AGENT DECISION MAKING IN SOCIAL SIMULATION

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Classification dimensions

Cognition	What kind of cognitive level does the agent architecture allow for: reactive agents, deliberative agents, simple cognitive agents or psychologically or neurologically-inspired agents?
Affective	What degree of representing emotions (if any at all) is possible in the different architectures?
Social	Do the agent architectures allow for agents capable of distinguishing social network relations (and status), what levels of communication can be represented and to what degree can one use the architectures to represent complex social concepts such as the theory of mind or we-intentionality.
Norm consideration	To what degree do the architectures allow to model agents which are able to explicitly reason about formal and social norms as well as the emergence and spread of the latter?
Learning	What kind of agent learning is supported by the agent architectures?

Architectures

1. Rule based agents
2. BDI agents
3. eBDI agents
4. BOID agents
5. BRIDGE
6. Normative agents
7. EMIL-A
8. NoA
9. PECS
10. Consumat
11. CLARION
12. ACT-R
13. SOAR
14. Social agents

Production rule agents
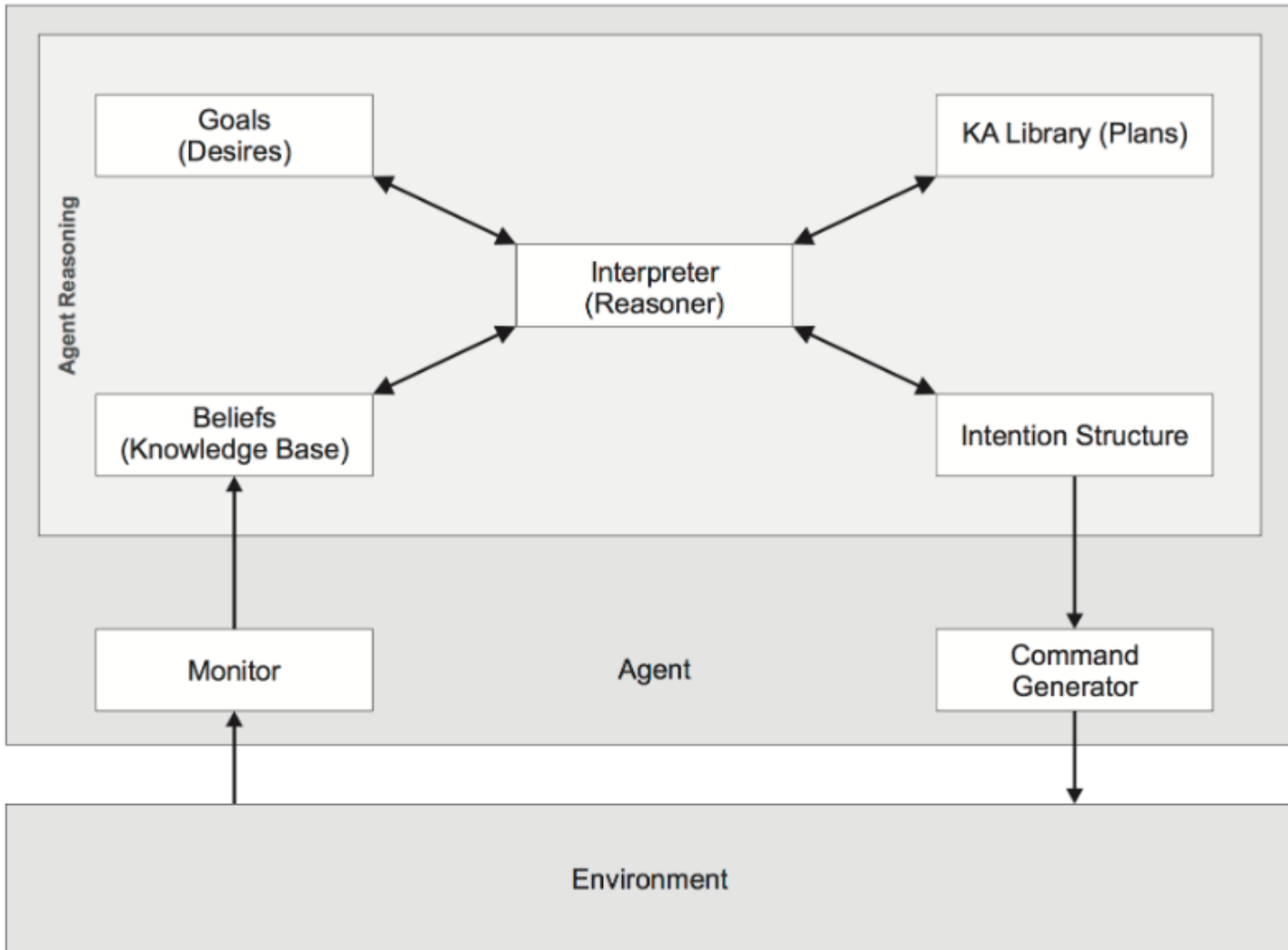
Production rule agents analysis

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Original Focus	information processing, pattern matching
Main User Community	used by all communities, fundamental for other architectures
Cognitive Level	reactive agent (production cycle)
Architectural Goal Management	goals indirectly expressed by rules
Symbolic or activation-based?	symbolic
Affective Level	none
Social Level	no communication and/or inclusion of complex social structures
Norm Consideration	no explicit norm consideration
Learning	none
Supported Operating Systems	n.a.
Resources	general literature on production rule systems, specific resources for existing implementations

BDI agents
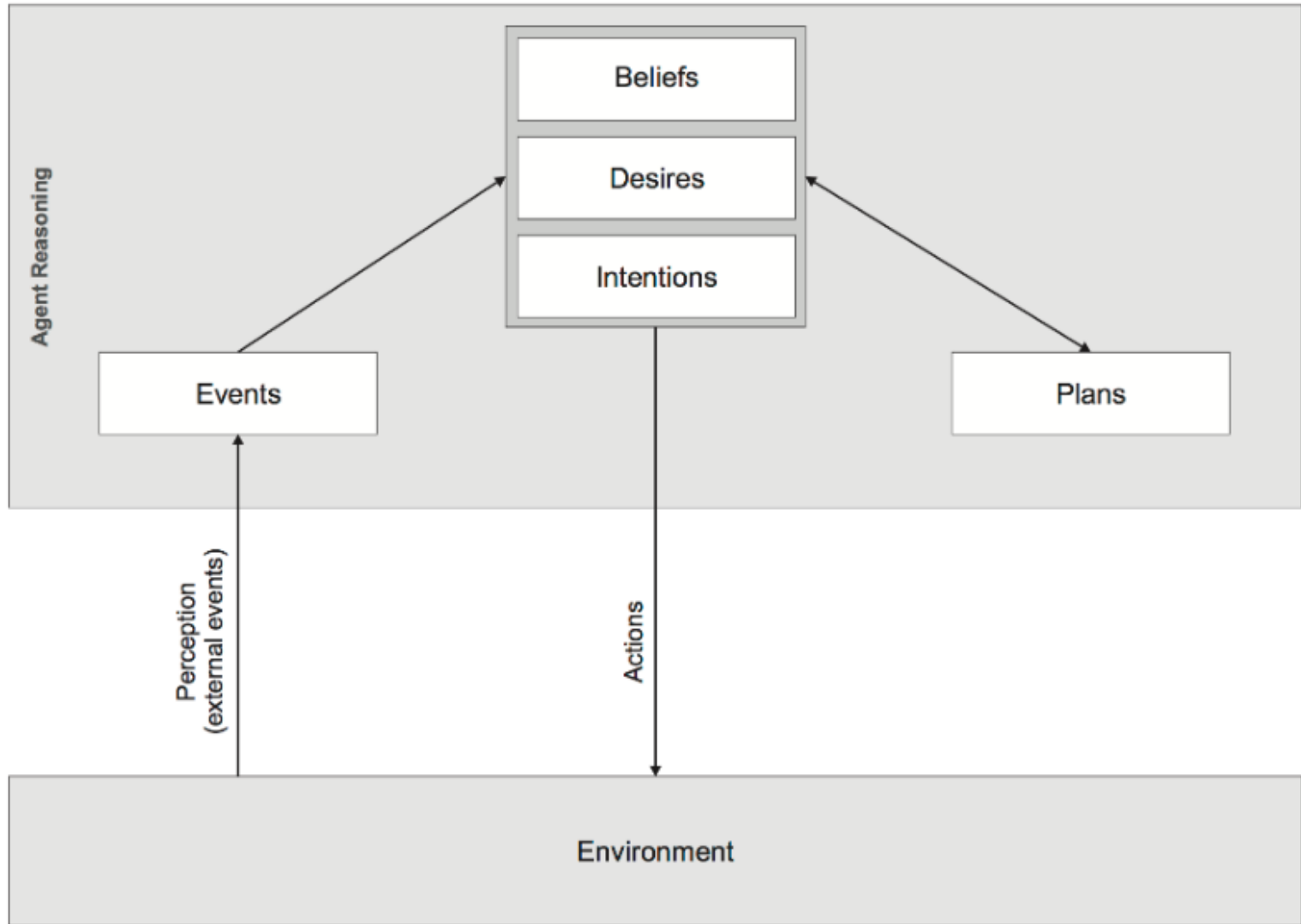
BDI analysis

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Original Focus	embedded applications in dynamic and real-time environments
Main User Community	agents/ABSS community in general
Cognitive Level	reactive and deliberative agents possible, though most implementations do not make use of the deliberation option
Architectural Goal Management	stored as desires, when activated turned into intentions; use of intention stack
Symbolic or activation-based?	symbolic
Affective Level	none
Social Level	no communication and/or inclusion of complex social structures in the original model
Norm Consideration	none in the original model
Learning	none in the original model
Supported Operating Systems	n.a.
Resources	general literature on BDI and multiple resources for mentioned implementations; for reference of sample implementations

eBDI agents
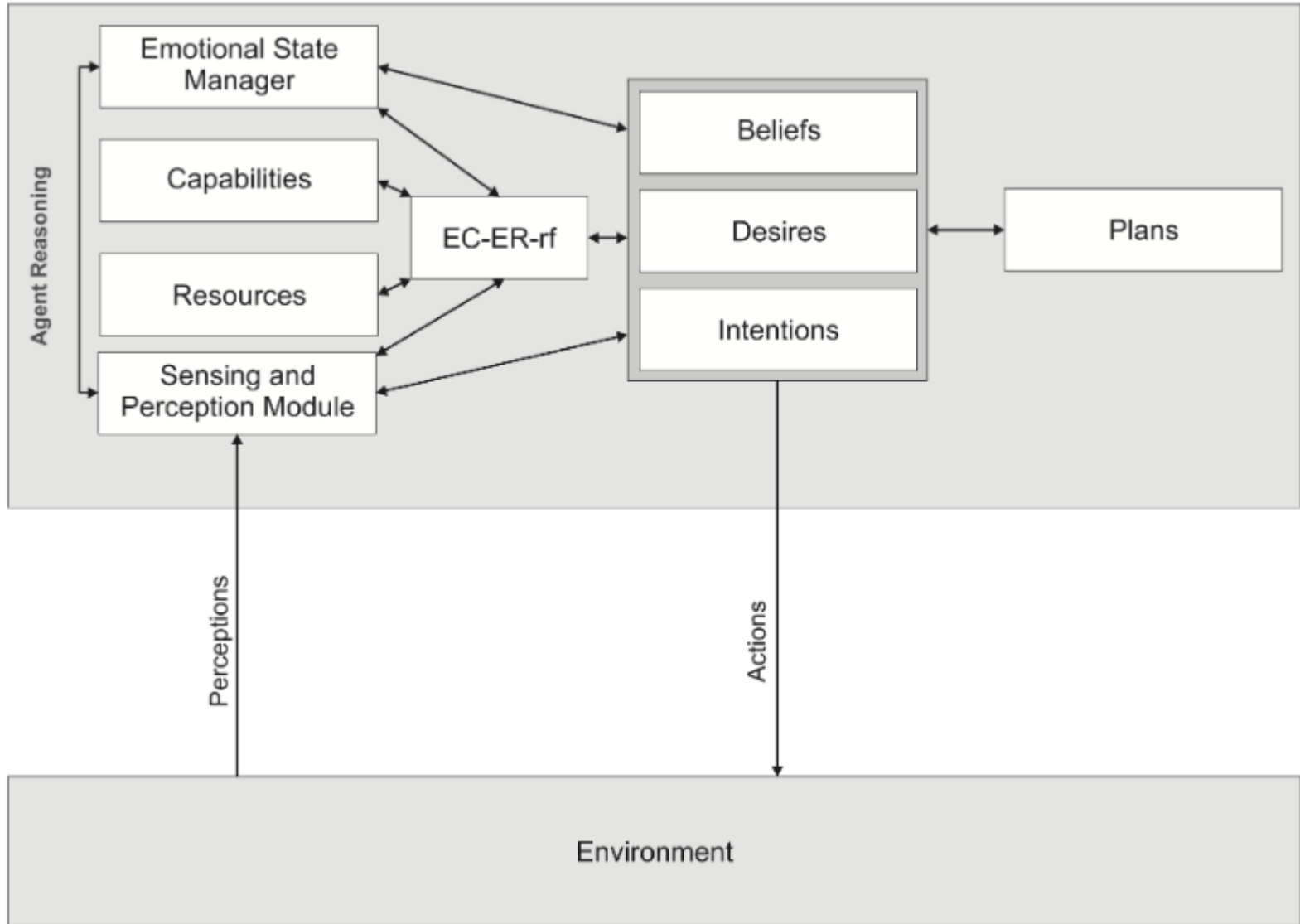
eBDI analysis

|	
Original Focus	adding emotions to BDI
Main User Community	no large community at this point
Cognitive Level	decision cycle with deliberation process possibility
Architectural Goal Management	when activated turned into intentions; use of intention stack
Symbolic or activation-based?	symbolic
Affective Level	emotions considered via Emotional State Manager
Social Level	no communication and/or inclusion of complex social structures
Norm Consideration	none
Learning	none
Supported Operating Systems	n.a.
Resources	in particular Jiang (2007)

BOID
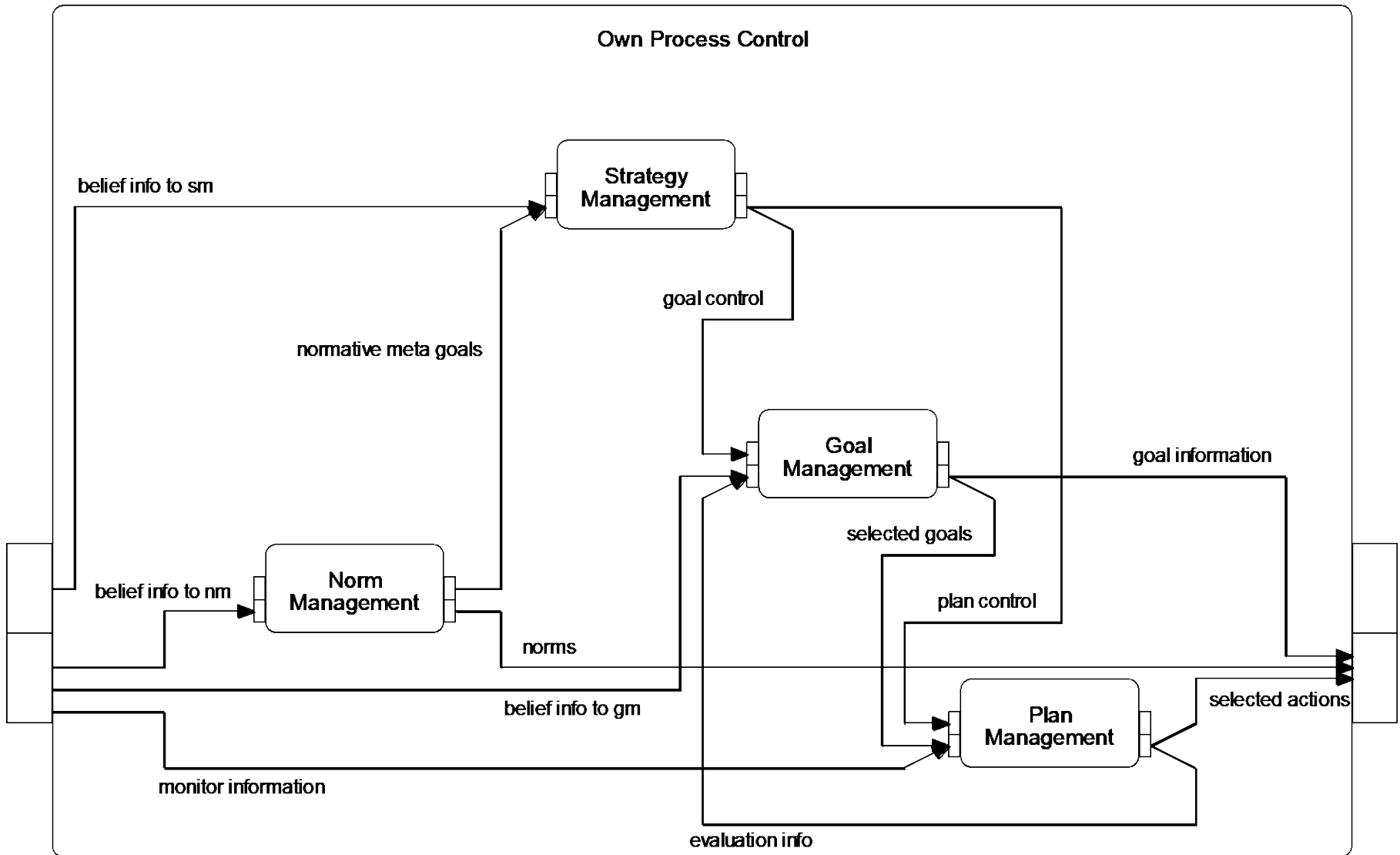
BOID analysis

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Original Focus	adding social obligation to BDI
Main User Community	normative MAS community
Cognitive Level	decision cycle with deliberation process possibility
Architectural Goal Management	when activated (under consideration of internalized social obligations) turned into intentions; use of intention stack
Symbolic or activation-based?	symbolic
Affective Level	none
Social Level	social norms are considered in form of obligations, no communication and/or inclusion of complex social structures
Norm Consideration	social norms considered in form of obligations deriving from them
Learning	none
Supported Operating Systems	n.a.
Resources	few scientific articles

BRIDGE
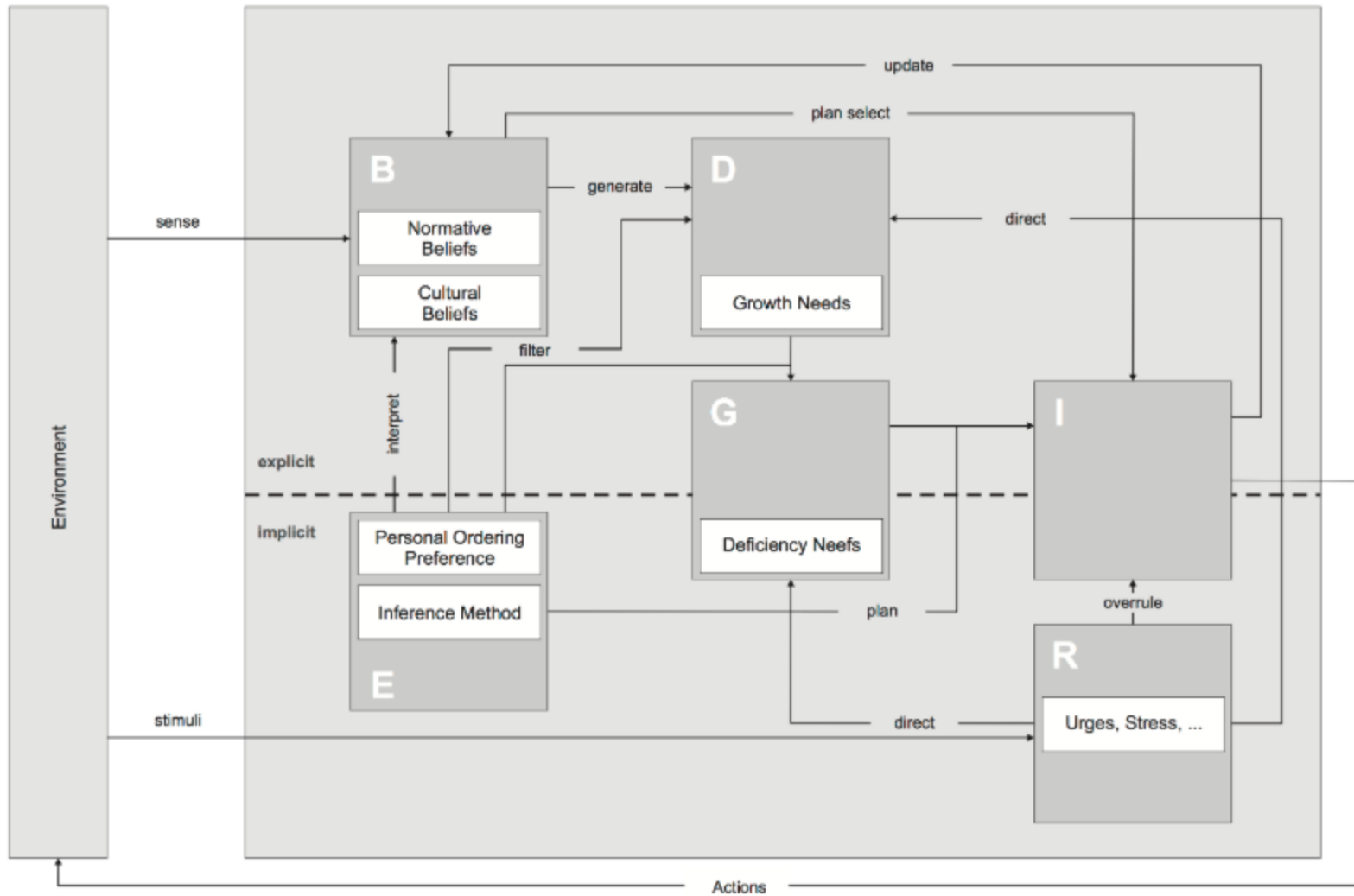
BRIDGE analysis

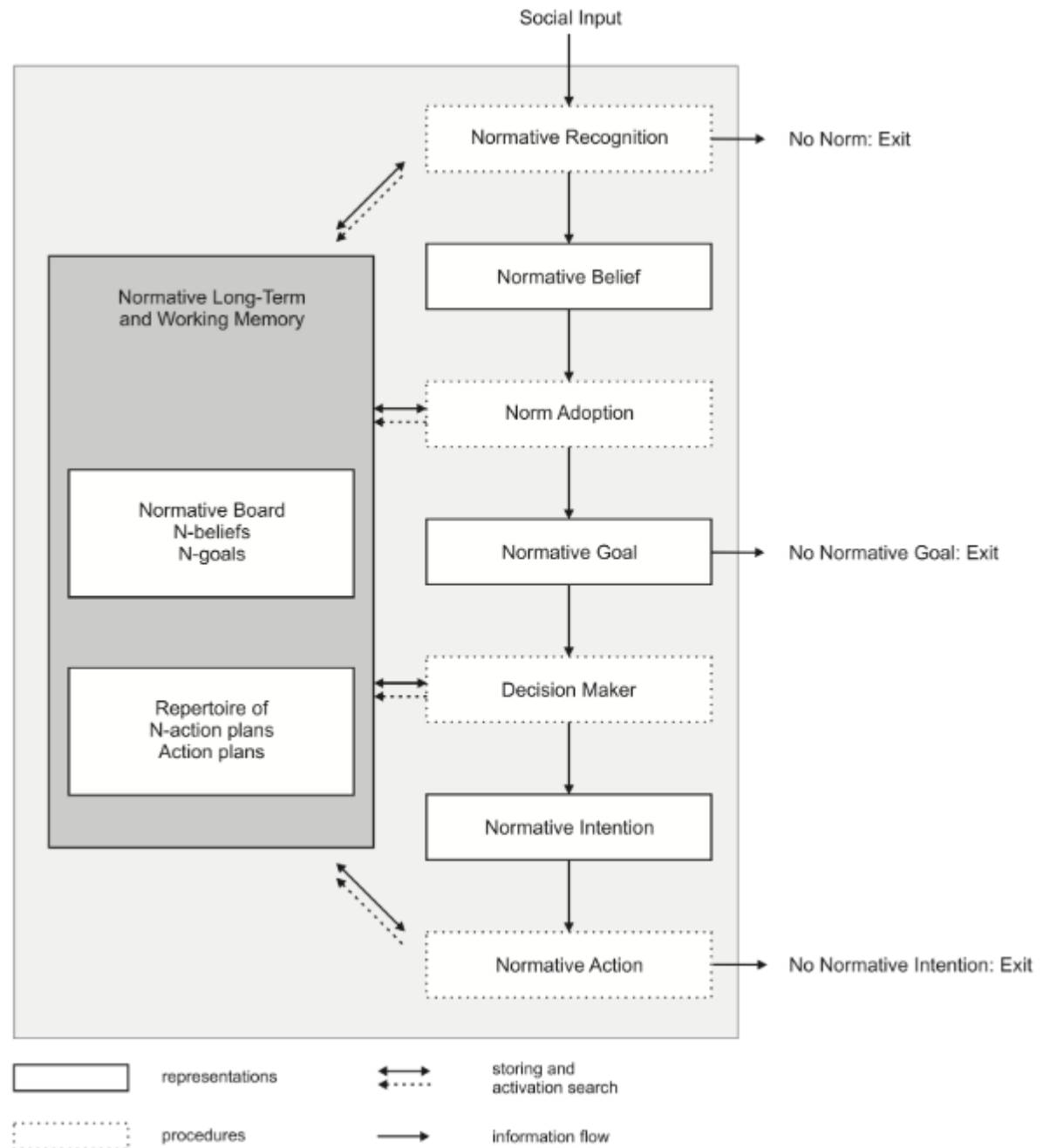|	
Original Focus	agents with own and social awareness as well as reasoning update for modelling decision in the policy context
Main User Community	so far little user community (mainly SEMIRA project[29]), possibly normative MAS community
Cognitive Level	decision cycle with deliberation process (concurrent processing of input) as well as short-cuts (based on response factors)
Architectural Goal Management	ordered list of candidate goals for which plans are generate, order can be overridden by response factors
Symbolic or activation-based?	symbolic
Affective Level	Not explicitly part of the architecture, but emotions could be represented using the EGO component
Social Level	self-awareness (distinction of self and others), consideration of culture and the need for social interaction
Norm Consideration	architecture explicitly developed to reason about policies and policy-aware agents; consideration of (social) norm which can be depending on culture; implementation of norms in form of obligations
Learning	none
Supported Operating Systems	intended implementation in a Repast environment, Repast is available for Windows, Mac as well as Unix
Resources	few scientific articles

Normative agents
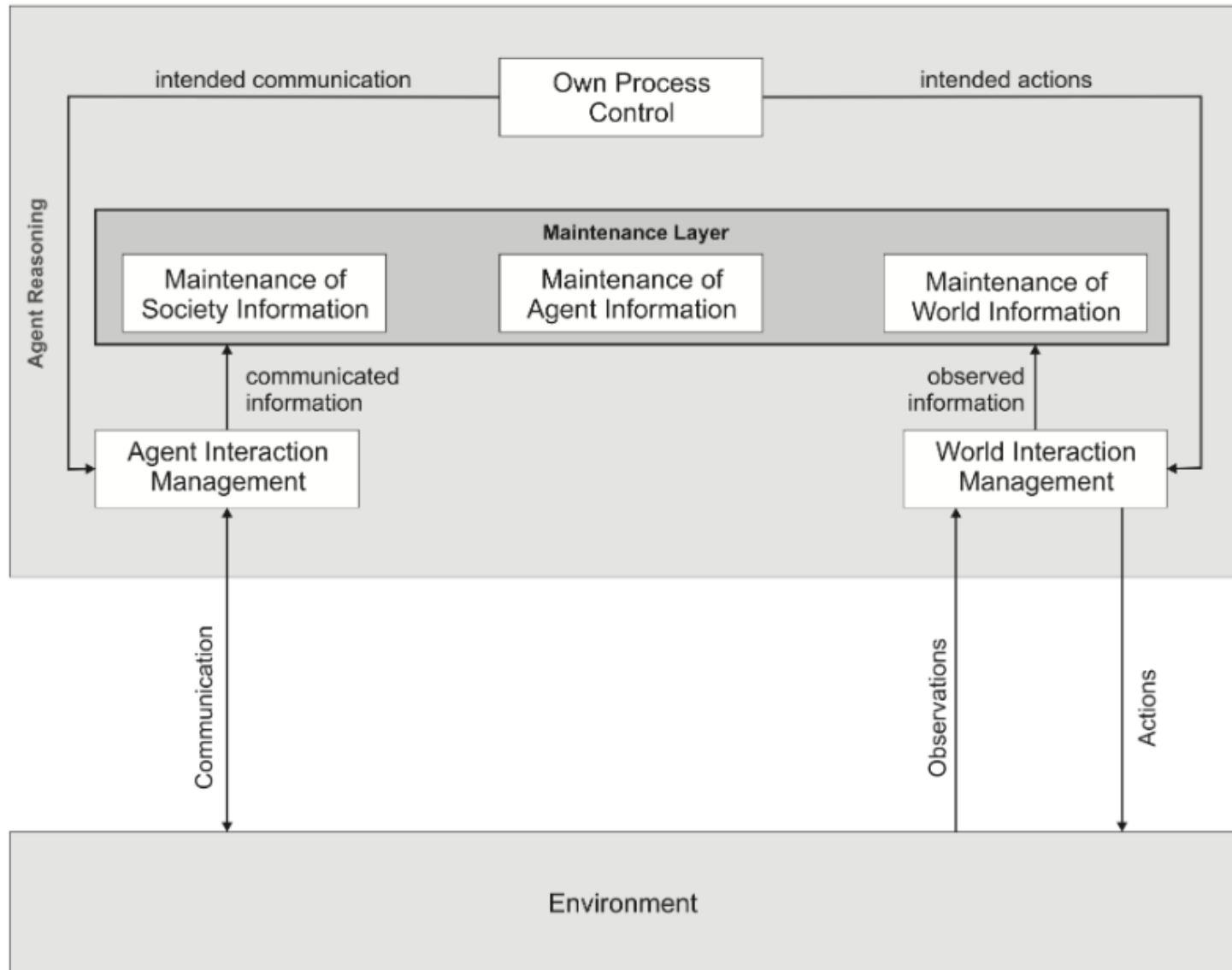
Normative agents analysis

Original Focus	social norms in decision making
Main User Community	normative MAS community
Cognitive Level	deliberative agents, separate norm-internalization cycle
Architectural Goal Management	similar to BDI, norms can influence intention selection
Symbolic or activation-based?	symbolic
Affective Level	none
Social Level	agent communication considered; inclusion of the social norm concept; distinction of one-self and others
Norm Consideration	norms considered
Learning	learning of norm-specific intentions mentioned
Supported Operating Systems	n.a.
Resources	few scientific articles

EMIL-A

Social Input

Normative Recognition → No Norm: Exit

Normative Belief

Normative Long-Term and Working Memory

Normative Board
N-beliefs
N-goals

Repertoire of
N-action plans
Action plans

Norm Adoption

Normative Goal → No Normative Goal: Exit

Decision Maker

Normative Intention

Normative Action → No Normative Intention: Exit

| | representations | | storing and activation search |
| | procedures | | information flow |

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EMIL-A analysis

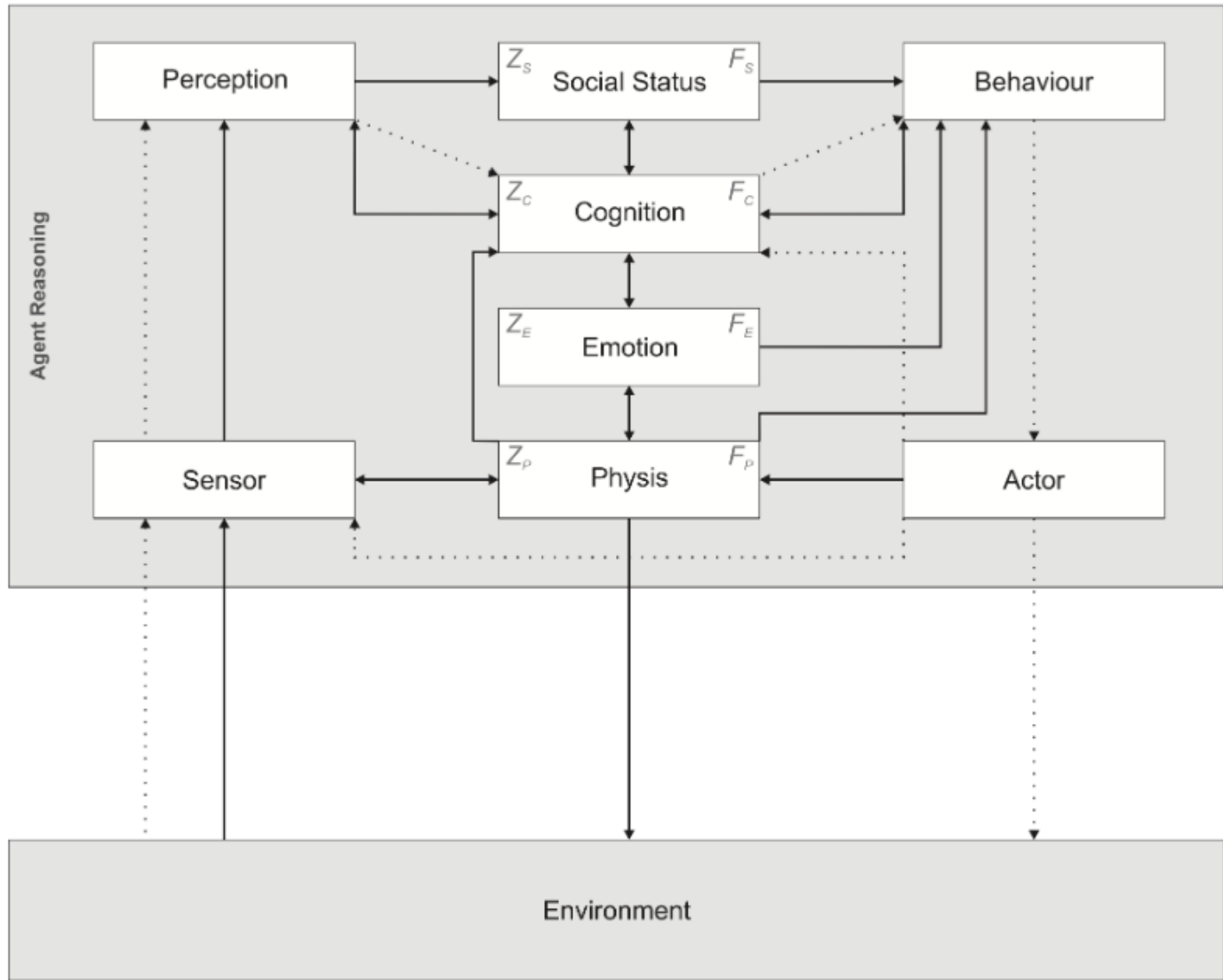|	
Original Focus	norm innovation and internalization
Main User Community	mainly ABSS community
Cognitive Level	general deliberation and deliberation-based norm-internalization cycle as well as stimuli short-cuts
Architectural Goal Management	normative board
Symbolic or activation-based?	both
Affective Level	none
Social Level	agent communication considered; inclusion of the social norm concept; distinction of one-self and others
Norm Consideration	norms considered
Learning	learning of norms and related change of intentions considered
Supported Operating Systems	EMIL-S implementation in Repast available, Repast is available for Windows, Mac and Unix
Resources	websites of project partners (http://cfpm.org/emil/) and project deliverables

NoA
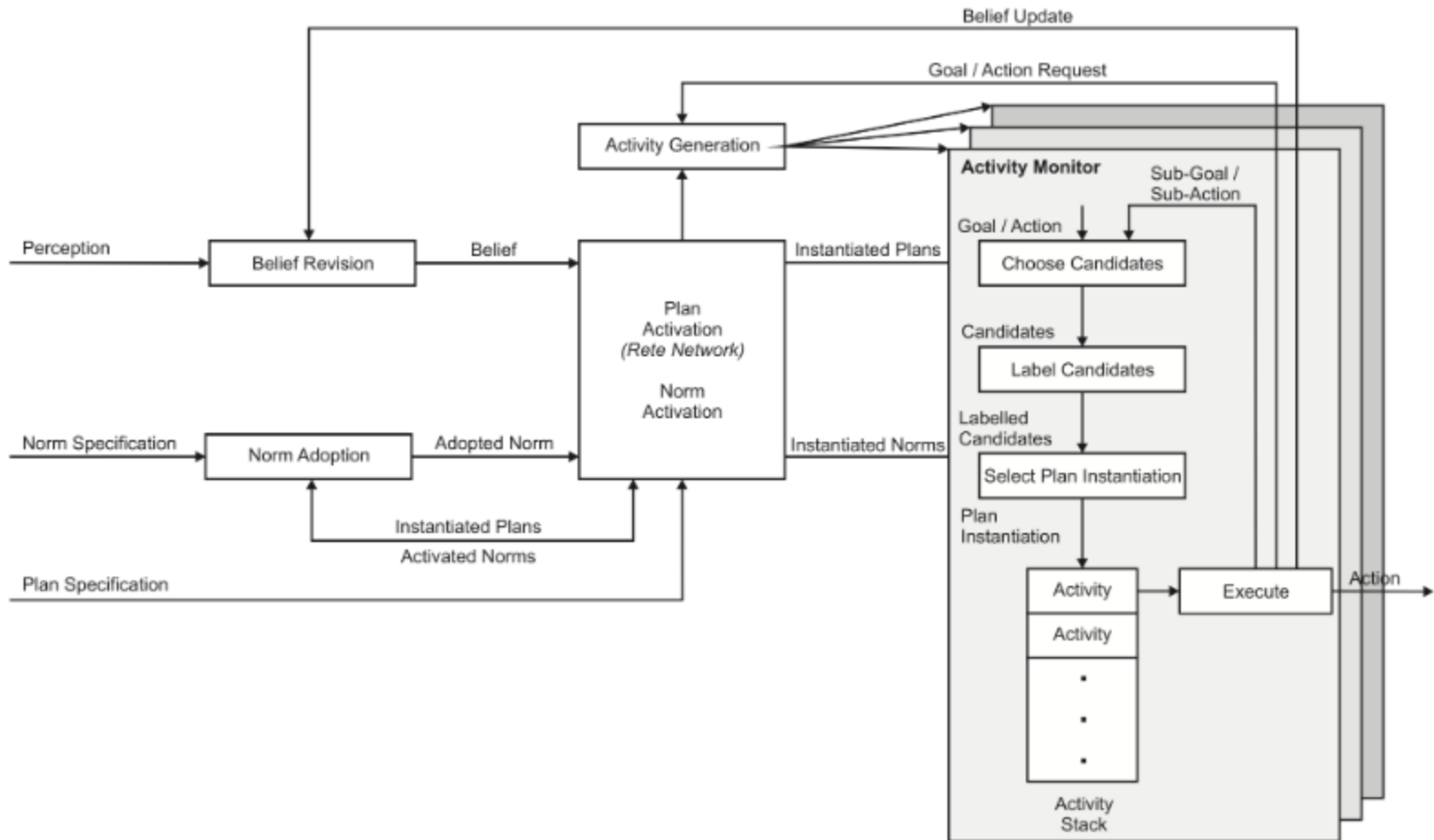
NoA analysis

Original Focus	norms in agent decision making
Main User Community	normative MAS community
Cognitive Level	deliberative decision cycle which is externally & internally motivated
Architectural Goal Management	sub-goal structure and activity stack
Symbolic or activation-based?	symbolic
Affective Level	none
Social Level	agent communication considered; inclusion of the social norm concept; distinction of one-self and others
Norm Consideration	norms considered; utilization of broader norm definition
Learning	conceptually mentioned, but not elaborated on in detail
Supported Operating Systems	n.a.
Resources	mainly scientific papers, especially Kollingbaum (2004)

Cognitive models
PECS

The diagram shows "Agent Reasoning" containing: Perception, Z_S Social Status F_S, Behaviour, Z_C Cognition F_C, Z_E Emotion F_E, Sensor, Z_P Physis F_P, Actor. Below is "Environment".

Legend: ⟷ / ⟶ Causal Dependencies   ·····▸ Information Packets

PECS analysis

Original Focus	consideration of physis, emotions, cognition and social status; meta-model
Main User Community	so far little community
Cognitive Level	decision process with both reactive as well as deliberation option
Architectural Goal Management	not described
Symbolic or activation-based?	symbolic
Affective Level	mentioned, however no explicit description
Social Level	inclusion of some social concept such as communication, but no implementation specifications
Norm Consideration	norms no considered
Learning	very little static learning using pre-defined rules in transition functions possible
Supported Operating Systems	n.a. (meta-model)
Resources	few scientific papers

Consumat
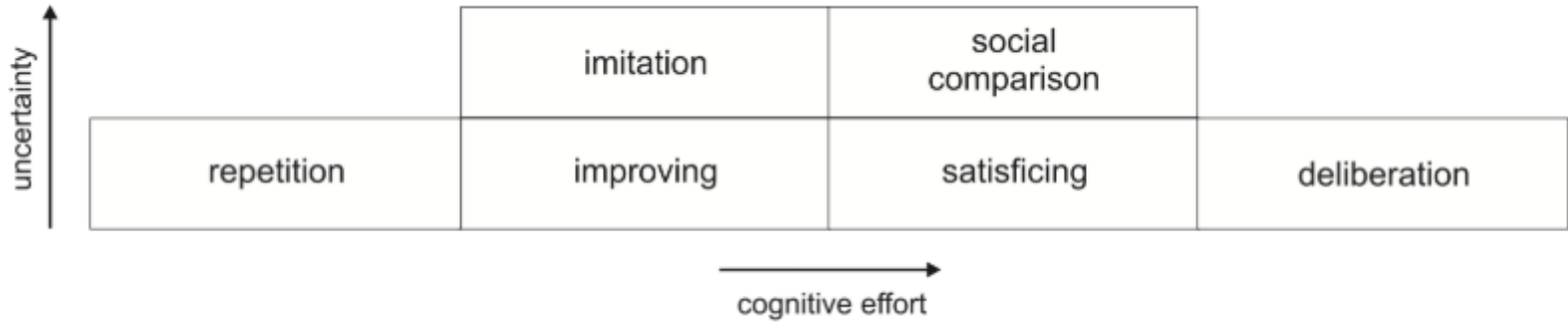
Contextual agent decision making

|	Individual	Social	Collective
Automatic	repetition	imitation	joining-in
Strategic	rational choice	game theory	team reasoning
Normative	(institutional) rules	(social) norms	(moral) values

CONSUMAT analysis

|	
Original Focus	study of consumer behaviour and market dynamics
Main User Community	ABSS, social science, marketing
Cognitive Level	deliberation and reactive decision making, as well as mixed heuristics possible
Architectural Goal Management	mental maps
Symbolic or activation-based?	both
Affective Level	values and morality considered, emotions not directly mentioned
Social Level	culture considered as one input parameter; main social focus on success comparison with peers
Norm Consideration	(non-social) norms and institutions mentioned as input for the agent behavioural model
Learning	learning of decision heuristics based on success of peers, inclusions of uncertainty metric
Supported Operating Systems	n.a.
Resources	mainly scientific applications, in particular Jager (2000)
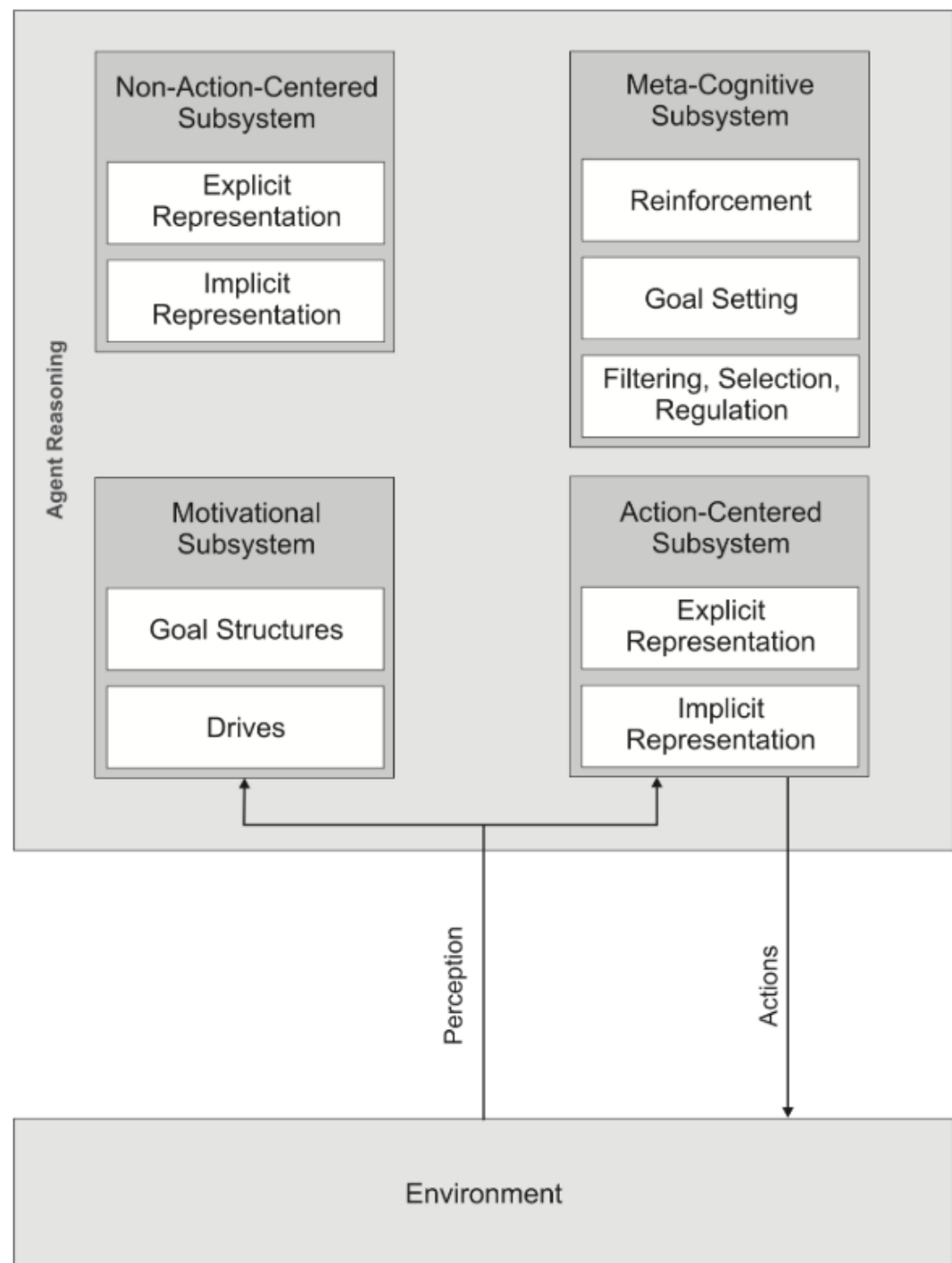
CLARION

CLARION analysis

|	
Original Focus	study of cognitive agents, special focus on learning
Main User Community	primarily cognitive and social psychology, as well as artificial intelligence
Cognitive Level	cognitive architecture relying on production rule based decision cycle
Architectural Goal Management	goal stack
Symbolic or activation-based?	both
Affective Level	not explicitly mentioned
Social Level	not considered
Norm Consideration	not considered
Learning	specific focus, learning both top-down as well as bottom-up
Supported Operating Systems	Windows, Mac, Linux
Resources	website with examples and scientific publications (http://www.cogsci.rpi.edu/~rsun/clarion.html)

ACT-R
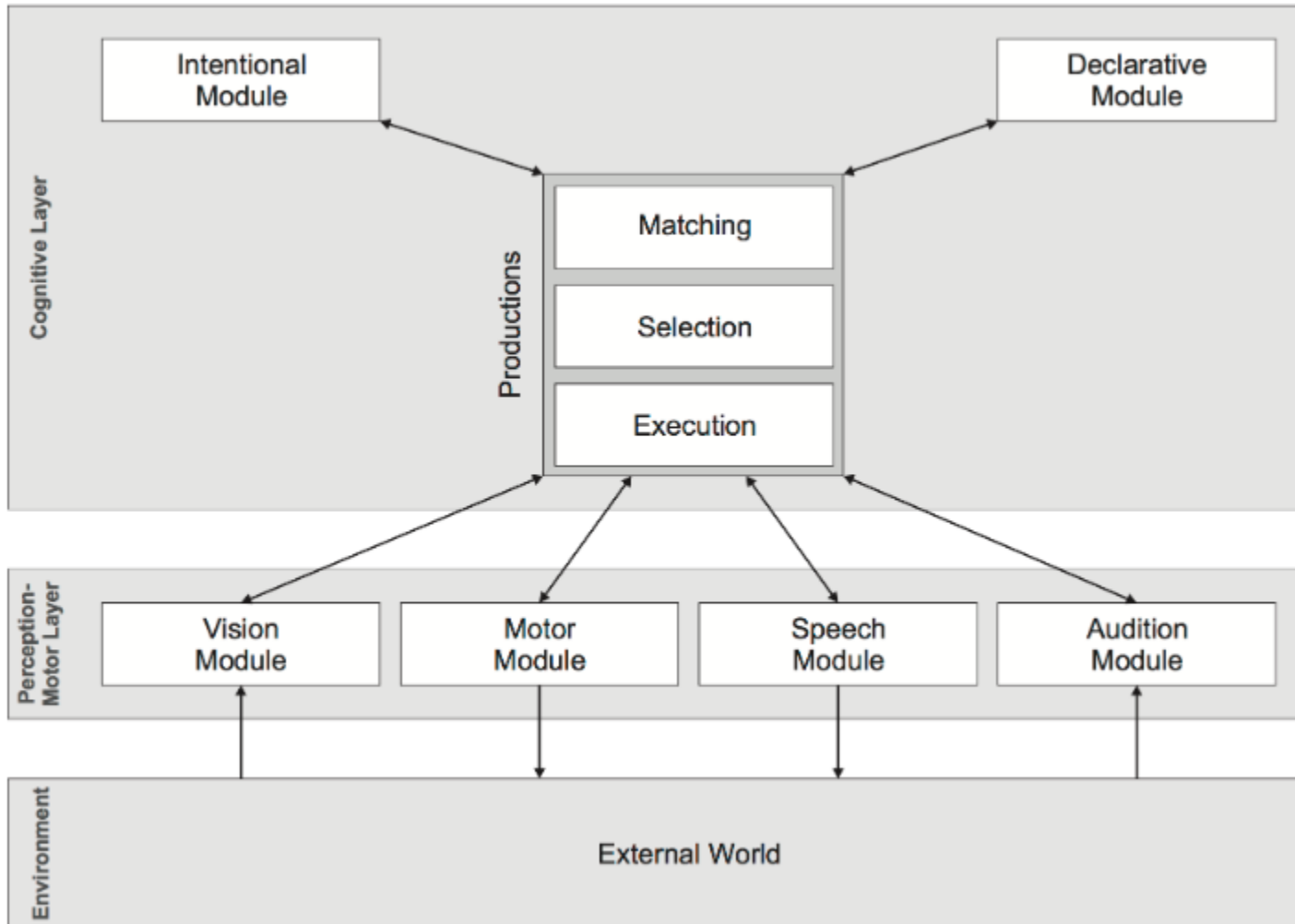
ACT-R analysis

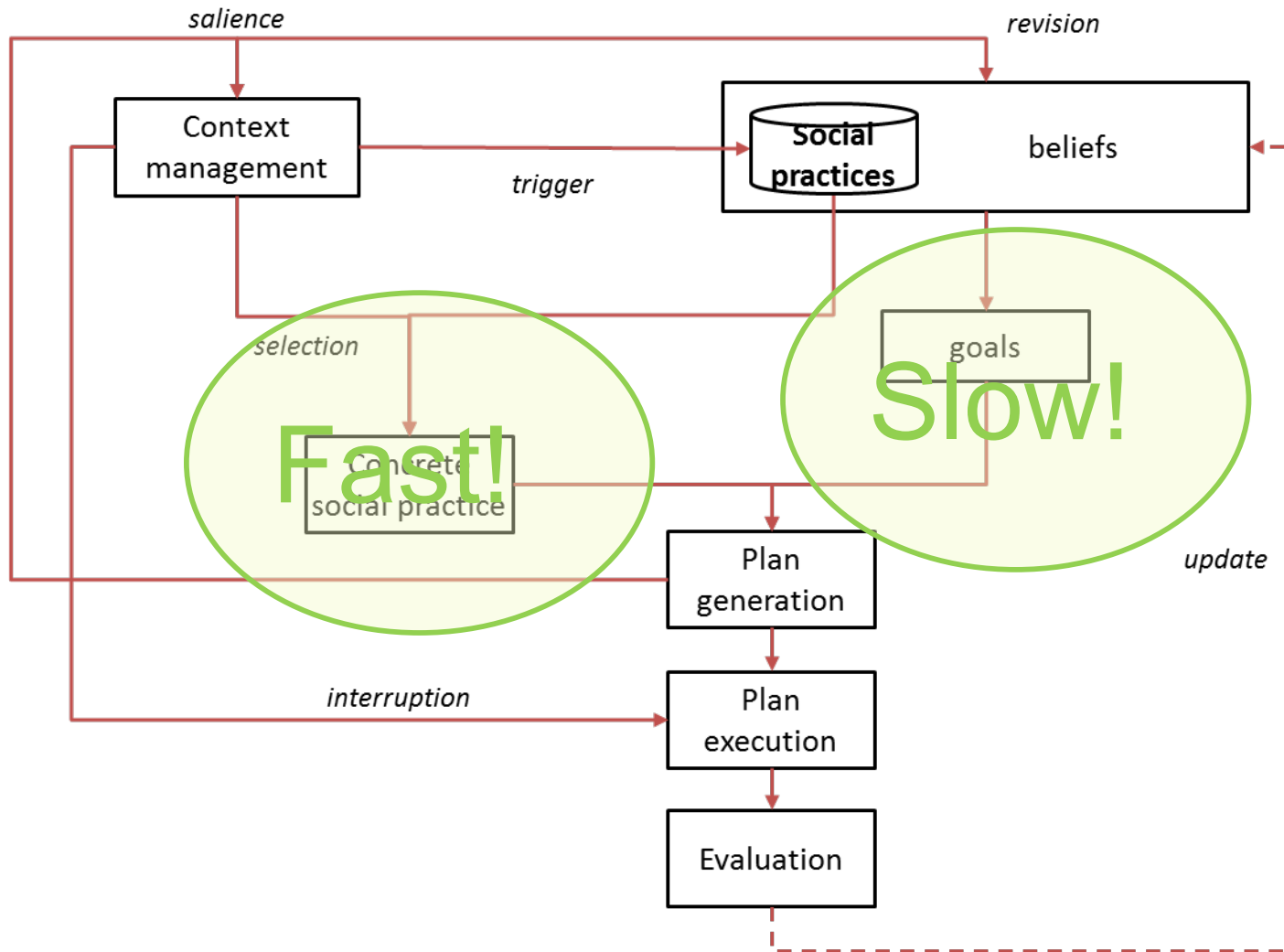|	
Original Focus	modelling of higher-level cognition (esp. memory and problem-solving)
Main User Community	primarily psychology and HCI
Cognitive Level	cognitive architecture with underlying production cycle (serial)
Architectural Goal Management	goal stack
Symbolic or activation-based?	both
Affective Level	not mentioned
Social Level	not main focus; one example (Best & Lebiere 2006) using the notion of teams and common team goals
Norm Consideration	not considered
Learning	yes for declarative and procedural memories
Supported Operating Systems	Windows, Mac OS X 10.5 or newer, (UNIX)
Resources	extensive tutorial materials & summer school (http://act-r.psy.cmu.edu/actr6/)

SOAR
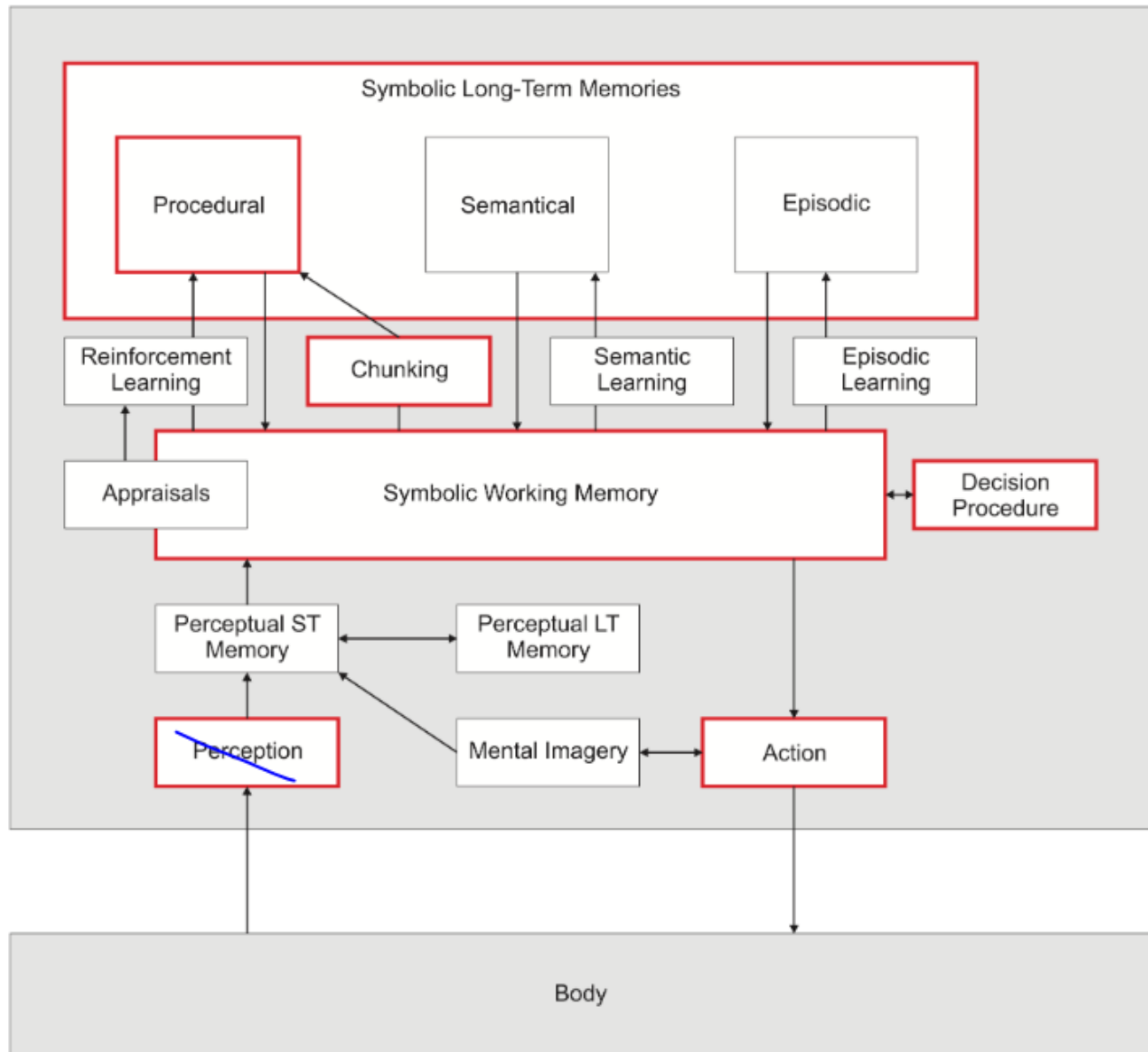
SOAR analysis

Original Focus	problem solving and learning
Main User Community	mainly HCI and artificial intelligence
Cognitive Level	cognitive decision cycle
Architectural Goal Management	universal sub-goaling
Symbolic or activation-based?	symbolic, non-symbolic knowledge representation added in SOAR 9
Affective Level	not strongly considered
Social Level	concept of teams and team coordination implemented in TacAir-Soar
Norm Consideration	not considered
Learning	yes, for all long-term memory components; by chunking, reinforcement learning (with SOAR 9)
Supported Operating Systems	Windows, Mac OS, Unix
Resources	website (http://sitemaker.umich.edu/soar/home) with documentation and examples as well as mailing list

Social Practice agent

Social agent

Social agent

Context management
- Focus
- Filter
- Change
- Adapt

contexts

salience

trigger

focus

Identity management

Social rules + systems | Value system | motives | beliefs

revision

social heuristics

Concrete context

- Goals
- Motivations

Plan generations

interruption

Plan execution

adapt

evaluation

Society based

Norms, Rituals, Organizations, Institutions

- Norms
- Rituals
- Organizations
- Institutions

- Monitor
- Central mechanism
- Punish
- Repair
- Adapt

Individual based

Shared
- Values
- Conventions
- Teams
- Social practices
- Institutions

- Drive
- Adapt

Social agent

Social agent

Social agent