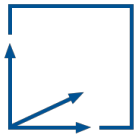
Module IN 2111

3D User Interfaces
- Dreidimensionale Nutzerschnittstellen -

Prof. Gudrun Klinker

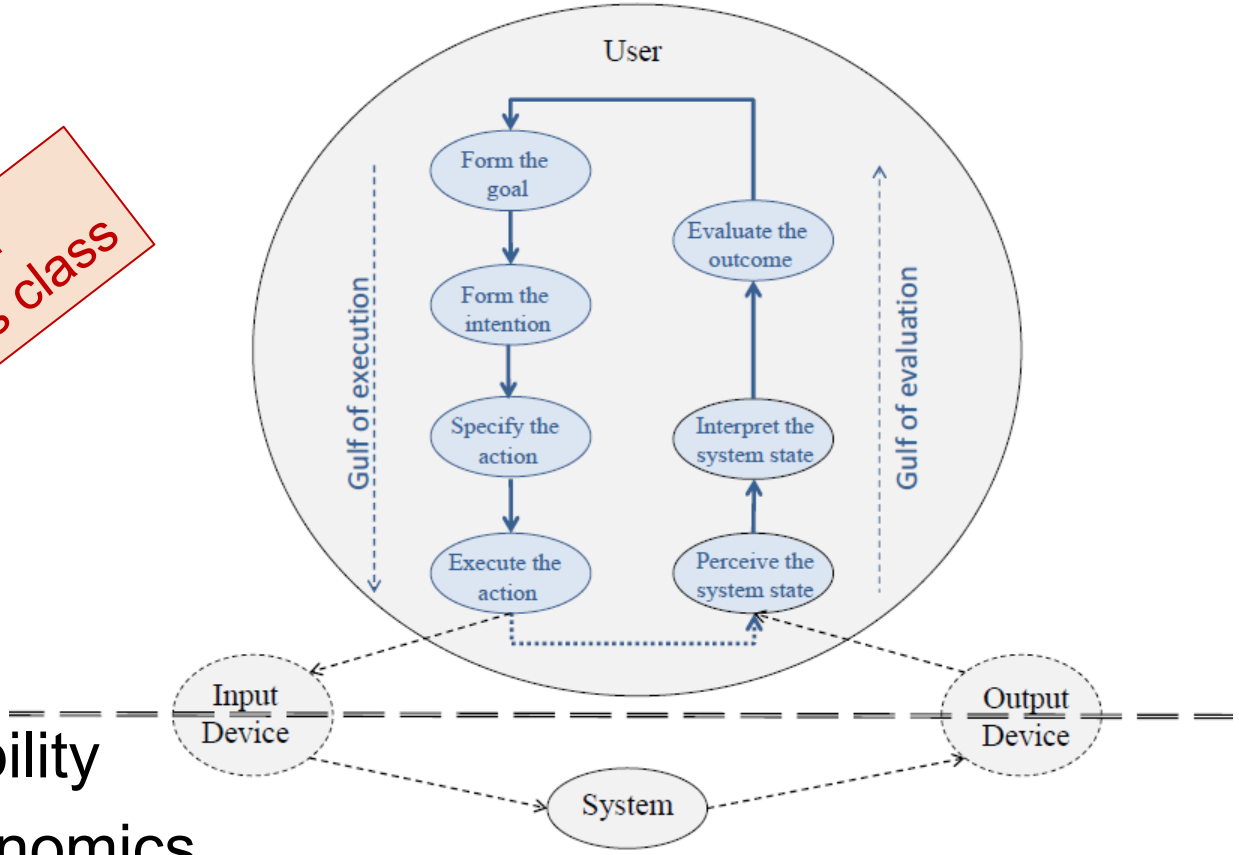


Human Factors Fundamentals: Cognition

SS 2023

HCI: The Human Side

Reminder: Previous class



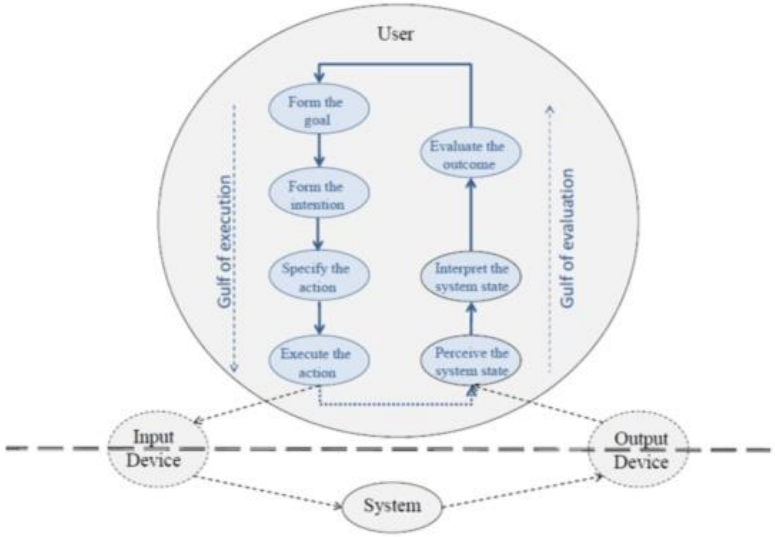
- Usability
- Ergonomics
- Function

[Don Norman: The Design of Everyday Things, 1988]

Overview

Agenda

1. Information Processing
2. Cognition



Literature

- Wickens and Carswell (1997), Information Processing. In: Salvendy (Ed.) The Handbook of human factors and ergonomics (2nd Ed.), pp. 89-129.
- Wickens (2002), Multiple resources and performance prediction. Theor. Issues in Ergon. Sci.: 3(2), 159-177.
- Wickens, Hollands, Banbury, Parasuraman (2016), Engineering Psychology and Human Performance (4th Ed.) Ch. 10, Routledge Taylor & Francis.
- LaViola, Kruijff, McMahan, Bowman and Poupyrev (2017), 3D User Interfaces Theory and Practice (2nd Ed.), Addison Wesley.

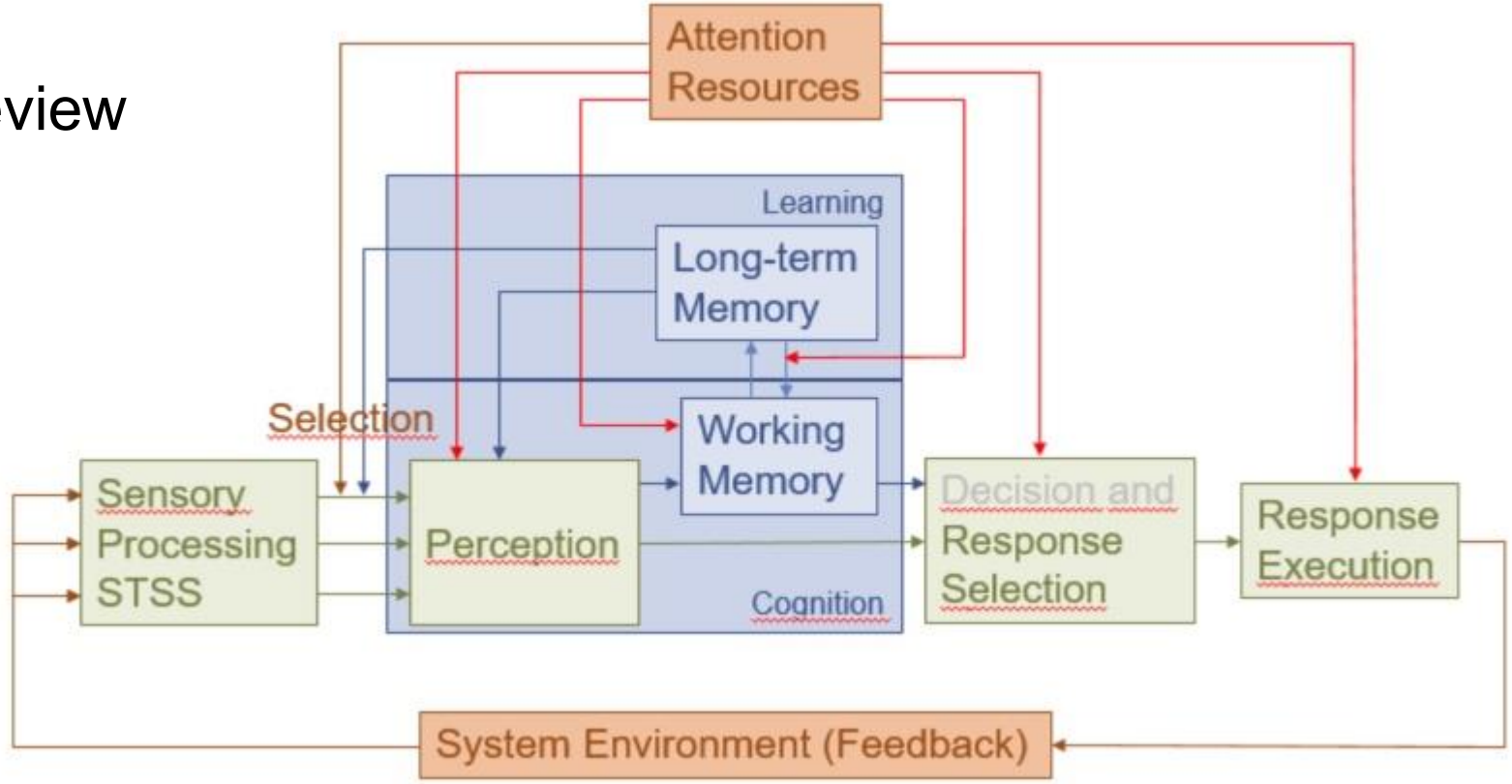
Overview

1. Information Processing

- 1.1 Foundations
- 1.2 Attention
- 1.3 Decision-Making, Behavior, and Skills
- 1.4 Selection and Control of Action

1.1 Foundations

Preview



[adapted from: Wickens and Carswell 1997, Wickens 2002, Wickens et al 2016, Laviola et al 2016]

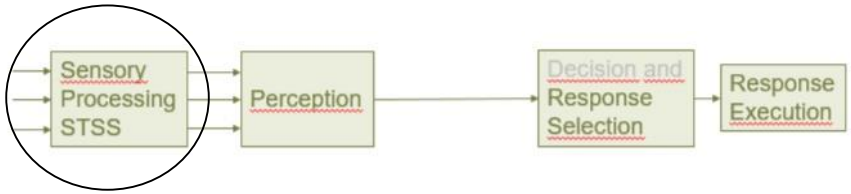
1.1 Foundations: Stages

- Stages

1.1 Foundations: Stages

Short-term sensory store (STSS)

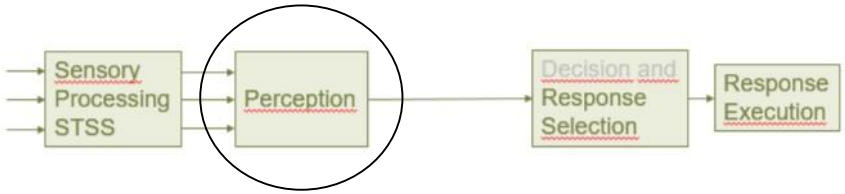
- Special storage capacity associated directly with sensory systems
  - Functionally limitless short-term store of massive amounts of information
  - Without much recoding (“raw data”)
- Temporary mechanism for prolonging the representation of the raw stimulus evidence for short durations
  - Visual: ½ second
  - Auditory: 2-4 seconds



1.1 Foundations: Stages

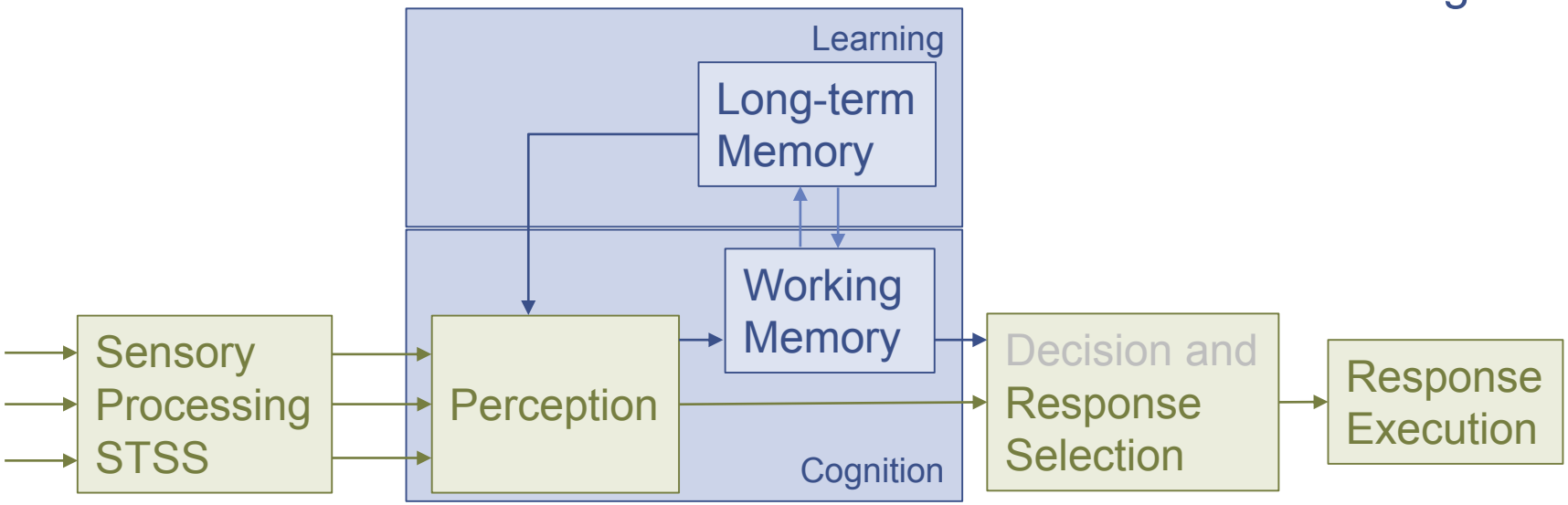
Perception

- Very fast
  - requiring little attention
- Processing modes
  - Bottom-up
    - Driven by sensory input
  - Top-down
    - Driven by long-term memory (expected events)



1.1 Foundations: Cognition, Learning

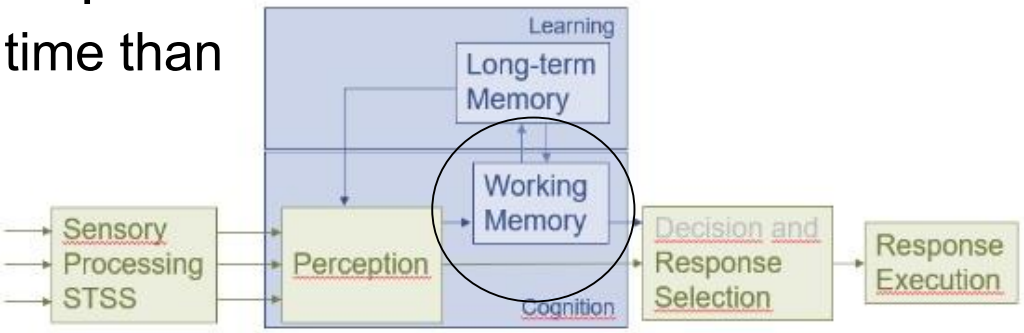
- Stages
- Cognition, Learning



1.1 Foundations: Cognition, Learning

Working memory

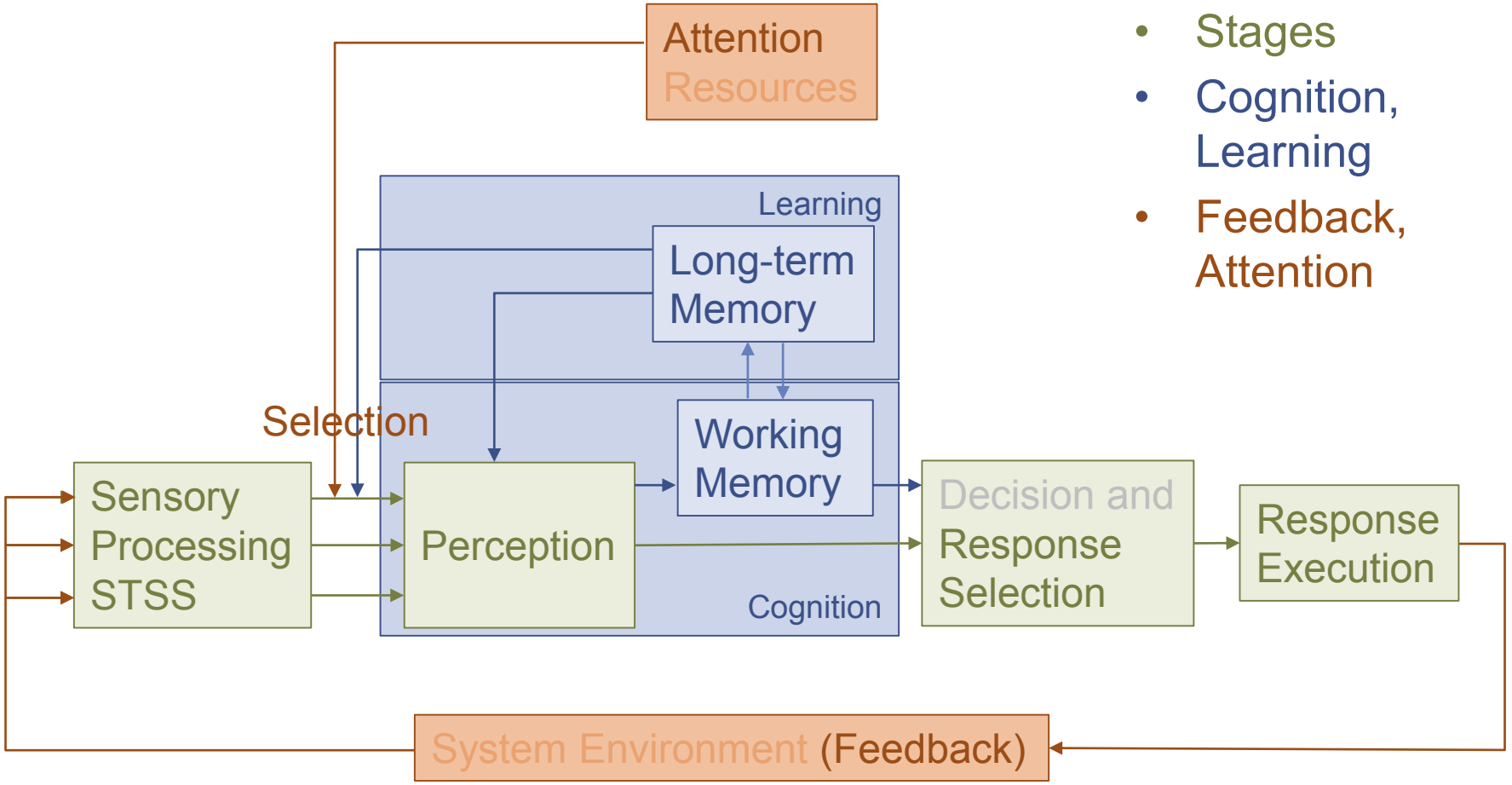
- Blurred boundary to perception
  - Processes require more time than pure perception
  - Cognitive operations
    - Rehearsal
    - Reasoning
    - Image transformation
    - Planning



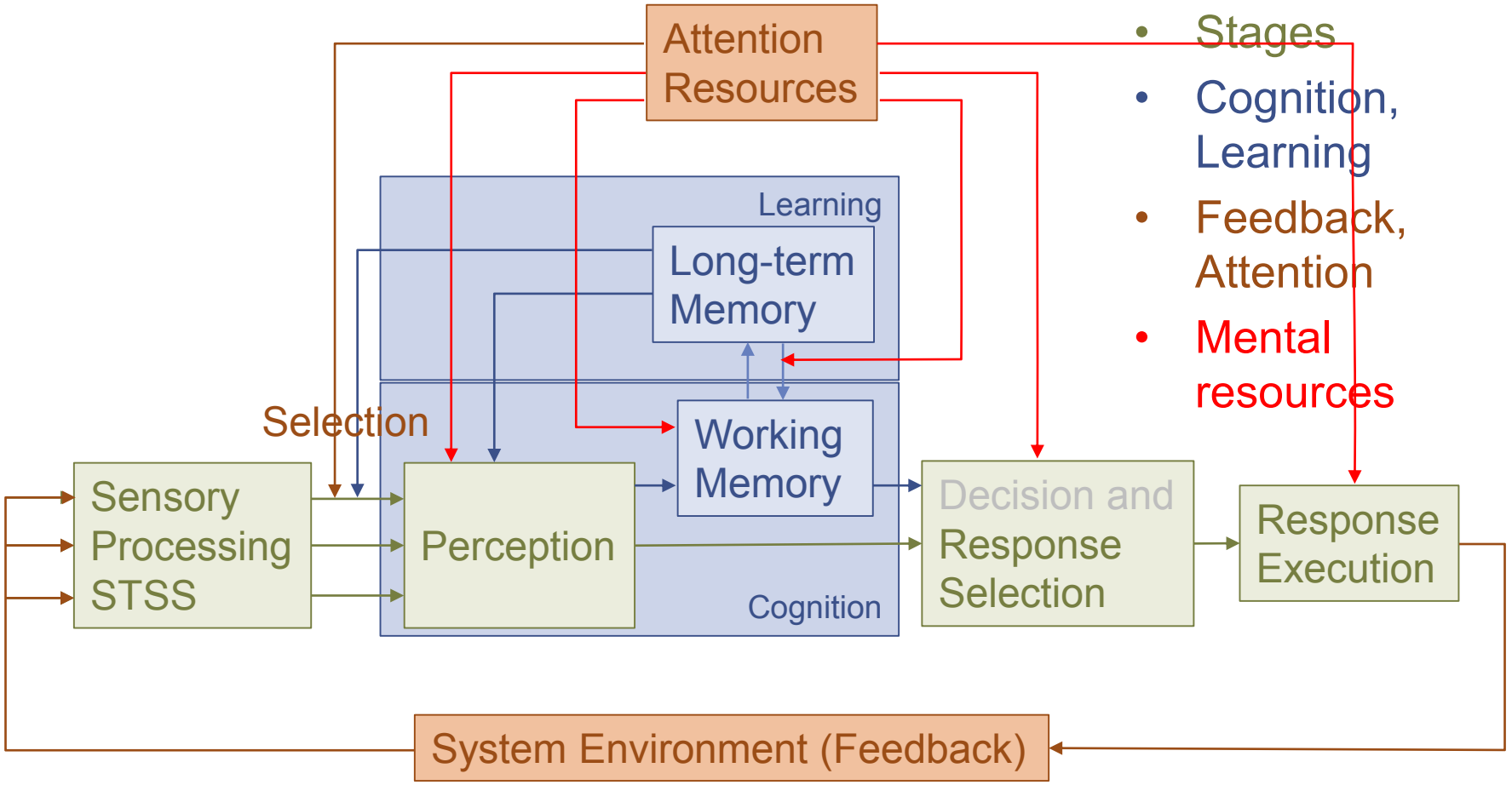
- Limited resources (capacity)!
  - Vulnerable to disruption when shared across several tasks
- Some transfer to/from long-term memory: learning

1.1 Foundations: Feedback, Attention

- Stages
- Cognition, Learning
- Feedback, Attention



1.1 Foundations: Mental Resources



- Stages
- Cognition, Learning
- Feedback, Attention
- Mental resources

Overview

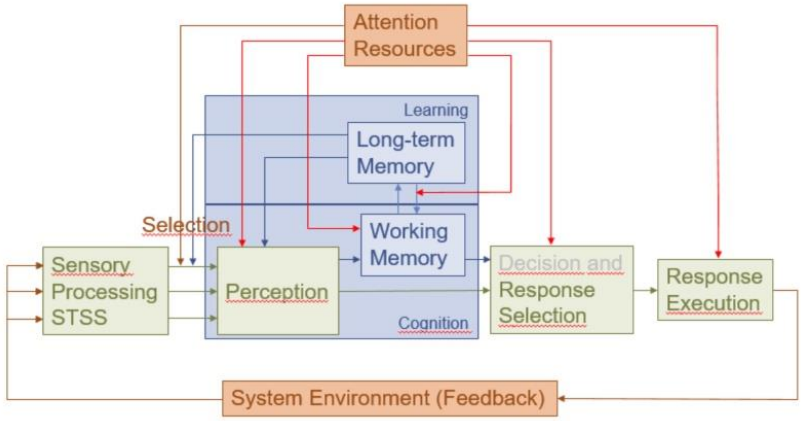
1. Information Processing

1.1 Foundations

→ 1.2 Attention

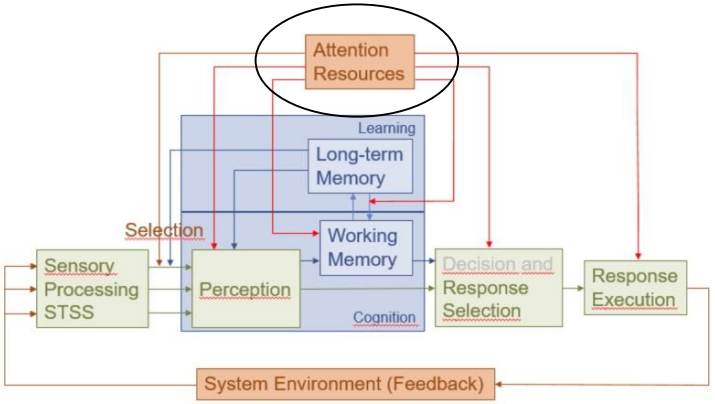
1.3 Decision-Making, Behavior, and Skills

1.4 Selection and Control of Action



1.2 Attention

1. Information Processing



- Major component in processing visual stimuli and search behavior
- Involves
  - Selection of some information for further processing
  - Inhibiting other information from receiving further processing
- Three components
  - Orienting to sensory events
  - Detecting signals for focused processing
  - Maintaining a vigilant/alert state

1.2 Attention

Forms of attentive behavior:

- Selective attention
  - Choosing which events or stimuli to process
- Focused attention
  - Effort to maintain processing these elements without being distracted
- Divided attention
  - Ability to process more than one event or stimulus at a given point in time

1.2 Attention

- Three mental operations:
  - Disengaging attention from current locus
  - Moving attention to new location
  - Reengaging attention in a new location

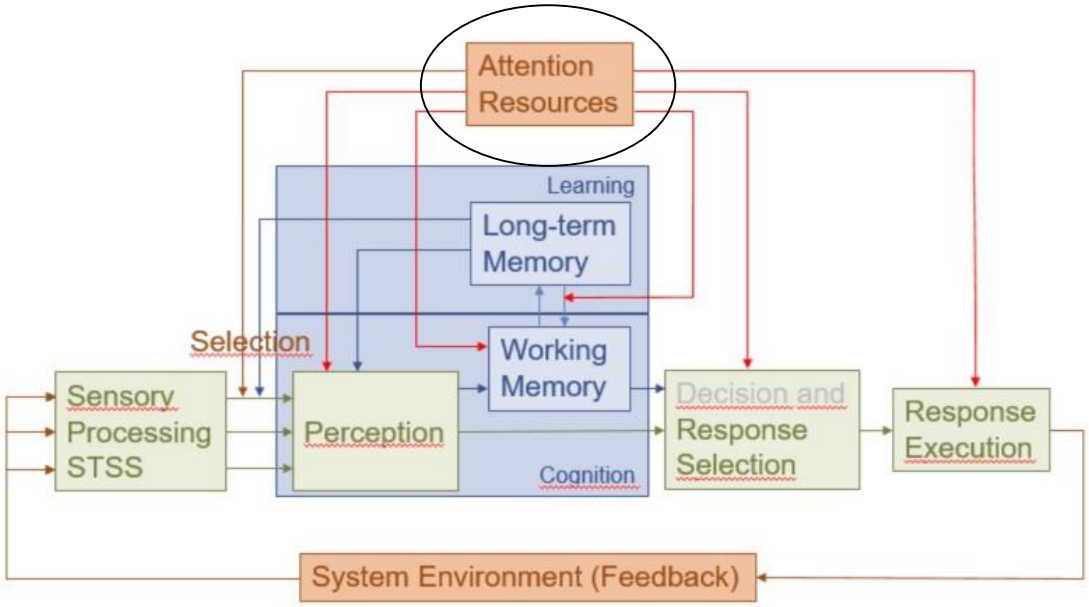
- Attention in one sensory channel can trigger attention within another channel

- Links between different sensory modalities (multisensory processing)

1.2 Attention

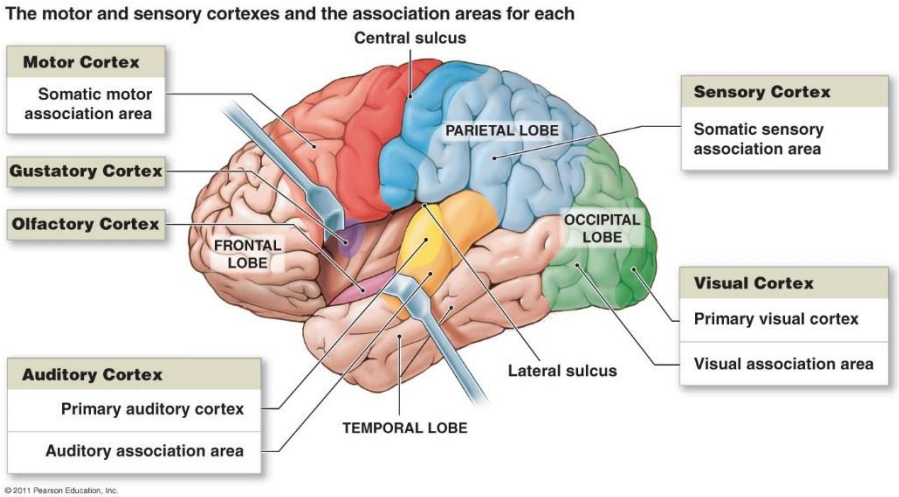
- Bottlenecks / errors
  - Limitations of our sensory systems
  - At a spatial or temporal level
  - Dependent on the mode of attention
  - Information overload
    - Spatial: too many objects in the FOV
    - Temporal: rapid sequences of stimuli
- Examples
  - Change blindness / change deafness
  - Perceptual tunneling
  - Cognitive capture

1.2 Attention: Resource Sharing

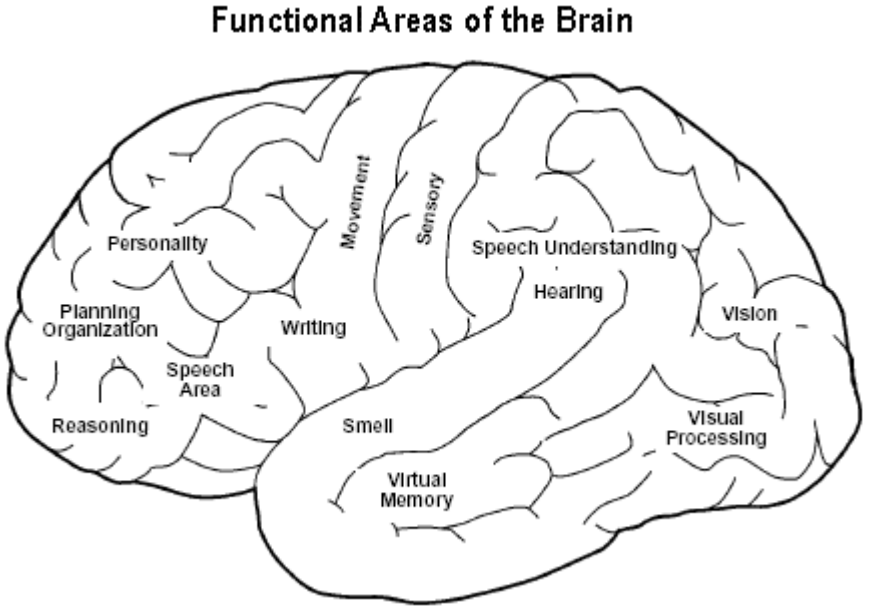


1.2 Attention: Resource Sharing

Functional brain models



[source: highlands.edu]

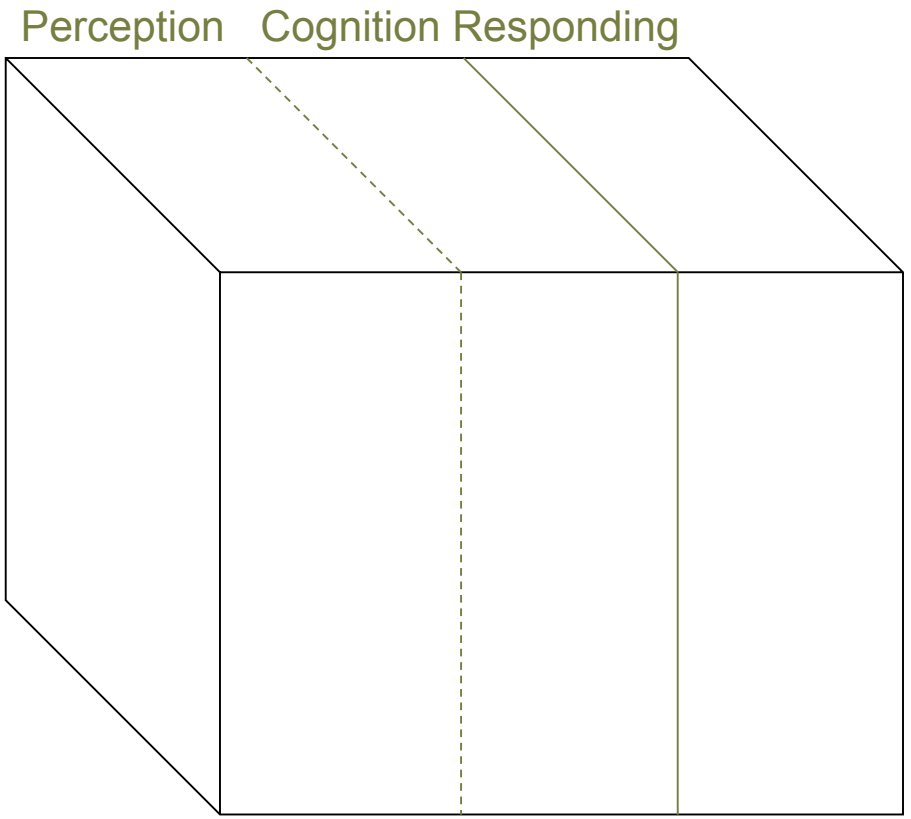


[scource: American Psychological Association]

1.2 Attention: Resource Sharing

Multitasking:
Separate resources for

- Stages



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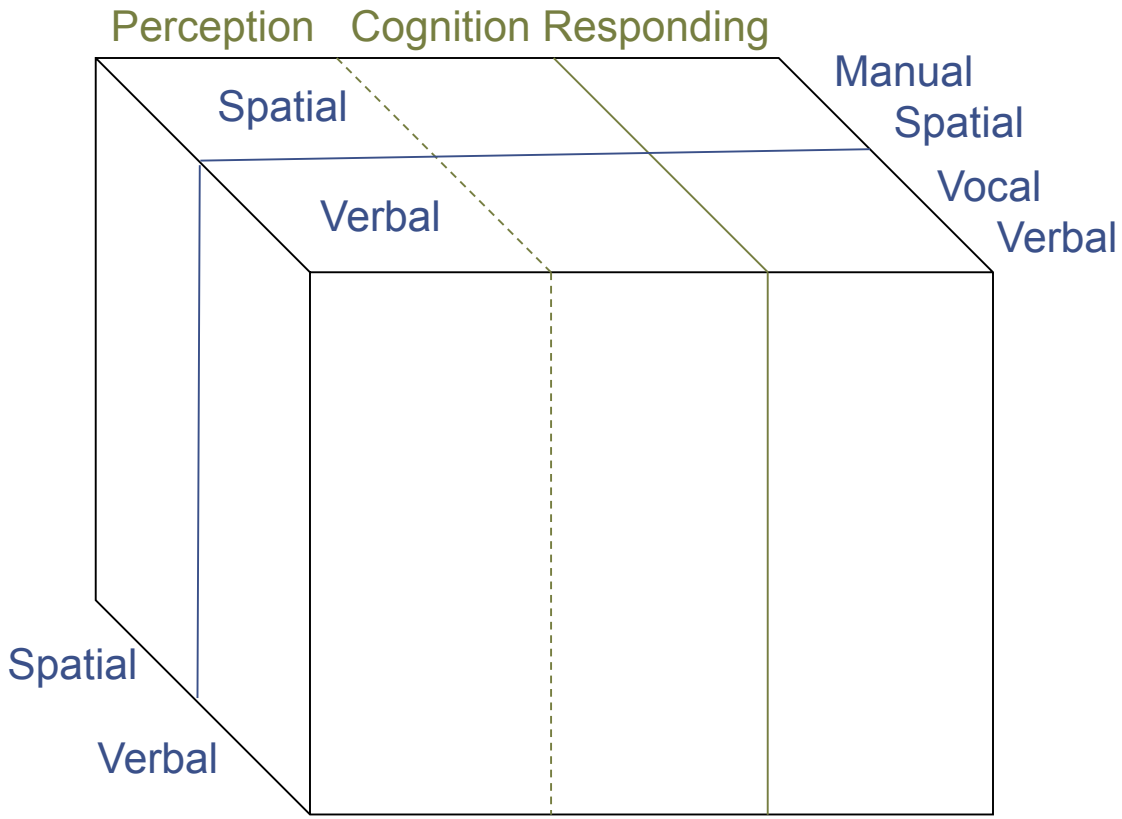
1.2 Attention: Resource Sharing

Multitasking:

Separate resources for

- Stages
- Processing Codes

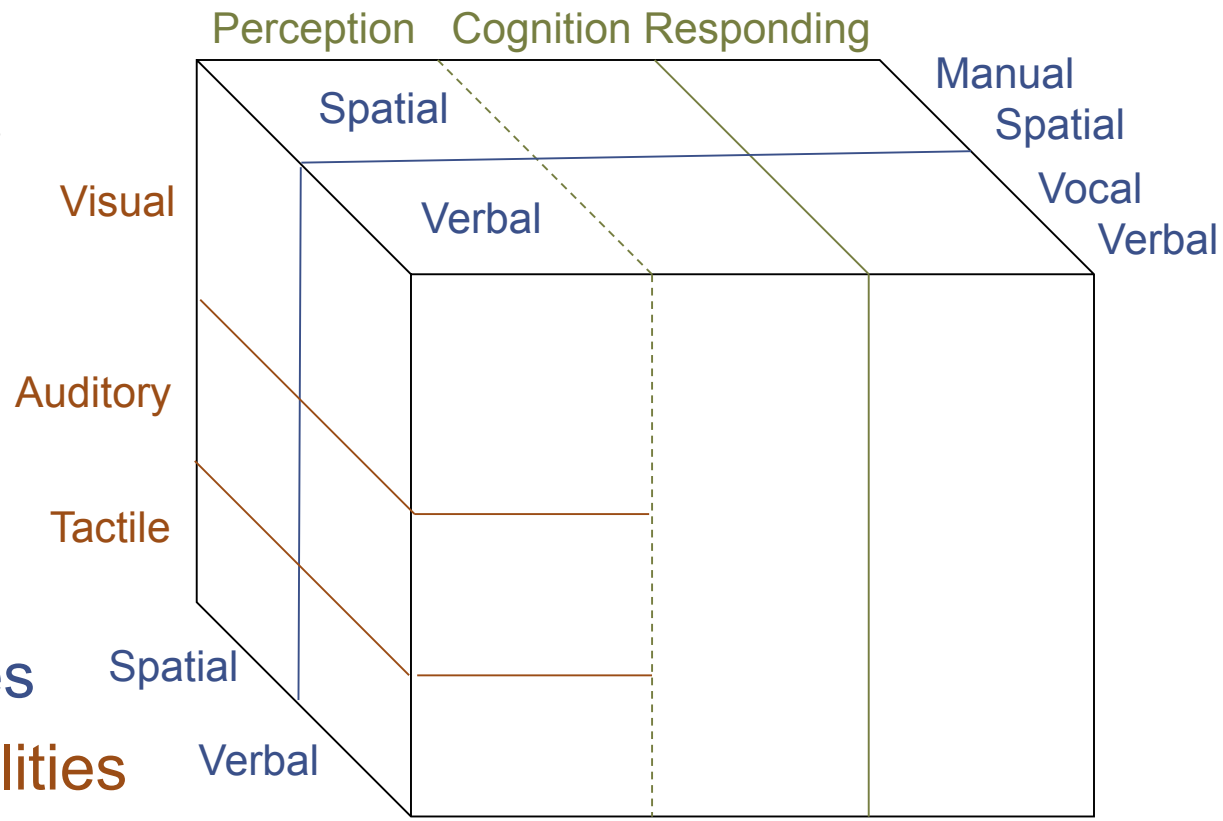


1.2 Attention: Resource Sharing

Multitasking:

Separate resources for

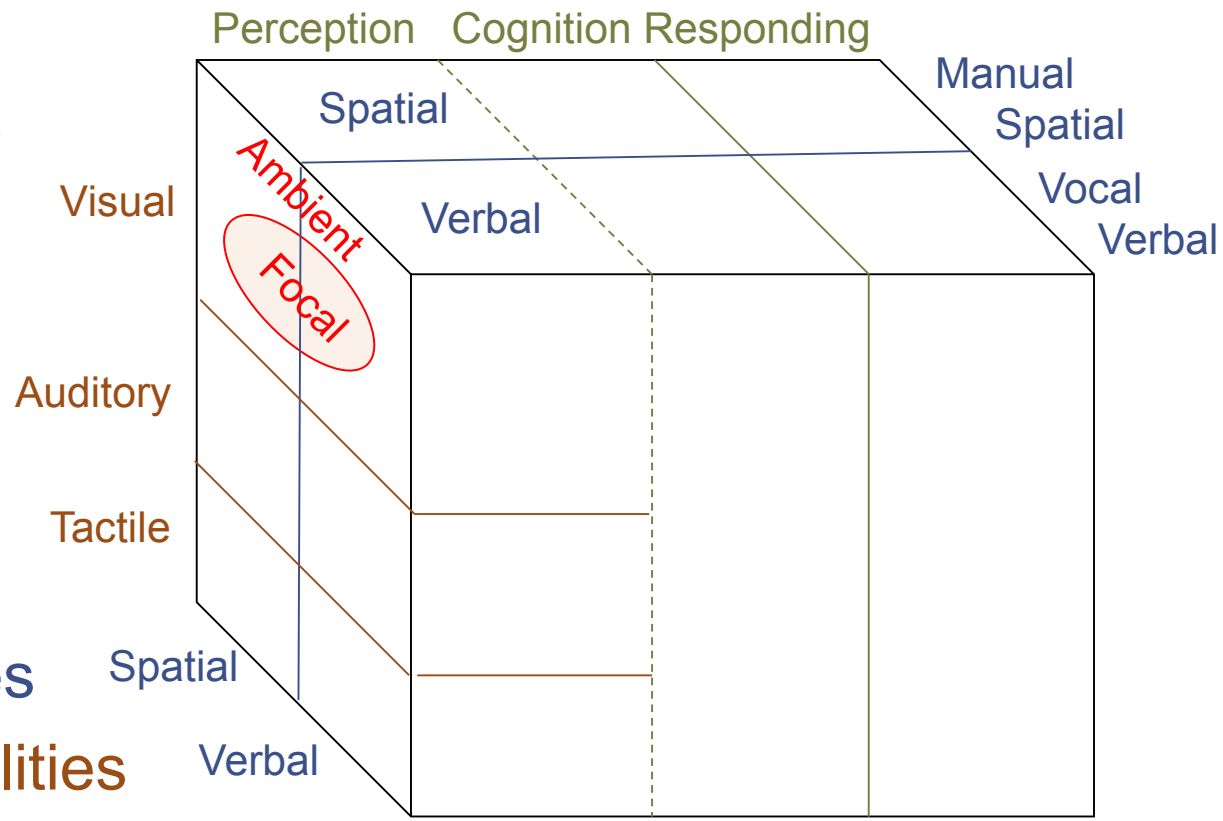
- Stages
- Processing Codes
- Perceptual Modalities



1.2 Attention: Resource Sharing

Multitasking:

Separate resources for

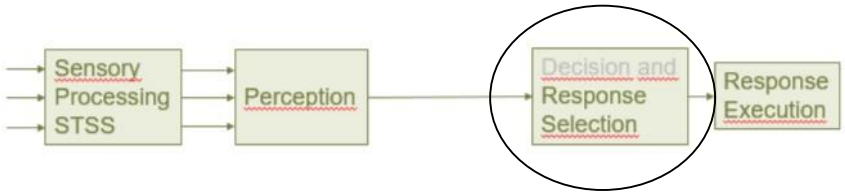


- Stages
- Processing Codes
- Perceptual Modalities
- Visual Channels

Overview

1. Information Processing

1.1 Foundations
1.2 Attention
→ 1.3 Decision-Making, Behavior, and Skills
1.4 Selection and Control of Action



1.3 Decision-Making, Behavior, and Skills

Based on the identification of

- Current situation
- Potential actions
- Consequences

1.3 Decision-Making, Behavior, and Skills

Decision models

- Normative
  - Statistical, economical methods, assuming rational behavior
- Behavioral / skills
  - Account for human limitations, heuristics
- Naturalistic
  - Task-based decision making in realistic situations

1.3 Decision-Making, Behavior, and Skills

Behavior

- Usage of specific strategies to make decisions
- Based on experience
- Can be affected by culture, belief
- Can be affected by emotional state
- Issues:
  - Temporal discounting
  - Dynamic inconsistencies
  - Conditioning
  - Habituation (can be used to cure phobias)

1.3 Decision-Making, Behavior, and Skills

Skills

- Allow for more accurate and faster responses
- Can be acquired over time

Three stages in acquiring skills

- Cognitive stage
  - Declarative knowledge, conscious set of instructions
- Associative stage
  - Behavioral tuning, decreasing error rates
- Autonomous stage
  - Non-declarative knowledge in long-term memory

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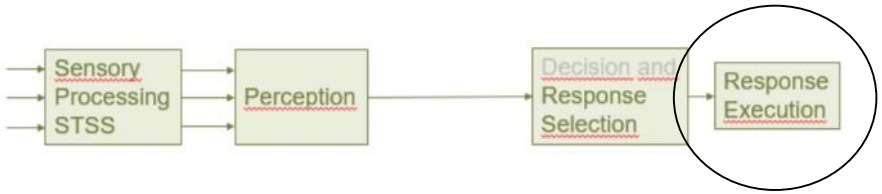


1.4 Selection and Control of Action

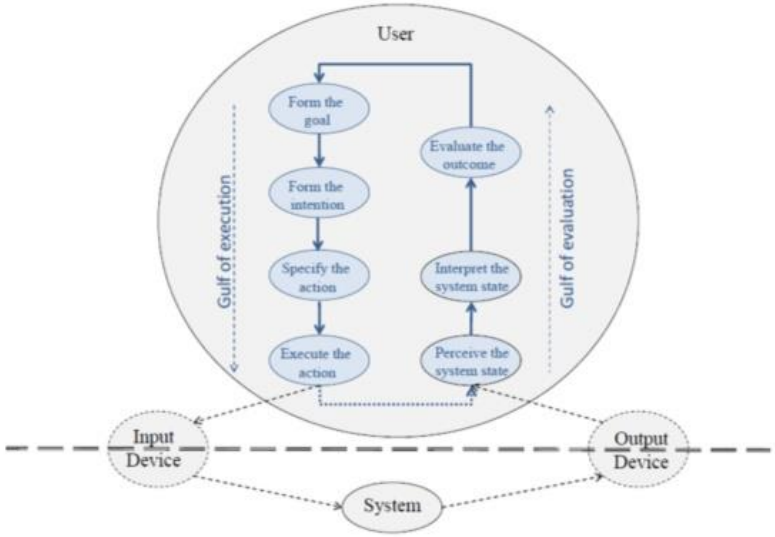
- Speed and accuracy of responses depend on
  - Stimulus-response compatibility
  - Stimulus-response consistency over time
  - Number of parallel tasks (task switching)
  - Uncertainty
  - Pre-cueing

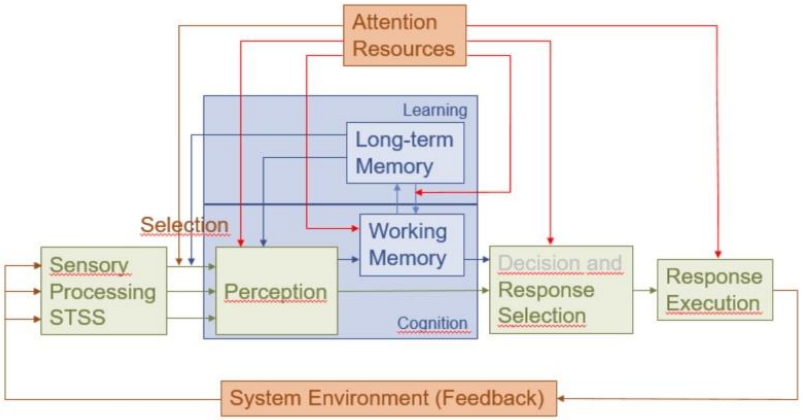
- Fitts' law: speed-accuracy tradeoff
- Steering law: time to steer through a tunnel

Overview

Agenda

1. Information Processing
2. Cognition

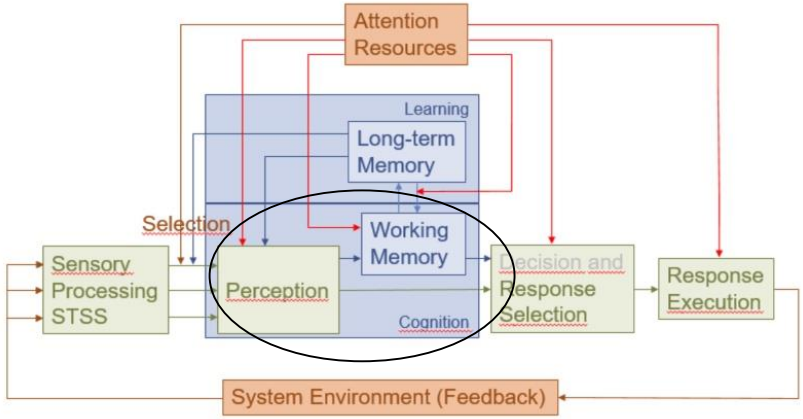




Overview

2. Cognition

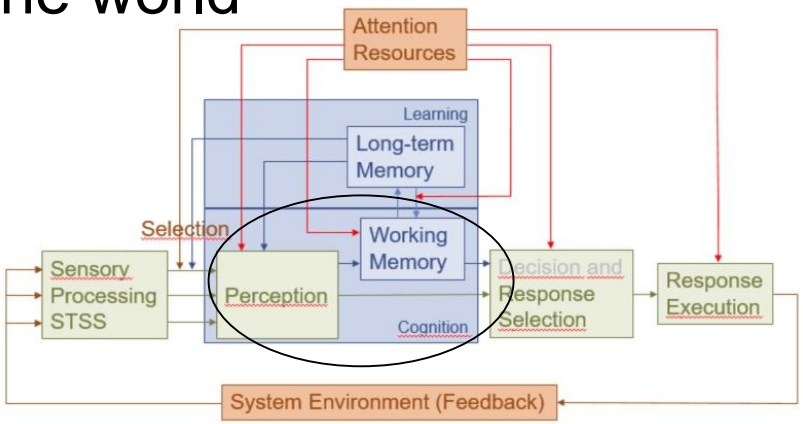
- 2.1 Foundations
- 2.2 Situation Awareness
- 2.3 Evaluating Cognitive Issues



2.1 Foundations

- Cognition related to knowledge stored in our brain

- Knowledge: information about the world
  Should be
  - True
  - Justified
  - Coherent



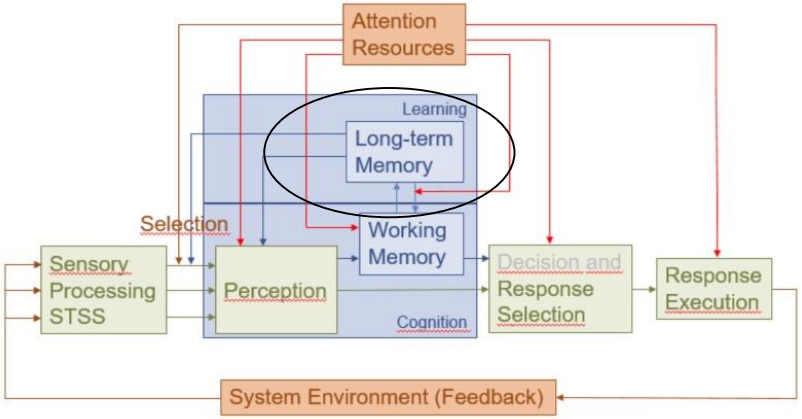
- Cognition: the driving force behind the generation and usage of knowledge

2.1 Foundations

Category knowledge in long-term memory

Represented as

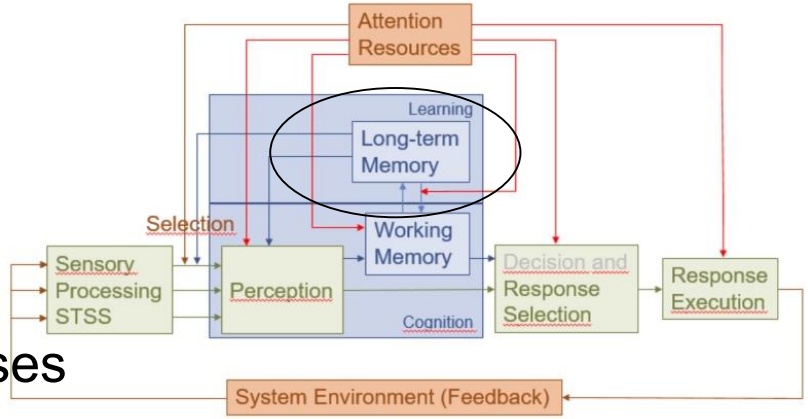
- images
- feature records
- amodal symbols
- statistical patterns in neural networks



2.1 Foundations

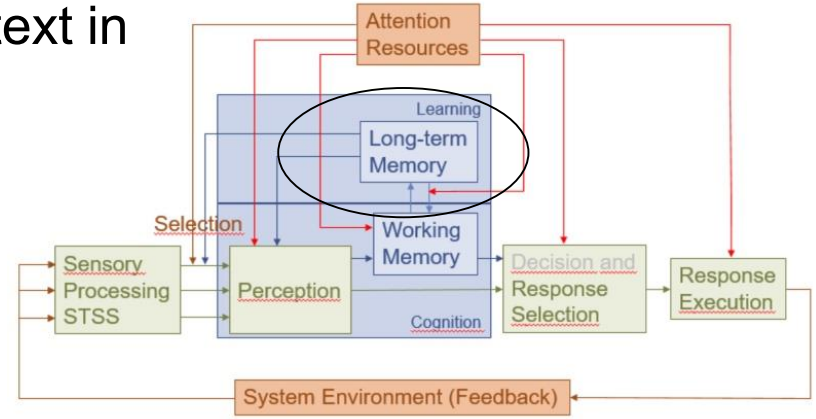
Types of category knowledge in long-term memory

- Declarative (explicit):
  - Facts, events
- Nondeclarative (implicit):
  - Priming
  - Procedural (skills, habits)
  - Associative memory
    →conditioning: emotional responses
  - Nonassociative memory
    →conditioning: habituation, sensitization



2.1 Foundations

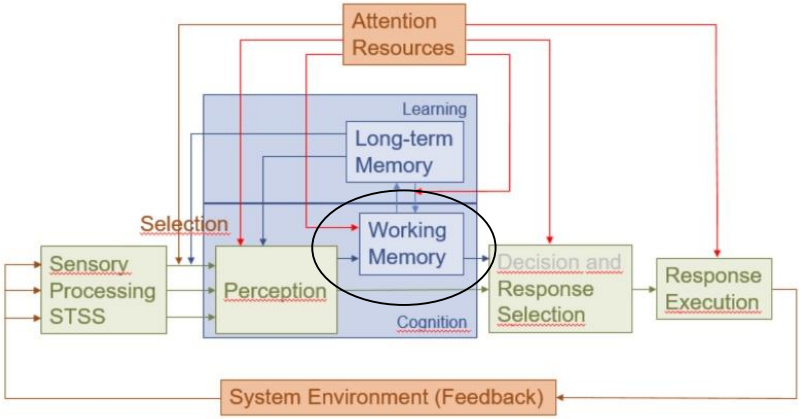
- Usage of long-term memory
  - (Re-)activation of specific memory traces through pattern completion and recapitulation
  - Recall (affected by cues and context in highly associative memory)
- Problems with memory recall
  - Biased
  - Misattribution due to wrongly matched cues
  - Suggestive triggering (→skewed recall)
  - Blocked / suppressed memory
  - Matching failure due to overload of cues



2.1 Foundations

Working memory

- Short-term storage
- Temporary



- Performs manipulations / transformation actions on bits and pieces of information
- Individual differences: memory span, amount of storage
- Fast memory decay:
  - Verbal item recall: 6 seconds

Overview

2. Cognition

2.1 Foundations

→ 2.2 Situation Awareness

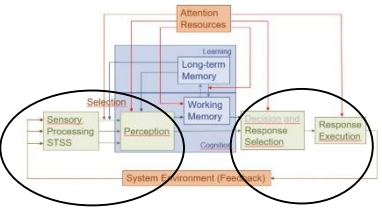
2.3 Evaluating Cognitive Issues

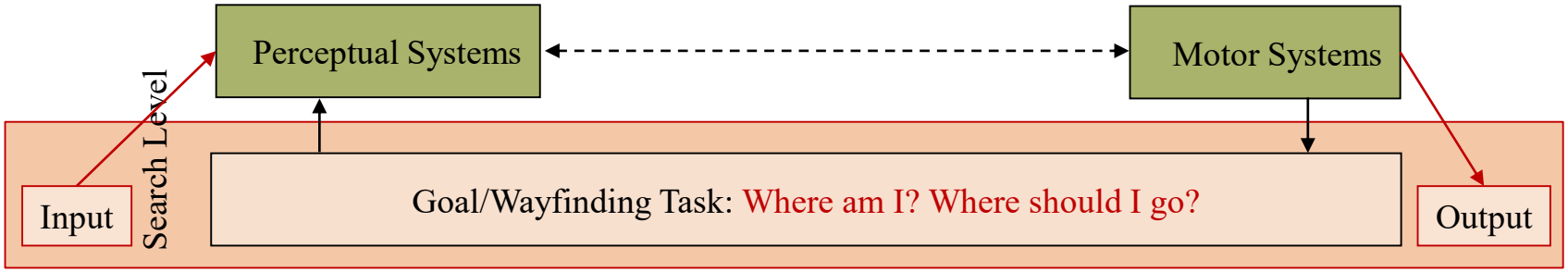
2.2 Situation Awareness

Impact of cognition on interaction in spatial environments

- Internalized model of the current state of the user's environment
  - Perception of elements in the environment (time and space)
  - Comprehension of their meaning
  - Projection of their status in the near future
- Information types
  - From various sources
  - Spatial relationships
  - Fellow users
  - Task states

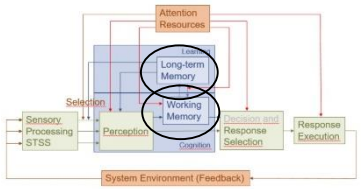
2.2 Situational Awareness: Wayfinding





[adapted from: Laviola et al 2017]

2.2 Situational Awareness: Wayfinding



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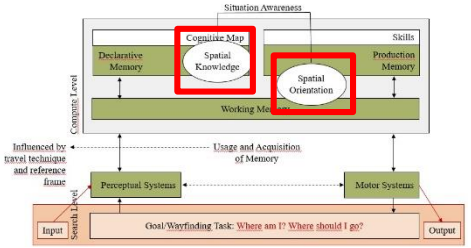
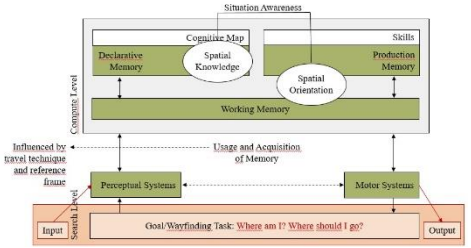
2.2 Situation Awareness: Wayfinding

Cognitive mapping



- Processing multiple sources of sensory information from the environment to execute a suitable travel trajectory
- Environment information stored in long-term memory (spatial knowledge, “cognitive map”)
  - Mental hierarchical structure (tree) of spatial knowledge
- Use of existing spatial knowledge, acquisition of new knowledge, combination of both
- Tight feedback loop (perceived new information vs. existing cognitive map)
- Spatial orientation: knowledge of current location and viewing direction

2.2 Situation Awareness: Wayfinding



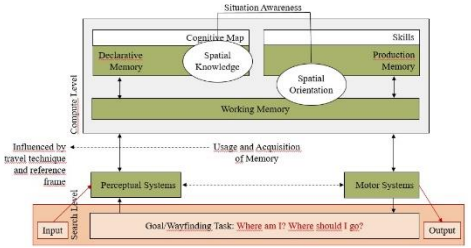
Types of spatial knowledge
(increasing levels of abstraction)

- Landmark knowledge
- Procedural knowledge (route knowledge)
- Survey knowledge

Search strategies

- Influence the effectiveness of spatial knowledge acquisition
- Affect the efficiency of building a cognitive map and also qualitatively different kinds of spatial knowledge

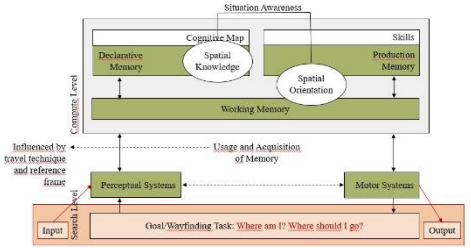
2.2 Situation Awareness: Wayfinding



Reference frames:

- Egocentric (egomotion):
  - Relative to certain part of the human body (station point (nodal point of the eye), retinocentric, headcentric, bodycentric, proprioceptive subsystems)
  - Provides information such as
    - Distance (physical feedback: number of strides, arm's length)
    - Orientation (direction of eye, head, torso; user motion)
- Exocentric: object- or world-relative

2.2 Situation Awareness: Wayfinding



Spatial judgments

- Egomotion:
  seeing oneself in the center of space
- Match egocentric information to cognitive map (exocentric)

- Upon entering a world:
  - egocentric information (landmark, procedural knowledge)
- By wayfinding methods (generalization):
  - Build up an exocentric representation (survey knowledge)

Overview

2. Cognition

2.1 Foundations

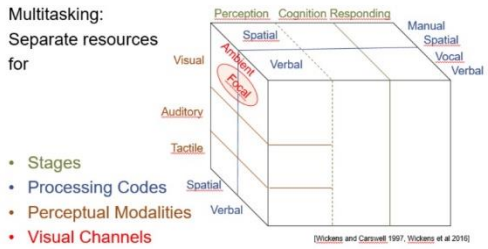
2.2 Situation Awareness

→ 2.3 Evaluating Cognitive Issues

2.3 Evaluating Cognitive Issues

Typical issues

- Mental load (cognitive load)
  - Exogenous demands (defined by the task being performed)
    - Task difficulty
    - Priority
    - Situational contingencies
  - Endogenous demands (attention and processing resources)
  - Resource allocation during different stages of processing
    - Stages
    - Processing codes
    - Modalities
    - Visual channels



2.3 Evaluating Cognitive Issues

Typical issues

- Human error
  - Lack of success in task performance
  - Examples:
    - Cognitive: long term / short term memory limitations
    - Physical: sensory / motor limitations
  - Strongly tied to our abilities and skills and depends on attention mechanisms

2.3 Evaluating Cognitive Issues

Evaluation methods

- Subjective measures
  - SBSOD (Santa Barbara Sense of Direction)
  - NASA TLX
- Performance measures
  - SAGAT (Situation Awareness Global Assessment Technique) (freeze online probe technique)
  - Drawing of maps after the tour
- Psycho-Physiological methods, measuring
  - Heart rate, pupil dilation, eye movements, brain activity(EEG)
  - (Emotional) stress and anxiety: galvanic skin response, heart rate, EEG

Thank you!