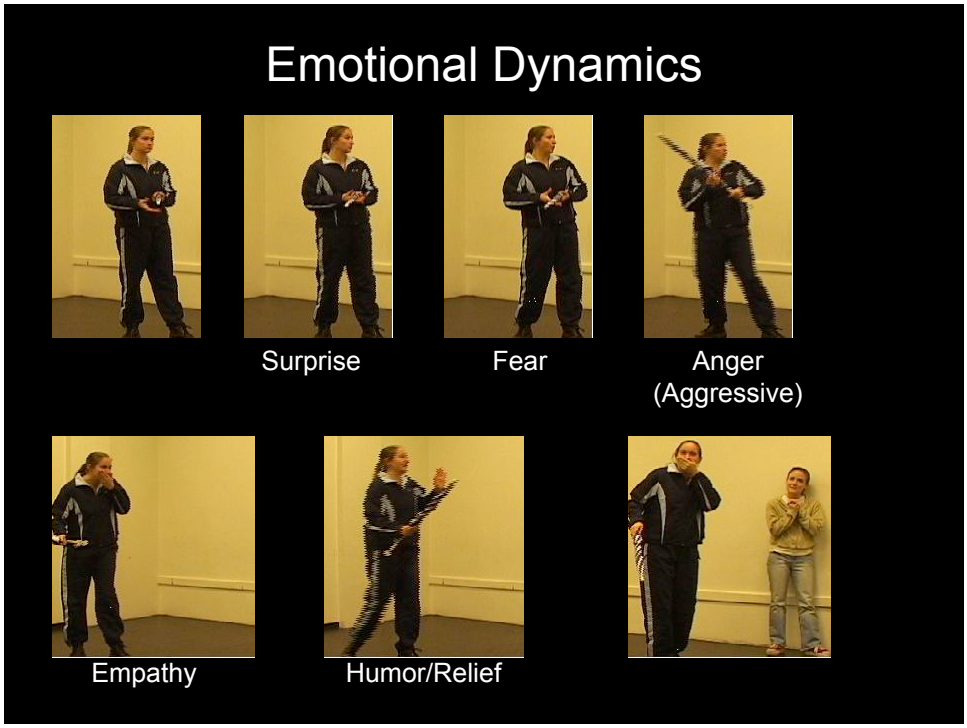
- Provides high-level requirements
- How do we map this into an architecture
  - How do we represent the person-environment relation?
  - How do appraisal processes operate over this representation?
  - How do coping processes impact beliefs, behavior
  - What is the relation between the processes of
    - Appraisal
    - Cognition
    - Coping
  - How do these interactions interact/unfold over time?

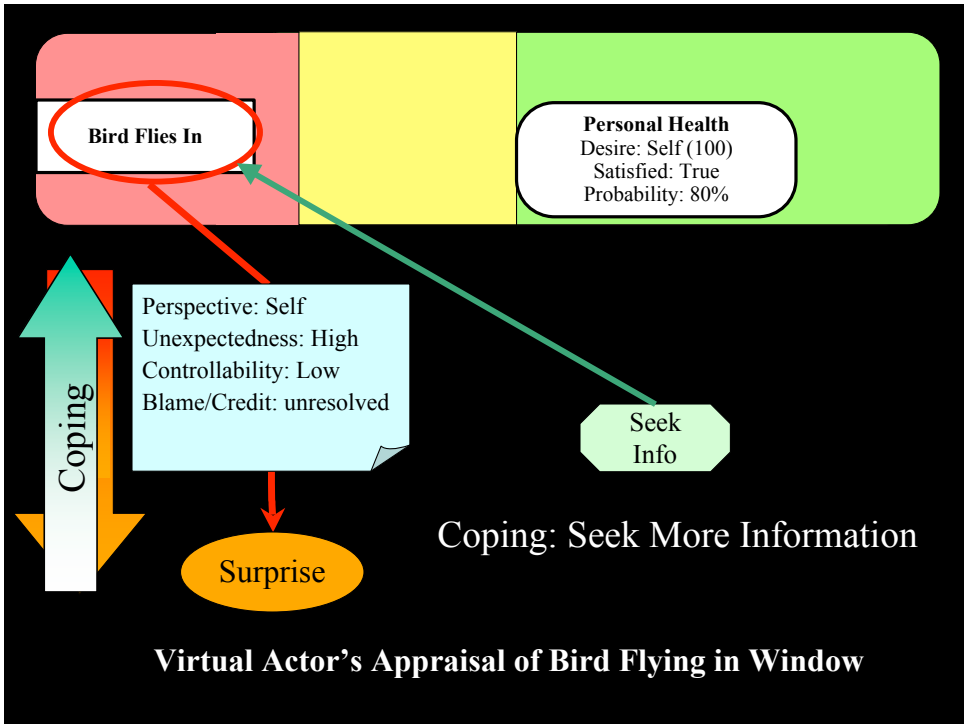


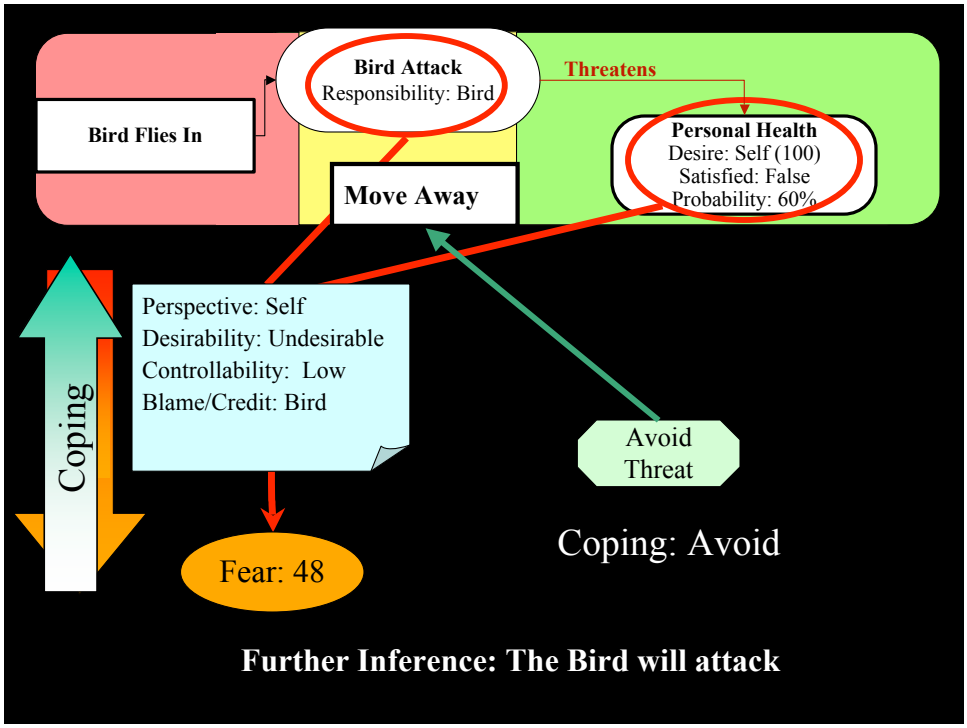
Modeling Appraisal & Coping

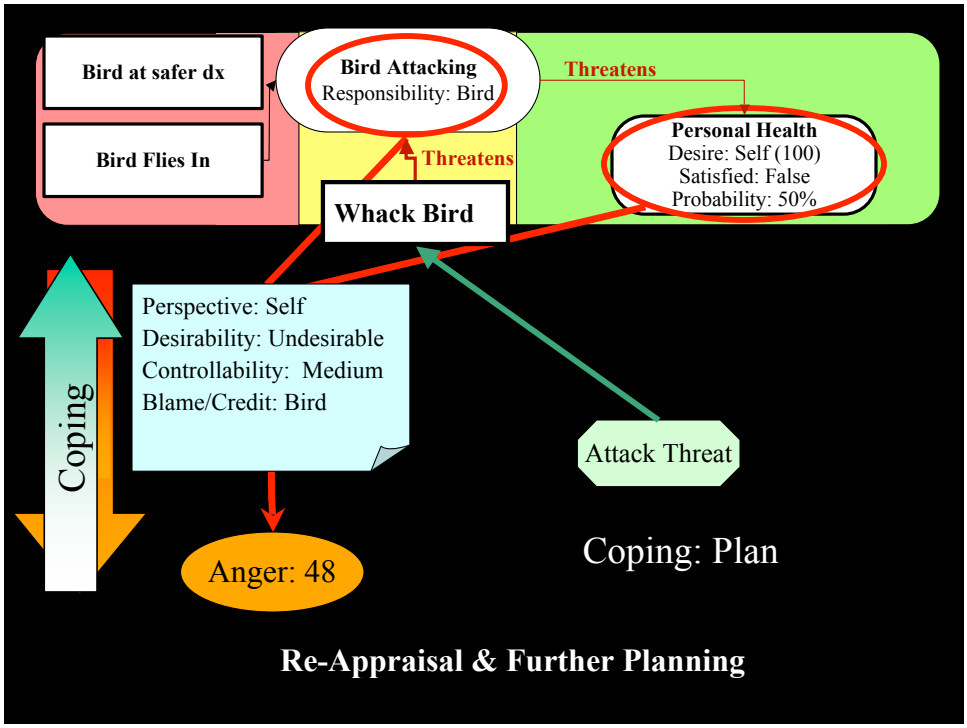
- Appraisal as evaluation of the causal interpretation
  - Define appraisal variables in terms of features of interpretation
  - Fast, automatic
- Coping: Operators that suggest ways to change interpretation
  - Sequential, deliberate, mediated by focus of attention
  - Problem-focused → Take Action, Make Plans
  - Emotion-focused
    - **Denial/Wishful Thinking → Change belief / likelihood**
    - **Find silver lining → Change utilities**
    - **Shift blame → Change causal attribution**
      → Dialogue moves
    - **Distancing/acceptance → Drop goal / intention**
    - **Avoidance → Change topic**
      → Add goal (e.g., go to party)

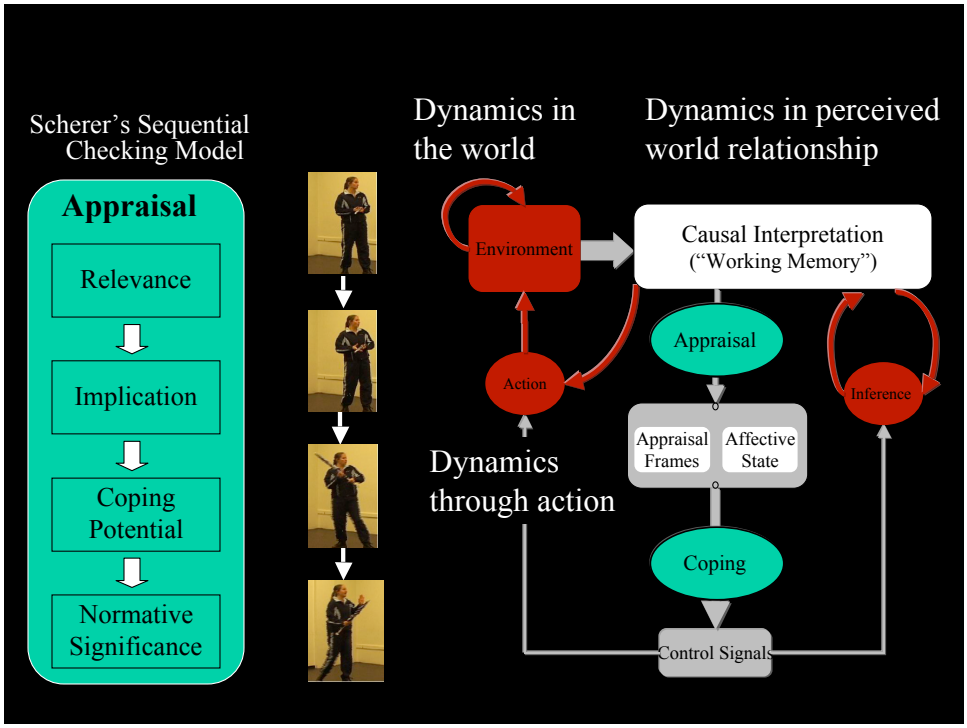
Key: A "Content" & "Process" Model

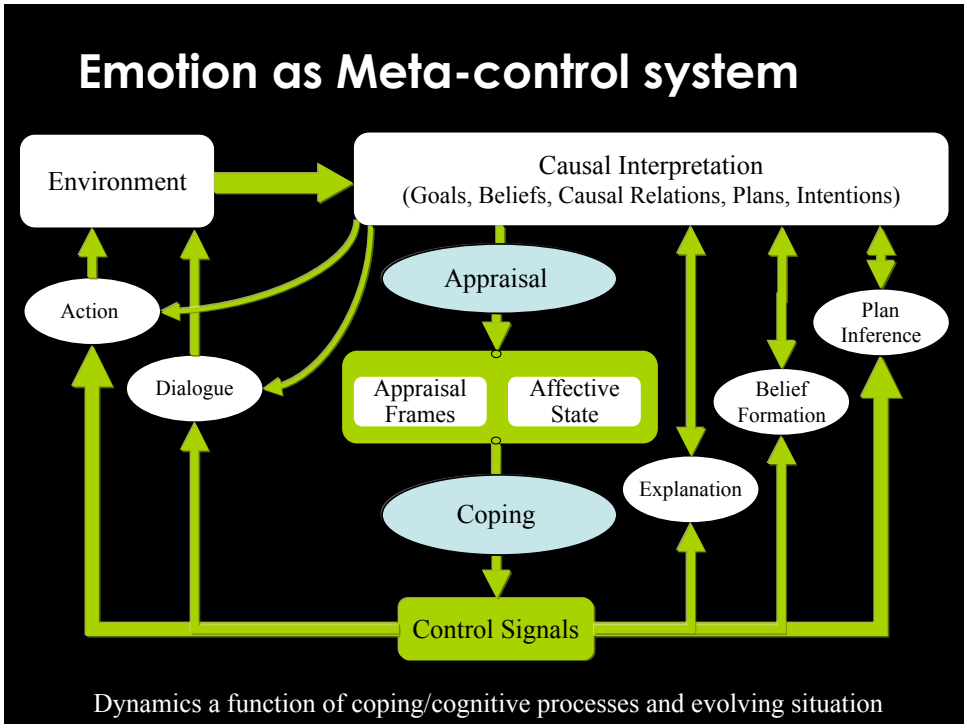

Emotional Dynamics
Surprise
Fear
Anger
(Aggressive)
Empathy
Humor/Relief


Bird Flies In
Personal Health
Desire: Self (100)
Satisfied: True
Probability: 80%
Perspective: Self
Unexpectedness: High
Controllability: Low
Blame/Credit: unresolved
Coping
Seek
Info
Surprise
Coping: Seek More Information
Virtual Actor's Appraisal of Bird Flying in Window


Bird Flies In
Bird Attack
Responsibility: Bird
Threatens
Personal Health
Desire: Self (100)
Satisfied: False
Probability: 60%
Move Away
Perspective: Self
Desirability: Undesirable
Controllability: Low
Blame/Credit: Bird
Coping
Avoid Threat
Fear: 48
Coping: Avoid
Further Inference: The Bird will attack


Bird at safer dx
Bird Flies In
Bird Attacking
Responsibility: Bird
Threatens
Threatens
Personal Health
Desire: Self (100)
Satisfied: False
Probability: 50%
Whack Bird
Perspective: Self
Desirability: Undesirable
Controllability: Medium
Blame/Credit: Bird
Coping
Attack Threat
Anger: 48
Coping: Plan
Re-Appraisal & Further Planning


Scherer's Sequential Checking Model
Appraisal
Relevance
Implication
Coping Potential
Normative Significance
Dynamics in the world
Dynamics in perceived world relationship
Environment
Causal Interpretation ("Working Memory")
Appraisal
Inference
Action
Appraisal Frames
Affective State
Dynamics through action
Coping
Control Signals

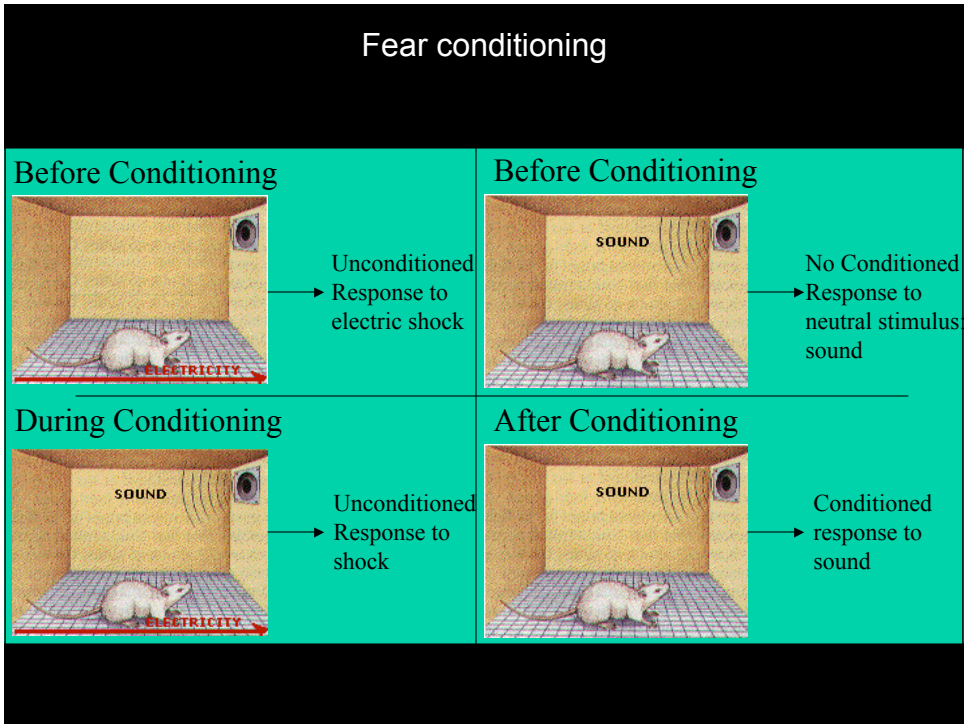

Emotion as Meta-control system
Environment
Causal Interpretation
(Goals, Beliefs, Causal Relations, Plans, Intentions)
Appraisal
Action
Plan Inference
Dialogue
Appraisal Frames
Affective State
Belief Formation
Explanation
Coping
Control Signals
Dynamics a function of coping/cognitive processes and evolving situation

Armony et al. model of fear conditioning

Theoretical Basis

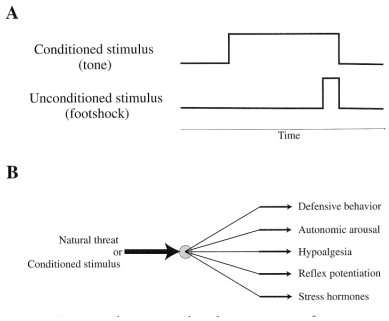
Fear Conditioning in the Rat (LeDoux)

Fear conditioning



Fear Conditioning

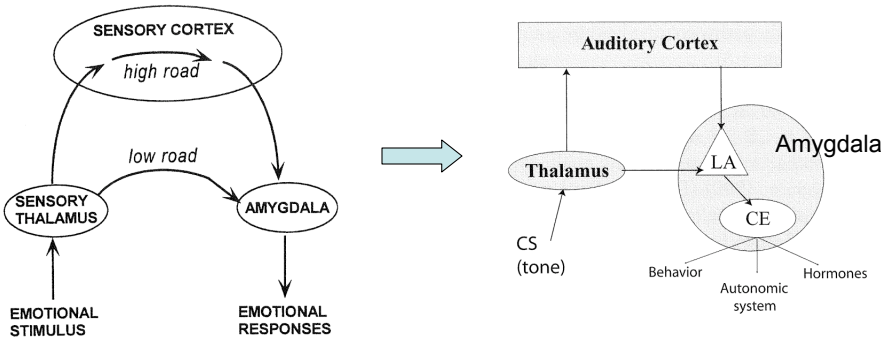
- Neutral stimulus (conditioned stimulus) can acquire affective properties if paired with a biologically significant event (unconditioned stimulus)
- Pair audio tone (conditioned stimulus) with electric shock (unconditioned stimulus)
- Rat eventually learns to react aversively just to tone
- Then study learned pathways and role of various brain regions via
  - Staining of neurons and dissection
  - Impact of lesions on behavior



Key Regions Studied

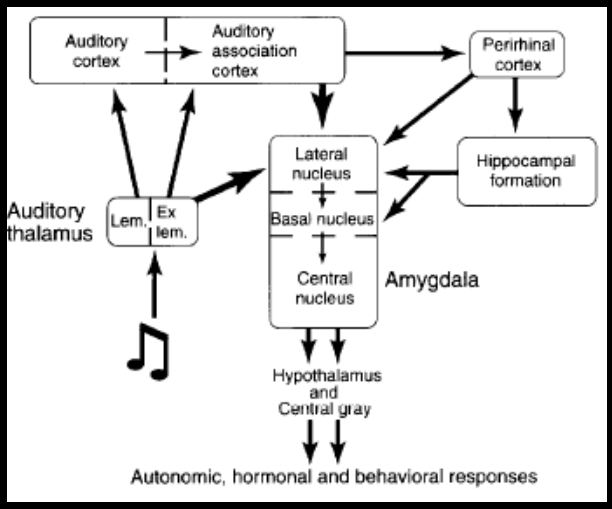
- Amygdala
  - Forms association of tone with reaction
  - Part of the cortex (cognitive processing, more recently evolved area)
  - Connects cortical to subcortical (older, reflexive behavior)
  - Has 12 (or more) subcomponents or nuclei
- Thalamus
  - Processing of stimuli
- Sensory/Auditory Cortex
  - More sophisticated processing/analysis of stimuli

Hi-Lo Roads



- **Low Road**:
  - Thalamus to Amygdala
  - Fast response
- **High Road**:
  - Thalamus to Sensory Cortex to Amygdala
  - Slower response, deeper processing of stimulus in cortex

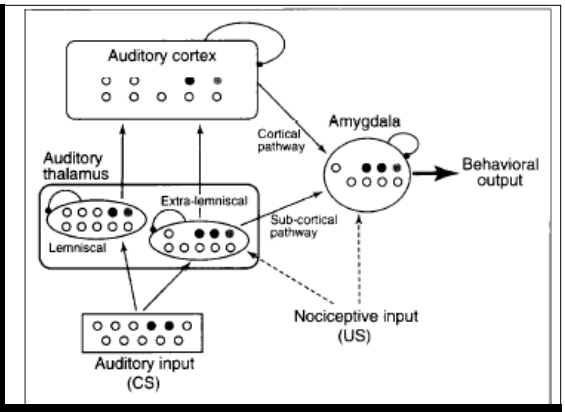
LeDoux's theoretical model

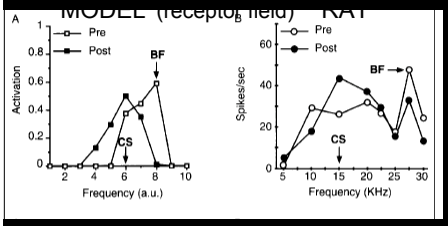


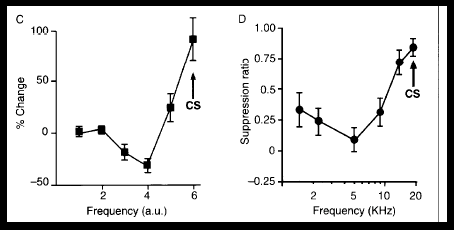
Armony et al. model of fear conditioning

- Anatomically inspired model of the fear circuit
  - Goal: Improve theories of human intelligence
  - Approach: Connectionist
  - Scope: Modeling specific emotional phenomenon

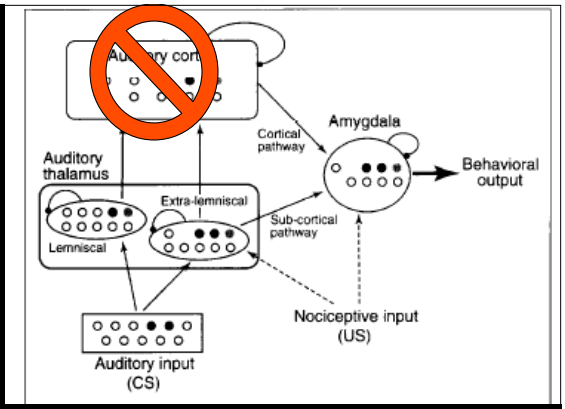
- Set of identical computational units representing neural structures of fear circuit
- Feedforward excitatory connections between modules.
- Units within module inhibitory
- Train through Hebb rule
- Simple Abstract Model
  - Attempts to be accurate about information flow
  - Not accurate in terms of imformation content/ computation
- Show model is consistent with data

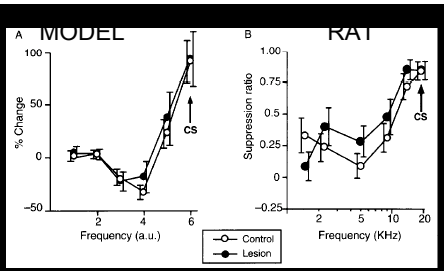






- INTERESTING PART
- "Lesion" model
- Make novel predictions
- Test prediction
- Predicted receptor field would be less discriminating w/o cortex. Both model and Rats showed no deficit
- Argue that thalamus can process more information than they believed
- Potential criticism: model also seems to invalidate their hypothesis that cortex improves discrimination
  - Here they argued stimulus was "auditory" but could be any stimulus.





EVALUATION

- Evaluations depending on model aims
  - Evaluating models of human behavior
    - Does model faithfully capture human performance
  - Evaluating "functional" models
    - Does emotion improve reasoning capabilities of an agent
  - Evaluating applications
    - Does model of emotion help achieve goals of application
- General methodological questions

Evaluating human behavior models

- Basic claim:
  - Emotions influence cognition (for good or ill)
  - This influence can be faithfully modeled
- Empirical questions
  - Does model exhibit posited influence
  - Does model performance compare with human performance *on the same task*
  - Does it show the proper emotional dynamics
  - Are the results "ecological"
- Model-driven experimentation
  - Can the model generate and test novel predictions

General Issues

- Human behavior models rarely tested
- Tests have tended to use weak criteria of "success"
  - Subjective judgments of plausibility (e.g. believability)
  - Post hoc fitting to existing data, not prediction
- Limits of existing data collection
  - Focus on irrelevant emotion (mood induction)
  - Focus on artificial/imagined situation
- Rarely assess process assumptions
  - "One-shot" experiments (e.g. lotteries, prisoner's dilemma)
  - Don't assess how appraisal changes as situation evolves
  - Don't assess how coping impacts re-appraisal

Experiment 1

(Gratch & Marsella, 2005)

Use established psychological instrument
Stress & Coping Process Questionnaire
(SCPQ; Perrez & Reicherts, 1992)

- Text description of 18 evolving situations
- Elicits self-reports of emotional state, Appraisals, Coping tendencies
- Identifies "normal" emotional trajectories

Onset: You forgot to do something important for your partner. They get very angry and blame you

I feel: (EMOTION)

Angry/furious	0 1 2 3 4 5
Depressed/sad	0 1 2 3 4 5

My judgments: (APPRAISAL)

Chances improve:	0 1 2 3 4 5
Chances of influence:	0 1 2 3 4 5

My intentions: (COPING STRATEGY)

To confront other	0 1 2 3 4 5
To remain calm	0 1 2 3 4 5

Experiment 1

(Gratch & Marsella, 2005)

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(SCPQ; Perrez & Reicherts, 1992)

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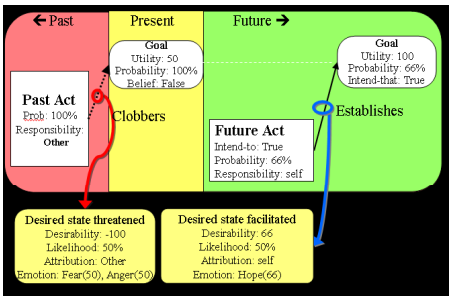
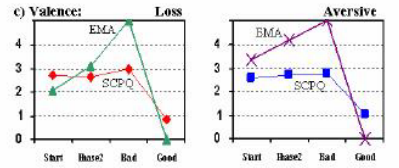


Encoded as causal theories in EMA

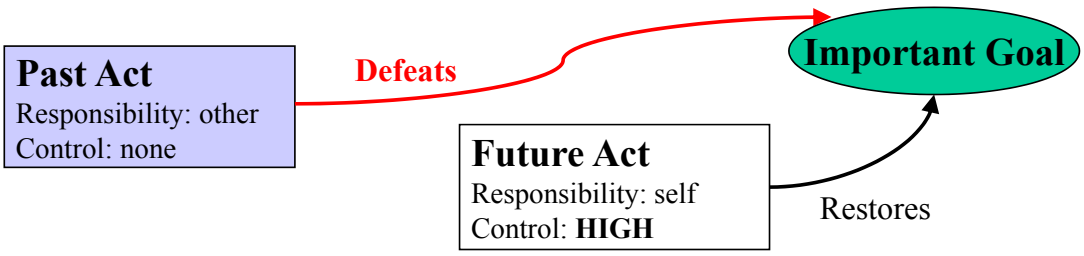
Results:

- EMA consistent with most trends

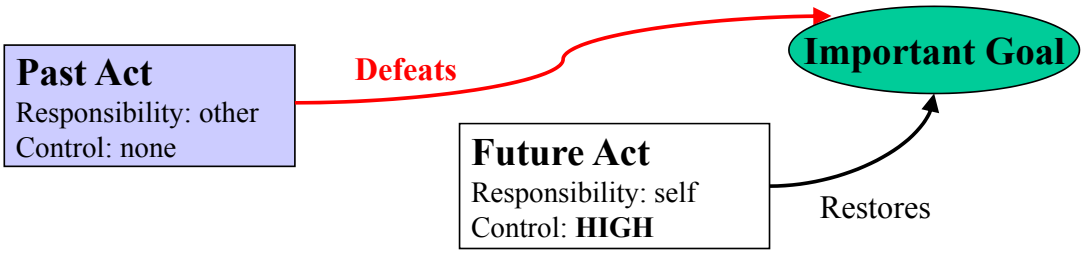


Dynamic Emotional Scenarios

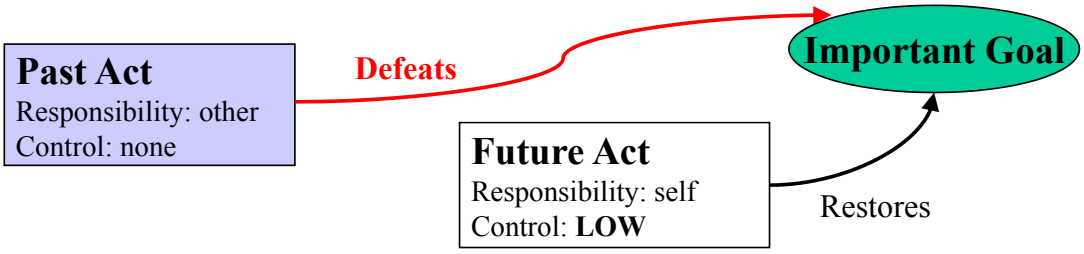
- Two prototypical scenarios
  - Aversive scenario
    - Goal was thwarted, some potential to reverse
    - Situation relatively controllable, changeable
  - Loss scenario
    - Potential threat to goal is looming
    - Less controllable, changeable
- Evolve over three discrete phases
  - Initial
  - Continuation
  - Good or Bad outcome
- Ask subject to self report aspects of their emotions



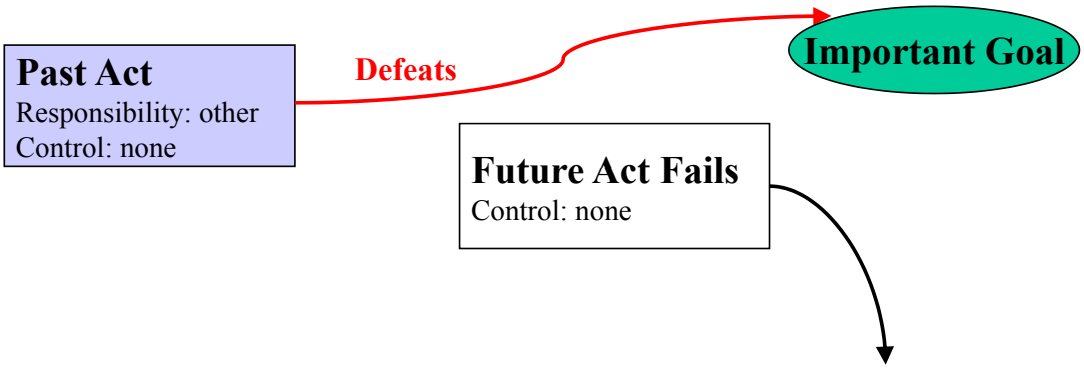
- E.g: aversive situation
  - Goal was thwarted, some potential to reverse
  - Situation relatively controllable, changeable



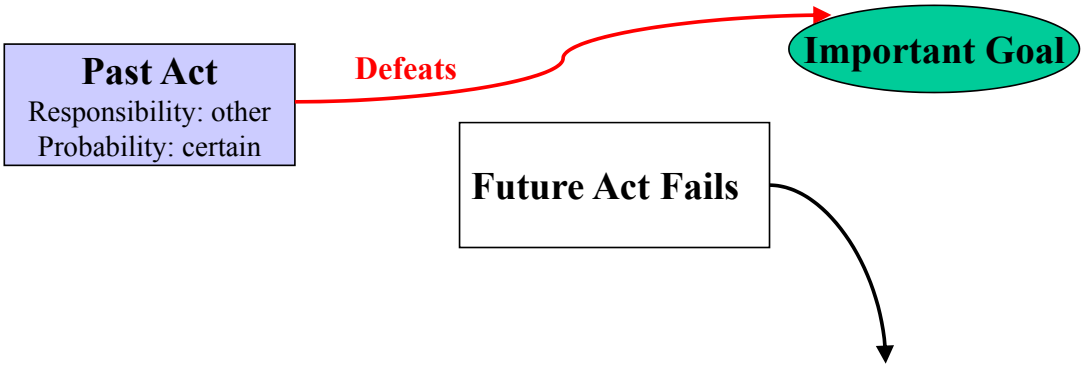
- Evolve scenario over phases: initial



- Evolve scenario over phases: continuation



- Evolve scenario over phases: outcome



- Translate, via a grammar, into text
  - **Onset**: You forgot to do something important for your partner. They get very angry and blame you
  - **Continuation**: After a while, their attitude hasn't changed
  - **Outcome**: They leave in an angry state.

Data Elicitation

- After each phase of each scenario, ask:
  - **I feel:** (EMOTION)
    - Angry/furious gentle/peaceful 0 1 2 3 4 5
    - Depressed/sad cheerful/serene 0 1 2 3 4 5
    - …
  - **My judgments** are: (APPRAISAL VARIABLES)
    - The chances of improving are: 0 1 2 3 4 5
    - The chances I can influence it are: 0 1 2 3 4 5
    - …
  - **My intentions** are (COPING STRATEGY)
    - To confront the other 0 1 2 3 4 5
    - To remain calm 0 1 2 3 4 5
    - …

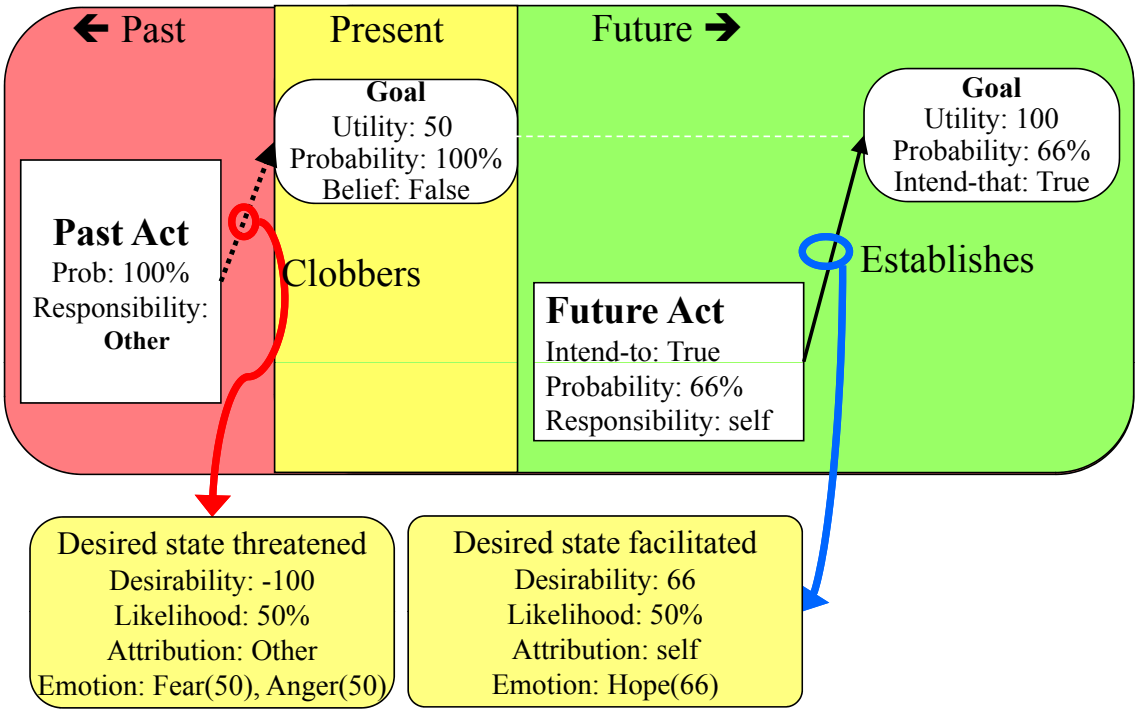
Predictions (“Healthy” trends)

1.1 “Aversive” situation → more appraised control
1.2 Control diminishes across phases
1.3 Negative valence increases across phases
1.3 Strong difference in valence on negative vs. positive outcomes
2.1 Less appraised control → less problem-directed coping

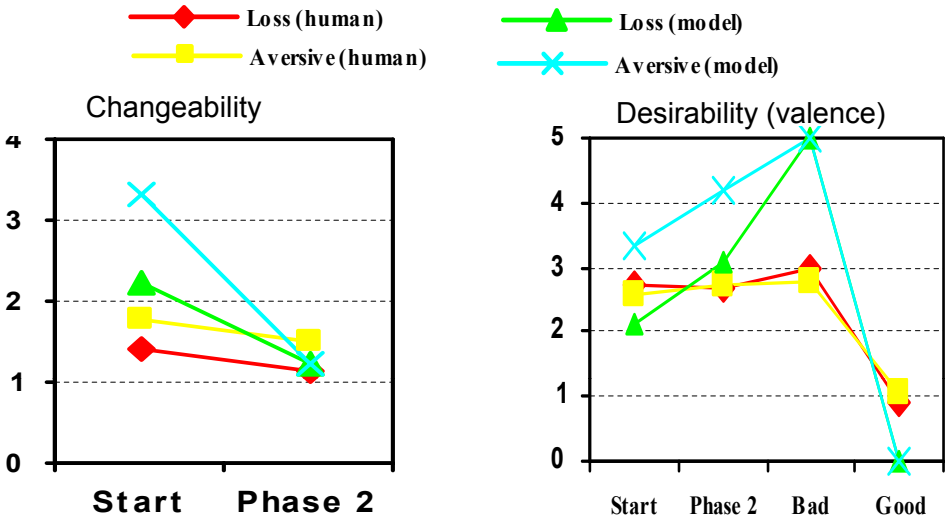
Methodology

- Encode situations in our model
- Evolve the situation
- After each phase, “quiz” the model
- Compare fit to “healthy” tendencies

Aversive Condition



Appraisal results (partial)



Coping results

More emotion-directed coping in Loss situation

Results

- Trends largely supported
- Except:
  - OCC “distress” ≠ “sadness”
    - Does not distinguish sense of control
  - Responsibility ≠ blame
    - Need attribution theory (Mao & Gratch 04)

Critique

- Results
  - Trends largely supported
  - OCC “distress” ≠ “sadness”
    - Does not distinguish sense of control
- Critique
  - SCPQ collapses individual differences
    - Fitting aggregate trends, not individual emotional responses
  - Doesn’t assess appraisal/coping interactions (Dynamics)
  - Issues with validity of self reports
  - Subjective interpretation in domain model

Experiment 2

- Address limitations
  - Use real, not imagined situations
  - Use behavioral measures as well as self-report
  - Test novel and specific predictions, not simply (previously reported) trends

- Turn-based strategy game
- Allows manipulation of appraisals
  - Partial Observability
  - Opportunities for deception
  - Social emotions
- Simple enough to model
- Complex enough for interesting dynamics

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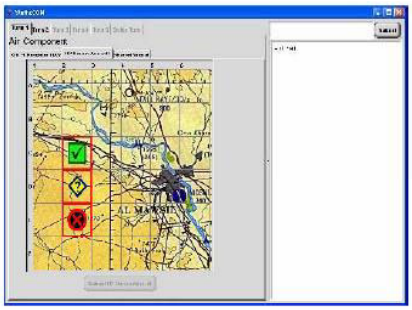
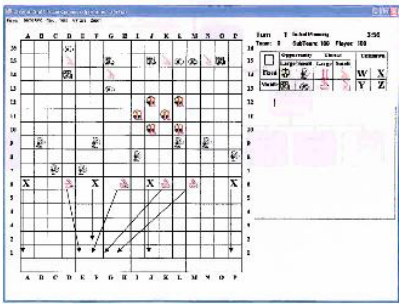


StrikeCOM (Burgoon et al)

Study group dynamics, deception



Robinson, Dasinger, Ilgen

AF Squadron Officer School Leadership Course

Battleship Game Study

OBJECTIVE: examine dynamics of appraisal & coping responses when goals of WINNING & FAIRNESS threatened

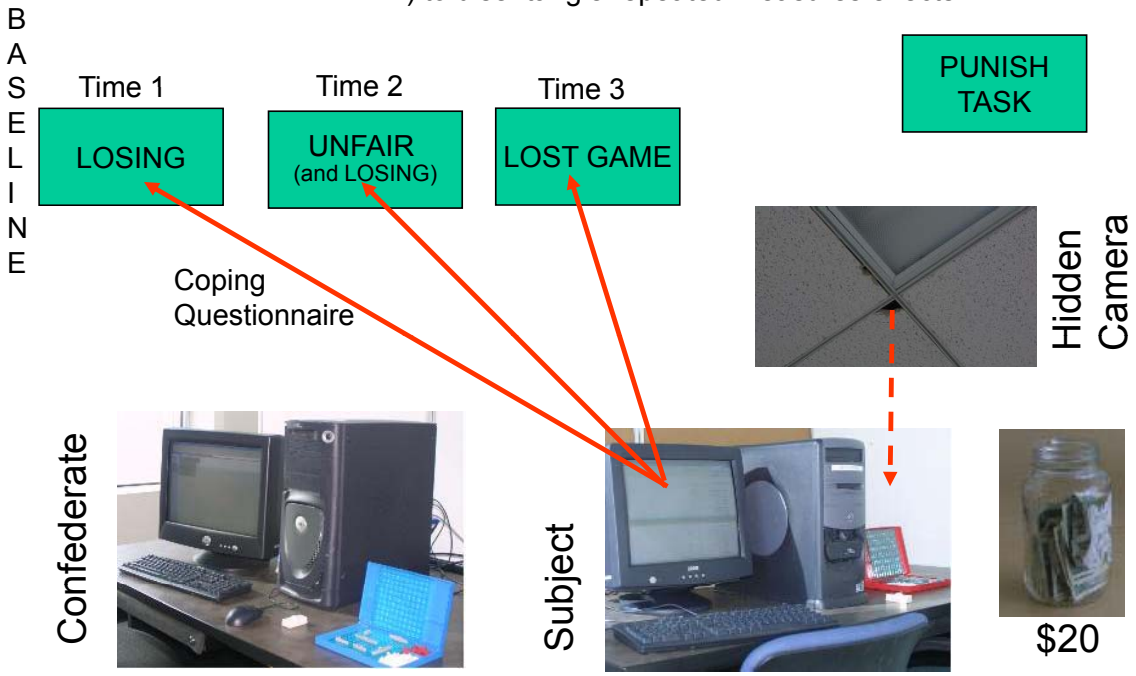
- Are threats to winning associated with sadness? (e.g.,Gibran, 1973)
  Are threats to fairness associated with anger? (e.g., Smith & Ellsworth, 1985; see Haidt, 2003)
- How do people cope with the emotions losing gives rise to?
  Do they distance themselves (i.e., change their goal weights)?
  Do they reappraise the situation in a positive light (i.e., change their appraisals)?
- How do people cope with the emotions unfairness gives rise to?
  Do they cheat back?
  Do they ask the experimenter for assistance?
- Do these coping efforts work?
- Do results corroborate model predictions?

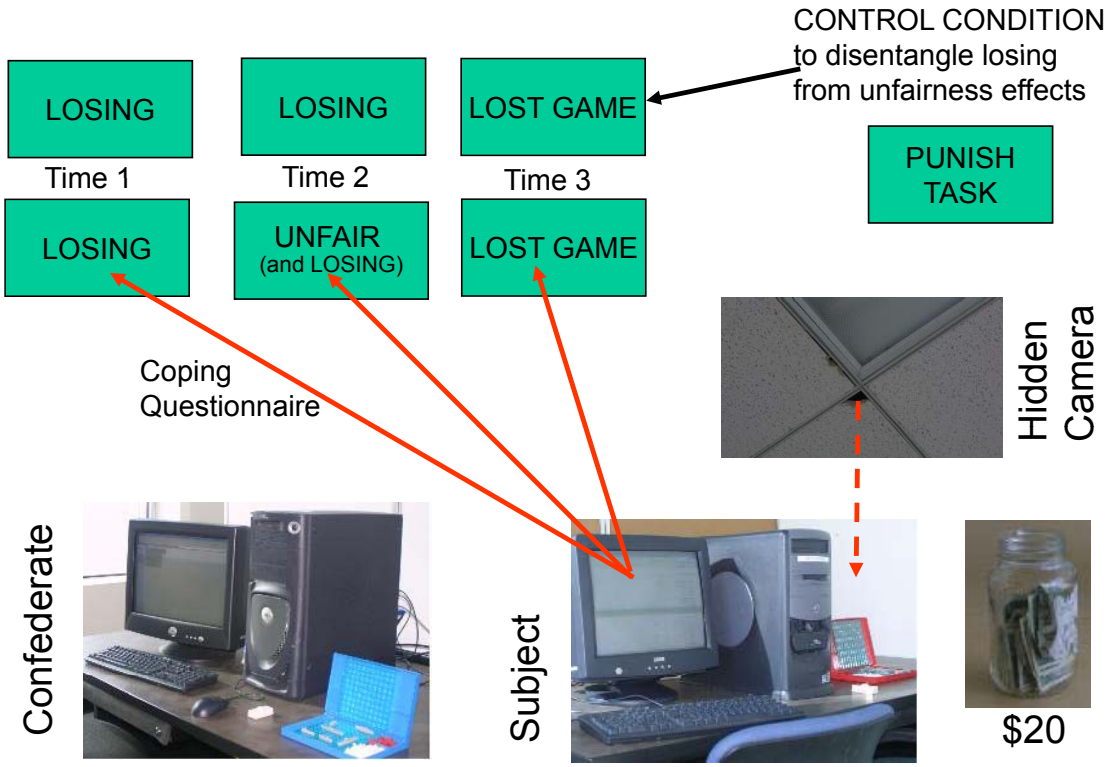
Instruments

- Appraisal assessed
  - Self-Report: based on Ellsworth and colleagues' appraisal questionnaire (e.g., Treynor, Ellsworth, & Gonzalez, in preparation; also see Smith & Ellsworth, 1985)

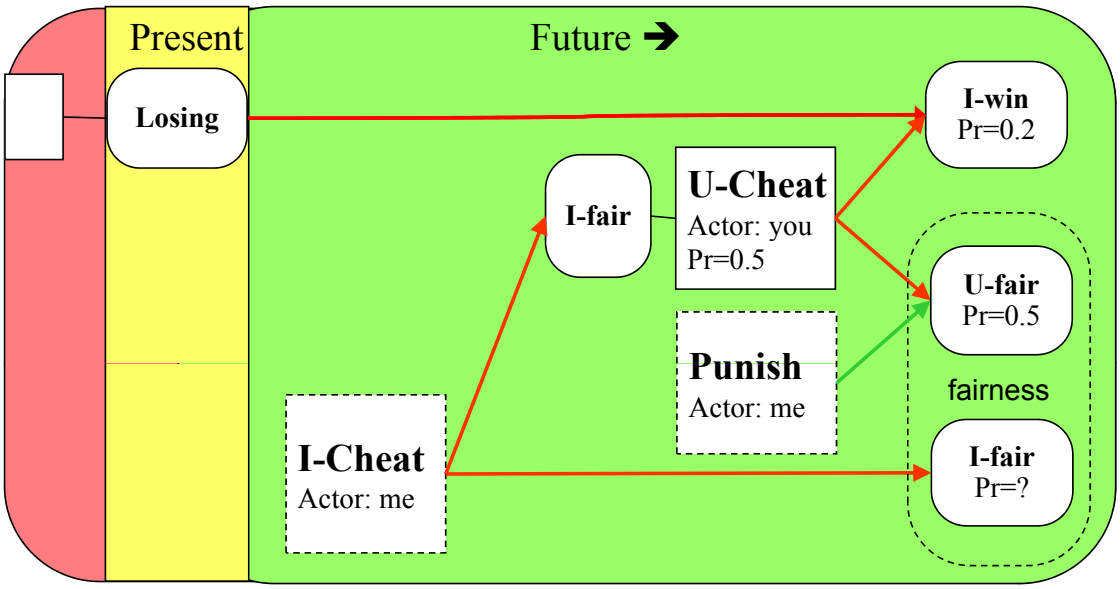
- Coping assessed
  - Behaviorally: Ask Experimenter for Assistance (DOORBELL)
    & Cheat Back (VIDEOCAMERA)
  - Self-Report: Computer Coping Questionnaire (based on SCPQ; Perrez & Reicherts, 1992)

We also have 2 comparison conditions:
1) to disentangle unfairness from losing effects
2) to disentangle repeated measures effects





Predictions

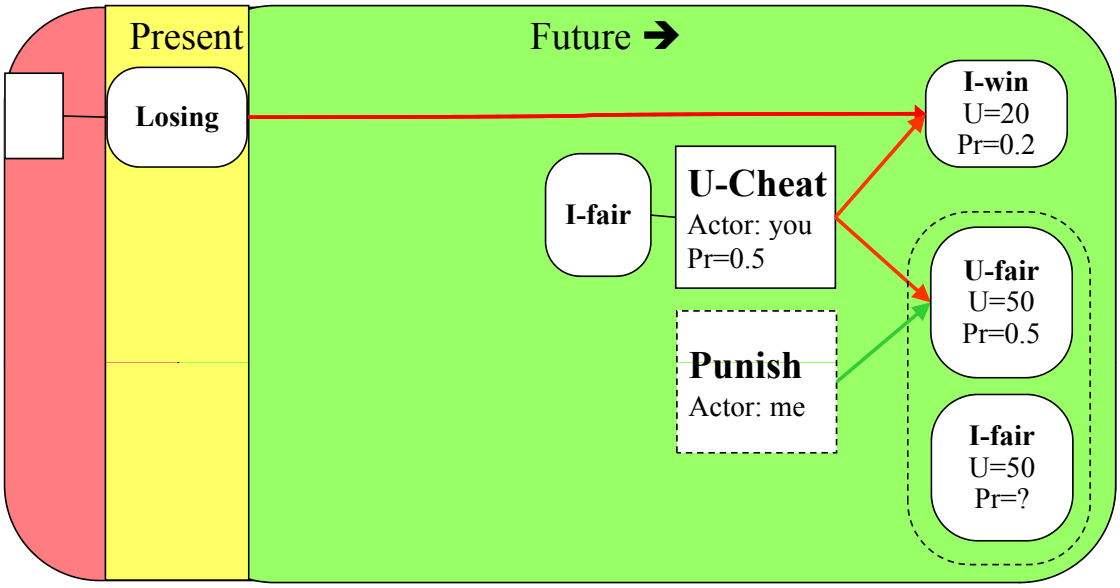


Subjects should differ depending on their goals:

-win or to play fair

Fair players:

self-report fairness more important than winning

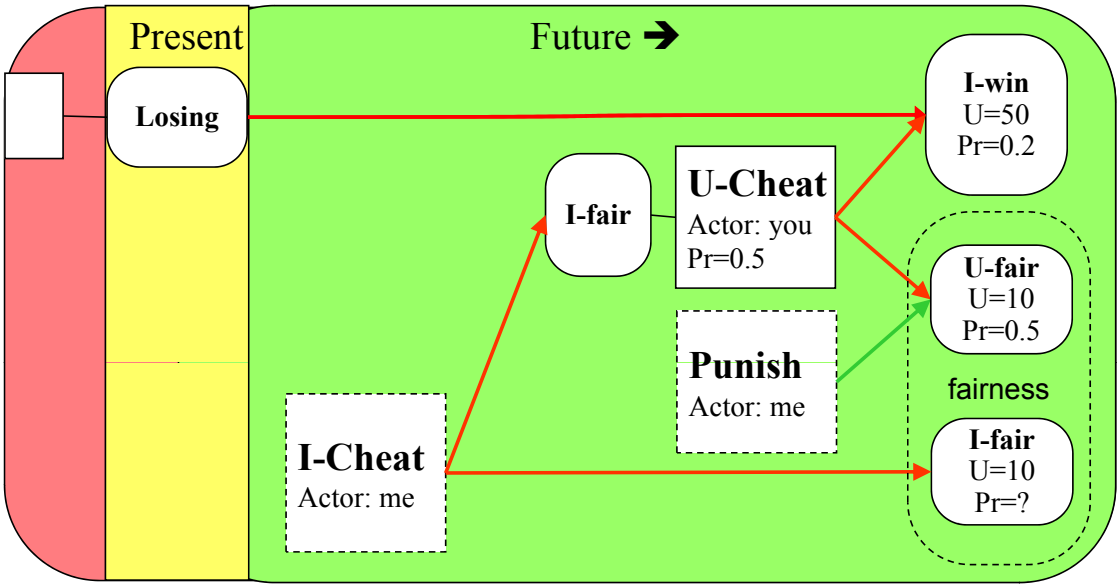


Detect Cheating → Distance from Wining (emotion directed)

Opportunity to Punish → High punishment

Competitive players:

self-report winning more important than fairness



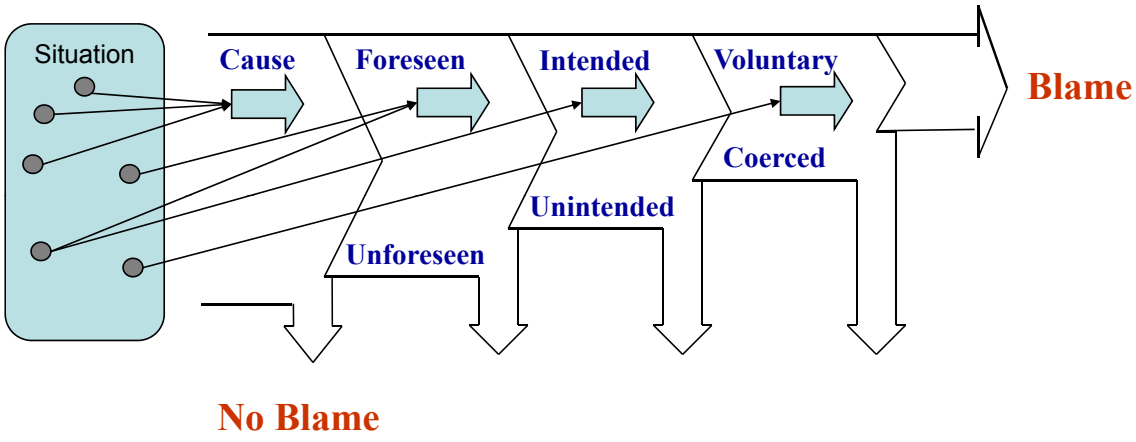
Detect Cheating → Cheat back (problem-directed),
Distance from fairness (emotion-directed)

Opportunity to Punish → Less punishment

Model-driven Experimentation

Model should be able to generate novel predictions

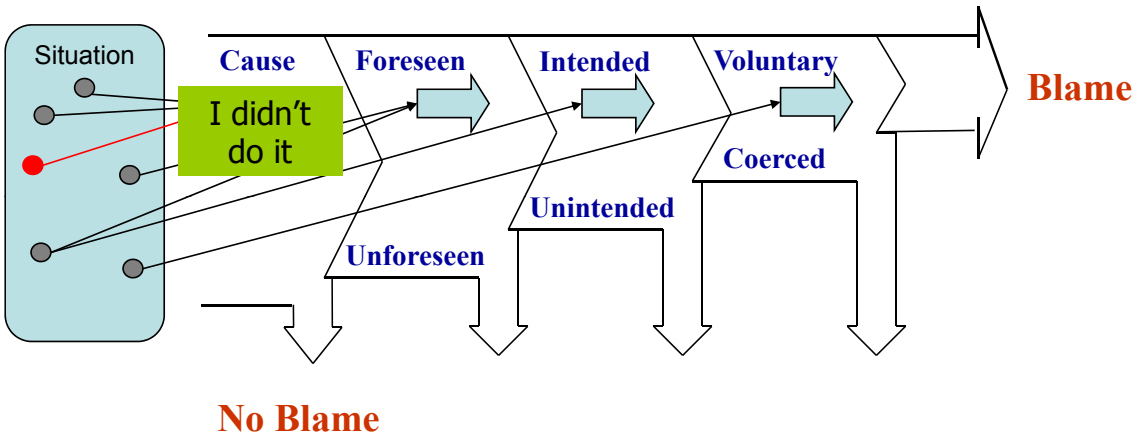
Example: Mao&Gratch2006



Model-driven Experimentation

Use model to construct "counterfactual scenarios"

what features of situation would have to change to yield a different appraisal?



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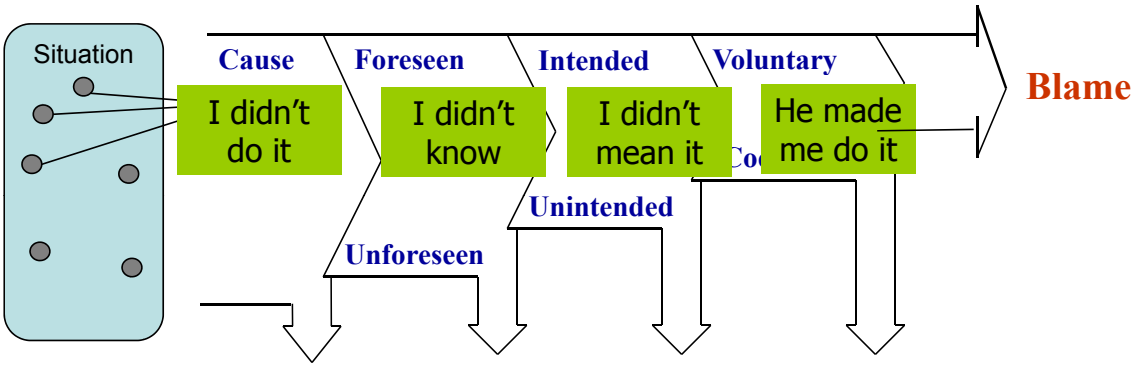


Scenario 1:

E1: The vice president of Beta Corporation goes to the chairman of the board and requests, "Can we start a new program?"

E2: The vice president continues, "The new program will help us increase profits,

E3: and according to our investigation report, it has no harm to the environment."

E4: The chairman answers, "Very well."

E5: The vice president executes the new program.

E6: The environment is harmed by the new program.

Questions:

Does the vice president want to start the new program?
Based on which information (circle all that apply)?
E1 E2 E3 E4 E5 E6

Does the chairman intend to start the new program?
Based on which information (circle all that apply)?
E1 E2 E3 E4 E5 E6

Is it the chairman's intention to increase profits?
Based on which information (circle all that apply)?
E1 E2 E3 E4 E5 E6

Does the vice president know that the new program will harm the environment?
Based on which information (circle all that apply)?
E1 E2 E3 E4 E5 E6

Is it the vice president's intention to harm the environment by starting the new program?
Based on which information (circle all that apply)?
E1 E2 E3 E4 E5 E6

How much would you blame the individuals for harming the environment?
Blame the chairman: 1 2 3 4 5 6
Blame the vice president: 1 2 3 4 5 6

Transformed scenarios

Scenario 2:

E1: The chairman of Beta Corporation is discussing a new program with the vice president of the corporation.

E2: The vice president says, "The new program will help us increase profits,

E3: and according to our investigation report, it will also harm the environment."

E4: The chairman answers, "I only want to make as much profit as I can. Start the new program!"

E5: The vice president executes the new program.

E6: The environment is harmed by the new program.

Results		Question 1		Question 2		Question 3		Question 4		Question 5		Question 6	
		Y	N	Y	N	Y	N	Y	N	Y	N	Chair	VP
S1	Model												
	People	**30**	0	**27**	3	**29**	1	2	**28**	0	**30**	3.00	**3.73**
S 2	Model												
	People	**30**	0	**30**	0	**30**	0	10	**20**	**22**	8	**5.63**	3.77
S 3	Model									N/A			
	People	**21**	9	2	**28**	**29**	1	**21**	9			**5.63**	3.23
S4	Model							N/A		N/A			
	People	**21**	9	5	**25**	5	**25**					4.13	**5.20**

Evaluating “functional” models

- Basic claim:
  - Emotions are functional
  - This function can be abstracted away and incorporated into general models of intelligence
- Empirical questions
  - Does emotion improve reasoning capabilities
  - Does model exhibit posited emotional function
  - Does this provide measurable benefit
  - Are the results “ecological”

General Strategy

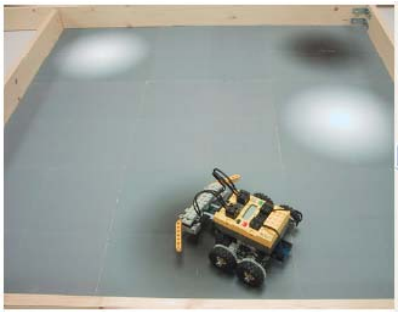
- Emotion literature claims that emotions evolved to help systems adapt to their environment

  Perhaps emotions could benefit agents in general
- Methodology
  - Identify the function some emotion performs for organism
  - Re-implement this function in agent system
  - Demonstrate this helps the agent
- Common paradigm: survival of the fittest
  - Scheutz01: fear and anger
  - Alvila-Garcia & Canamero05: fear and aggression

Alvila-Garcia & Canamero: Model inspired by behavioral function of hormones

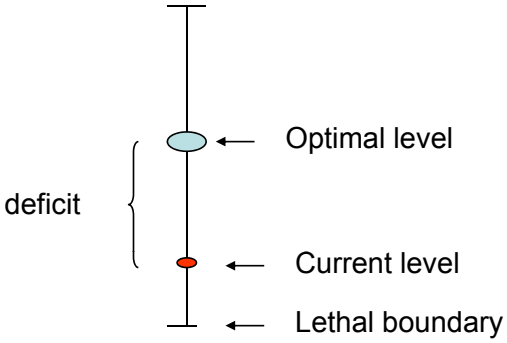
- Use “affect” (represented as hormone level) to modulate fixed stimulus-response mapping

  (emotion a mediating variable)
  - Appraisal → Risk of death
  - Risk of death → level of “hormone”
  - Changes action selection
    - Diminish opportunistic behavior
    - Increase “aggressive” behavior



Drive model

- Homeostatic variables (DRIVES)
  - Warmth, energy



- If in deficit, should consider behavior that satisfies this drive

- Perceptual cues (smell)
- Should opportunistically exploit resources that would satisfy drives if they are near
- Motivation = deficit + deficit X cue_relevance X incentive_cue

Winner take all action selection

"Hormones"

- Loosely inspired by neurophysiological studies (of lobsters)
  - Certain hormones elicited when organism in danger
  - These reduce opportunistic satisfaction of drives
  - Increase aggressive behavior
  - Create "appraisal" Risk of Death – measure how close homeostatic variables are to boundary conditions
  - Use this to lower cue-relevance
    - Opportunism: reduces impact of seeing resource when selecting behavior (tied more to real deficits)
    - "Increases aggression" More likely to "walk over" other robots because doesn't "see" them (doesn't perform avoidance behaviors)
- Evaluation:
  - Built artificial task: robot food foraging
  - Compare hormonal with non hormonal
  - Showed hormonal better

Scheutz01

- Examined 2 types of agents
  - Reactive agents
  - Affective agents
- Affective functions
  - Fear: if energy low, avoid other agents
  - Anger: if energy high, approach other agents
- Evaluation
  - Foraging task in virtual environment
  - Used evolutionary paradigm
    - Affective functions could appear through mutation and could be passed to offspring
  - Showed affective agents tend to dominate

Critique

- Evaluations compared two algorithms.
  - Is one better or is one just broken
  - How would these compare to “optimal solutions”
    - Does this really tell us better solutions for intelligence in general?
    - Does this really introduce new function not considered by “classical” techniques? And how would we show this
- Ecological validity
  - Evaluations performed on artificial environments with arbitrary parameter settings
    - How sensitive are results to parameter settings?
    - How natural/typical is this situation. Is this a real problem? Would it generalize?

Evaluating system models

- Basic claim:
  - Emotion models help in design of applications
    - Ease the development of systems
      - e.g., make it easer to author interactive emotional behaivors
    - Improve system performance
      - e.g., improve learning performance of tutoring systems)
- Empirical questions
  - Does model facilitate system design
  - Does model improver user performance over other methods

Claim

- some evaluations of systems
  - FearNot! – teach kids about bullying
  - CBI – psychotherapy
- no controlled studies
  - e.g. system w/ and w/o emotion model
  - no way of assessing overall contribution of emotion model

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> Emotions are an important aspect of human intelligence and have been shown to play a significant role in the human decision-making process. Researchers in areas such as cognitive science, philosophy, and artificial intelligence have proposed a variety of models of emotions. Most of the previous models focus on an agent's reactive behavior, for which they often generate emotions according to static rules or pre-determined domain knowledge. However, throughout the history of research on emotions, memory and experience have been emphasized to have a major influence on the emotional process. In this paper, we propose a new computational model of emotions that can be incorporated into intelligent agents and other complex, interactive programs. The model uses a fuzzy-logic representation to map events and observations to emotional states. The model also includes several inductive learning algorithms for learning patterns of events, associations among objects, and expectations. We demonstrate empirically through a computer simulation of a pet that the adaptive components of the model are crucial to users' assessments of the believability of the agent's interactions.

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Spurred by a range of potential applications, there has been a growing body of research in computational models of human emotion. To advance the development of these models, it is critical that we evaluate them against the phenomena they purport to model. In this paper, we present one method to evaluate an emotion model that compares the behavior of the model against human behavior using a standard clinical instrument for assessing human emotion and coping. We use this method to evaluate the EMA model of emotion [1-3]. The evaluation highlights strengths of the approach and identifies where the model needs further development.

Gratch, J., A. Okhmatovskaia, et al. (2006). Virtual Rapport. 6th International Conference on Intelligent Virtual Agents, Marina del Rey, CA, Springer.

Effective face-to-face conversations are highly interactive. Participants respond to each other, engaging in nonconscious behavioral mimicry and backchanneling feedback. Such behaviors produce a subjective sense of rapport and are correlated with effective communication, greater liking and trust, and greater influence between participants. Creating rapport requires a tight sense-act loop that has been traditionally lacking in embodied conversational agents. Here we describe a system, based on psycholinguistic theory, designed to create a sense of rapport between a human speaker and virtual human listener. We provide empirical evidence that it increases speaker fluency and engagement.

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COSMO

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Psychophysical theories of risk (e.g., Bernoullian utility theory, prospect theory) are compared with motivational theories (e.g., those of McClelland and Atkinson). A new theory is proposed that describes risk taking in terms of two factors: Factor 1 is a dispositional variable involving motivation for security risk versus potential risk. This factor distinguishes averse and risk seeking individuals and reflects primarily whether the individual is motivated to avoid bad outcomes

or to achieve good outcomes. Factor 2 is a situational variable involving current level of aspiration. In the theory, these two factors are sometimes in correspondence and sometimes in conflict, predicting complex patterns of data. Evidence is presented to support the theory and the relationship of the theory to other concepts (e.g., safety-first, disappointment, regret, emotion, aesthetics) is discussed. Keywords: decision making, motivation.

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Research on counterfactual thinking has shown that people's emotional responses to events are influenced by their thoughts about "what might have been." The authors extend these findings by documenting a familiar occasion in which those who are objectively better off nonetheless feel worse. In particular, an analysis of the emotional reactions of bronze and silver medalists at the 1992 Summer Olympics--both at the conclusion of their events and on the medal stand--indicates that bronze medalists tend to be happier than silver medalists. The authors attribute these results to the fact that the most compelling counterfactual alternative for the silver medalist is winning the gold, whereas for the bronze medalist it is finishing without a medal. Support for this interpretation was

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emphasizes the role of anticipated affective impact of outcomes in guiding choices, and the effects of comparisons with alternative outcomes (i.e., counterfactual effects).

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Recent theorizing and research has attempted to explicate the functions of moods and emotions within small groups. In this paper, we examine these areas and suggest that affect in groups, as well as specific mechanisms to regulate and maintain certain affective states in groups, have had important roles in promoting group survival over evolutionary history. Specifically, we suggest that affect in groups serves a coordination function, which can take one of two forms. First, affect in groups quickly provides information about the environment and group structure to other group members, thus coordinating group activity via a communication function. Second, shared affect in groups coordinates group activity through fostering group bonds and group loyalty. These two functions of affect in groups are closely related and mutually reinforcing. Current research and directions for future research within an evolutionary perspective are also discussed.

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