(How) Can Appraisal Theory be Formalized at a Meta-level?

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Why formalize appraisal structure at high level?

- Appraisal theory development.
  - Comparison, refinement, convergence
- Architectural basis for computational models
  - Development and debugging.

Emotions in Agents

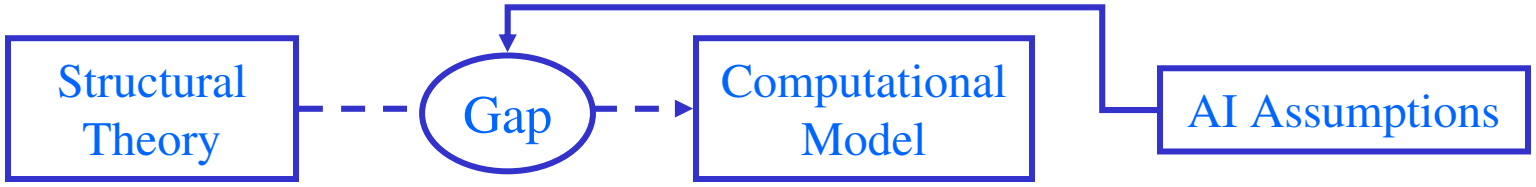
- What is an emotion?
  - Heuristic relating events to goals, needs, desires, beliefs of an agent (cognitive definition).
  - Communication medium.
  - Related to homeostasis and hormonal state
- Why use an emotion in agents and robots?
  - heuristic aspect (efficient evaluation), communicative aspect.
- Which agents might need emotions?
  - Games, HCI, HRI, Virtual-Reality, Decision-making and planning.
- *Computational models of emotion, in general, are based on Cognitive Appraisal Theory.*

Structural Theories (what), Process Theories (how)

- *Structural Theory*: structural relation between:
  - Environment of agent (**perception**)
  - Appraisal processes that interpret the environment in terms of values on appraisal dimensions (**appraisal**)
  - Mediating processes that relate appraisal dimension values to emotions (**mediation**)
  - Processes are black-boxes.
  - Declarative semantics
- Process Theory:
  - Detailed cognitive operations and mechanisms involved in processes and their interaction as described by structural theory of appraisal.
  - Procedural (cognitive) semantics

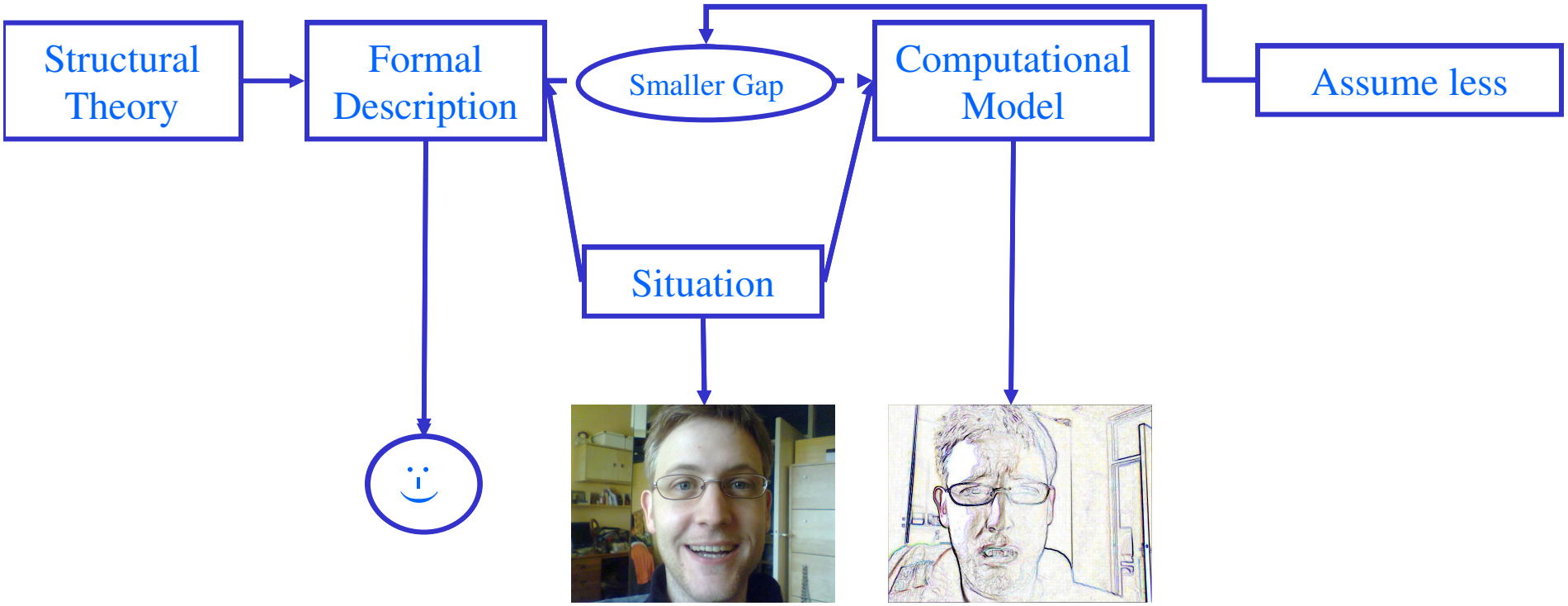
Computational models of Emotions

- Structural Theory + assumptions from AI = computational model (Gratch and Marsella, 2004).
- This poses a problem (Gratch and Marsella, 2004)
  - Structural Appraisal Theory: abstract.
  - Computational model: algorithmic, detailed.
- *What if the model does something unexpected?*



What's wrong?

- The Computational Model or the Theory (or the observer)?



Problem: How to Debug Your Computational Model?

- Debugging is a problem:
  - Large gap between theory and computational model.
  - Highly complex agent designs complicate debugging.
  - Understanding emotions is not something computer scientist are trained, in contrast it's the appraisal theorist's job.

Benefits of Such Formalisms

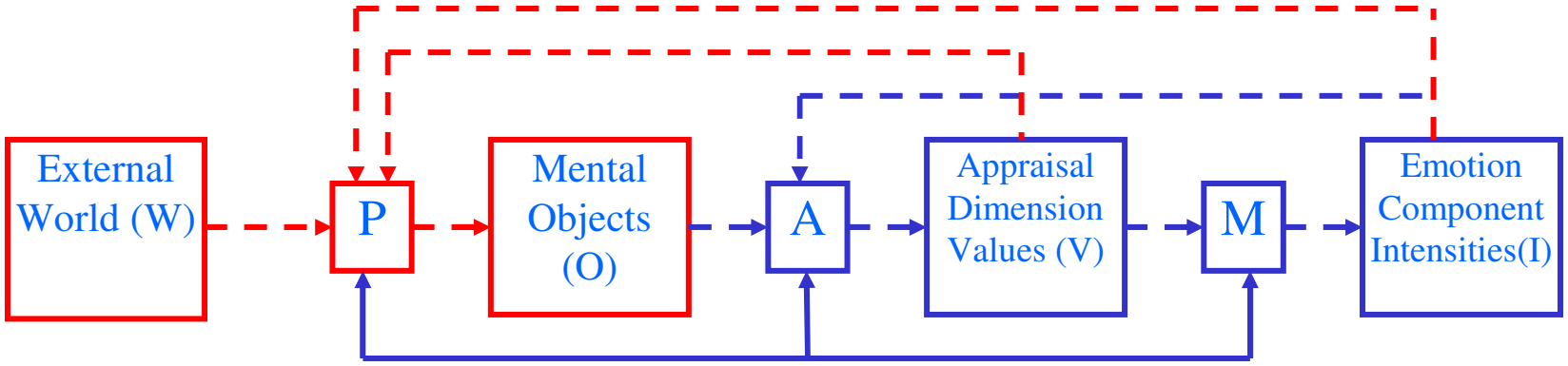
- Appraisal Theory
  - Comparison, Integration, Convergence (Wherle and Scherer, 2001)
  - Precise and structured theory revision
  - Process of Formalization helps theory development and refinement.
  - Formal annotation of experimental results.
- Computational models
  - Formal architecture of appraisal.
  - Evaluation of computational model in relation to the theory
  - Structured storage of annotated experimental results (human/agent)
    - Compare computational models.
    - Feedback to theory and human-subject based experimental results

Requirements for a Formalism for the Structure of Appraisal

- How many, which processes exist (perception, appraisal, mediation)
- When and how are these activated (threshold, continuous?)
- How much time needed to evaluate?
- What kind of information needed for these processes?
- How many and which appraisal dimensions, emotional response components?
- How do appraisal dimension values relate to emotional response components?
- See also (Reisenzein, 2001).

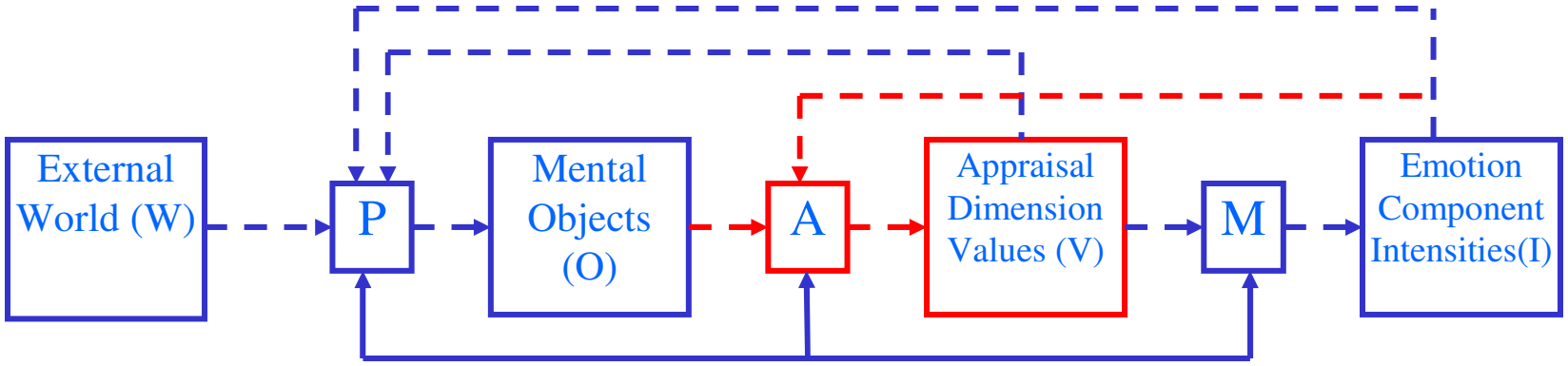
Overview of the Formalism (1/4): Perception

- W = observable objects and events in the environment of the agent
- P = the set of all perception processes available to the agent. $p_i: W^n \times V^n \times I^n \rightarrow O^n_i$. Is a perception process translating the world into mental objects (O) in the context of a current emotion (I) and appraisal state (V).
- O = set of all mental objects currently perceived by the agent with



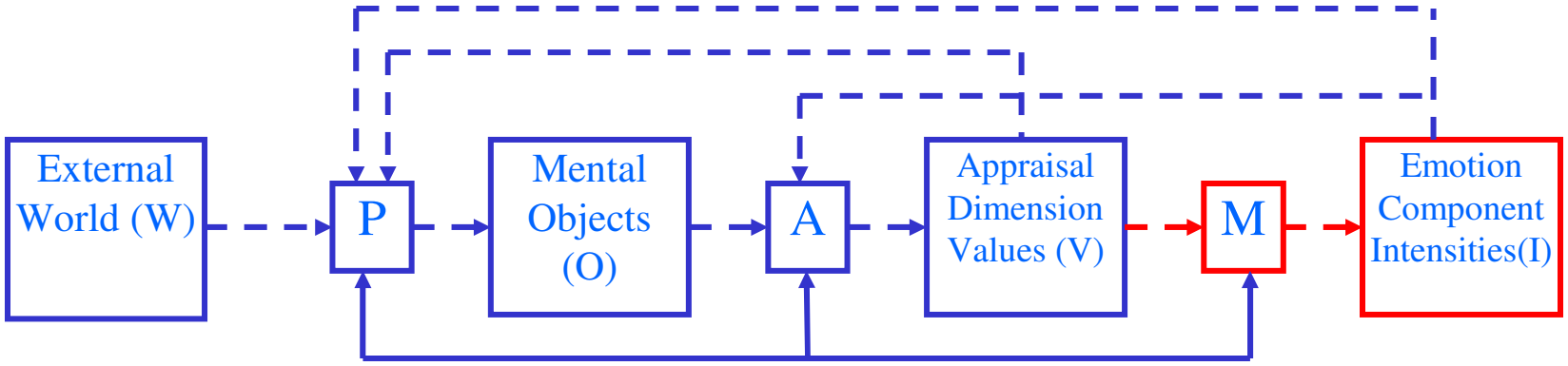
Overview of the Formalism (2/4): Appraisal

- A = the set of appraisal processes. $a_i: O^n \times I^n \rightarrow V_i^n$, a_i is an appraisal process, mapping mental objects (O) to possible appraisal dimension values (V) in the context of the current emotion (I).
- D = set of appraisal dimensions defined by the theory.
- V = set of current appraisal dimension values $V \subseteq O^n \times D \times [-1,1]$



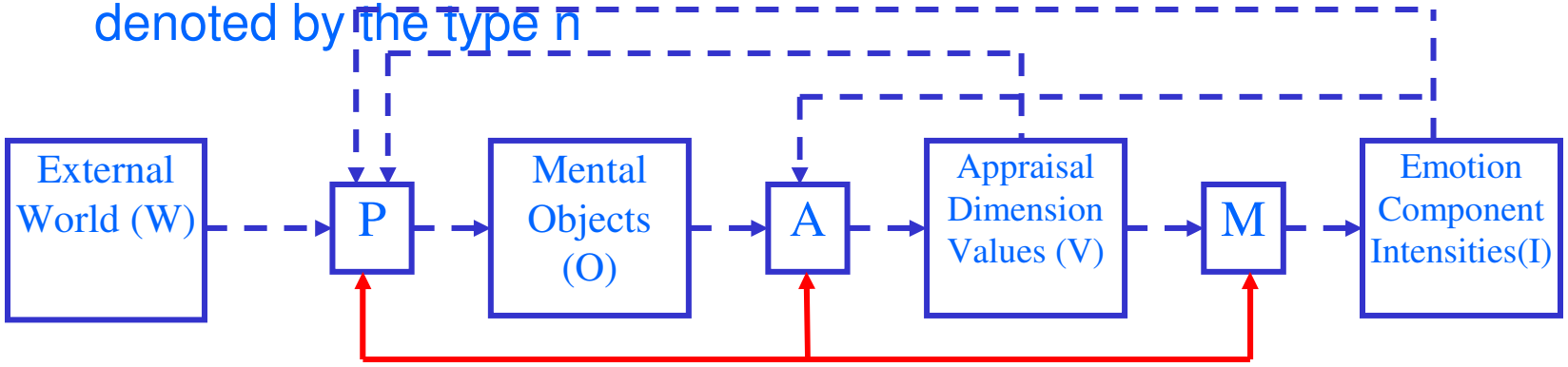
Overview of the Formalism (3/4): Mediation

- E = set of possible emotional response components
- I = set of emotional response component intensities $I=I\subseteq E\times[0,1]$
- M = set of mediating processes. $m_j:V^n\rightarrow I_j$ is a mediating process relating appraisal dimension values (V) to emotional component intensities (I)



Overview of the Formalism (4/4): Process dependencies

- PP = set of all processes (P, A and M)
- LT= set of process dependency types.
- G = set of guards
- L = set of process dependencies. L = PPxPPxGxLT
- $(\forall x)(\exists y)$ processing in q_x is influenced iff $((p_y,q_x,g,n) \in L \wedge g=true \wedge p,q \in PP \wedge g \in G \wedge n \in N)$
  If a dependency exists between a process p and q and the guard g of that link is true, processing in q is influenced in a way denoted by the type n



Formalization of structure

- Appraisal theory development.
- Architectural basis for computational models

Application 1: Integration of two Appraisal Theories.

- Integration based on:
  - Scherer's Stimulus Evaluation Checks (SEC) (Scherer, 2001)
  - Smith and Kirby's Appraisal Detector Model (ADM) (Smith and Kirby, 2000)
- SEC: multiple appraisal processes (stimulus checks)
  - Appraisal Processes activate in four* consecutive steps: Relevance detection, Implication assessment, Coping potential, Norm/self compatibility.
  - Processes exist at three perception levels: sensory-motor, schematic, conceptual.
  - Current result of appraisal processes stored in appraisal registers.

* Here we only use the first three.

Application 1: Integration

- ADM:
  - Appraisal detectors integrate appraisal information coming from different perception levels (levels equivalent to those defined in SEC, i.e., sensory-motor, schematic, conceptual)
  - Appraisal detectors produce emotional response.
  - Feedback from emotional response to processing, specifically conceptual (reasoning) and schematic (associative learning) levels.
- Integration basics: common architectural concepts
  - Separation of appraisal in three levels of information processing.
  - Appraisal registers/detectors

Application 2: Formal Description of a Computational Model

- Formal description:
  - Based on simplified version of integrated model (SSK)
  - Used to define the architecture of appraisal (i.e., appraisal steps, appraisal detectors, levels of perception, appraisal dimensions)
  - Used to evaluate behavior of resulting computational model of emotions.
- Test environment: PacMan
  - Appraisal of events in PacMan's environment is simulated.
  - Architecture and appraisal dimensions used based on simplified SSK model

Formal description helped to verify model's behavior.

- No activation of relevance detection…
  - Due to bipolar variable: *conductiveness*.
  - Summing negatively conductive and positively conductive events results in *no conductivity activation*→ not plausible.
- Separate conductiveness in pos and neg.
  - Relevance detection active and activation of implication checks at right moments.

Some Conclusions

- Formal description facilitated development of computational model.
  - Clear definition of architecture of appraisal processes
- Formalism facilitated integration of theories.
- Open:
  - How to formally encode experiments and experimental results, comparing experimental results, etc.
  - What is the relation between BDI-based formalism and Meta-level formalisms.

Questions?

Referred literature:

Reisenzein, Rainer. *Appraisal Processes Conceptualized from a Schema-Theoretic Perspective: Contributions to a Process Analysis of Emotions*. 2001.

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