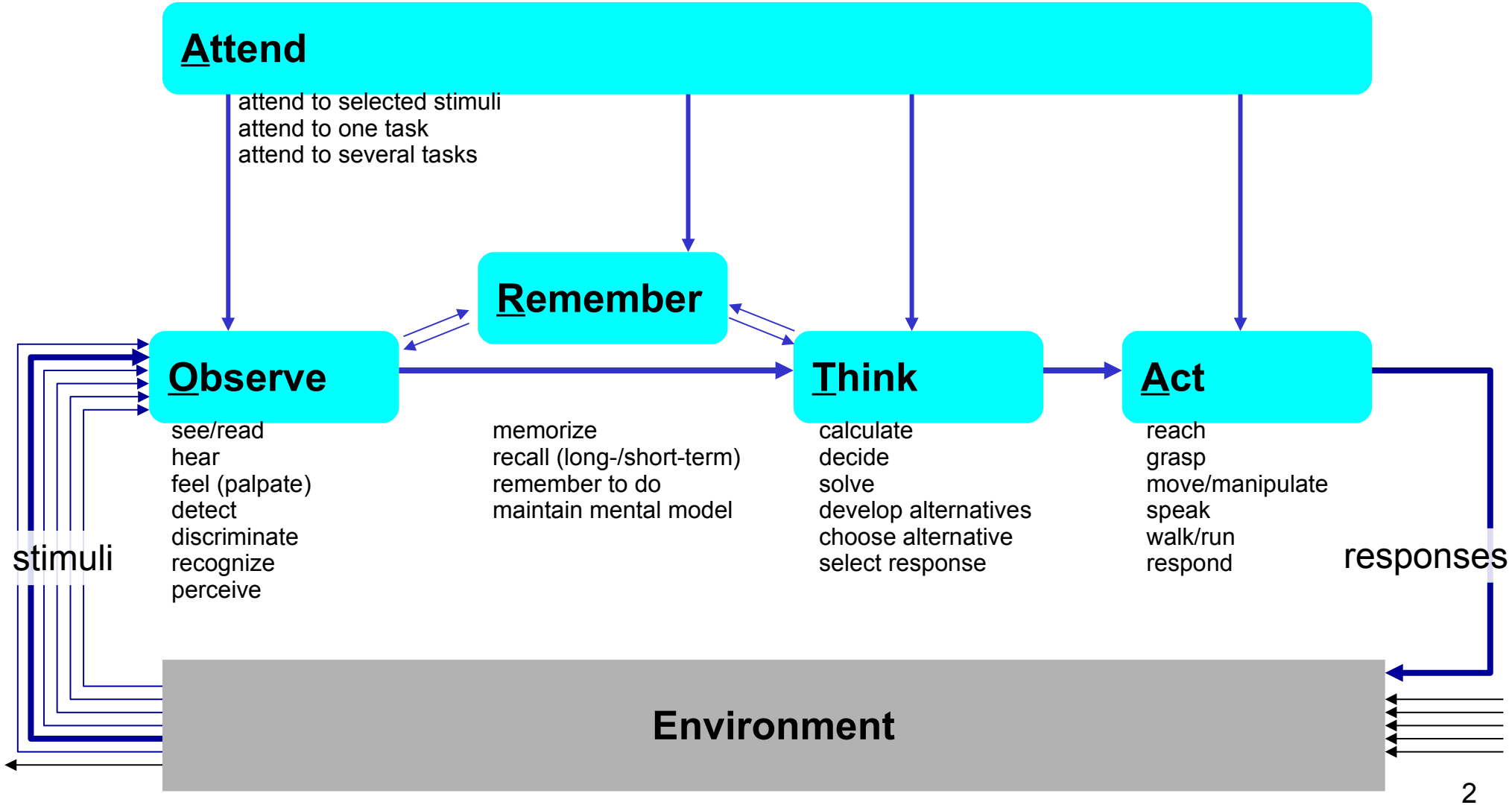
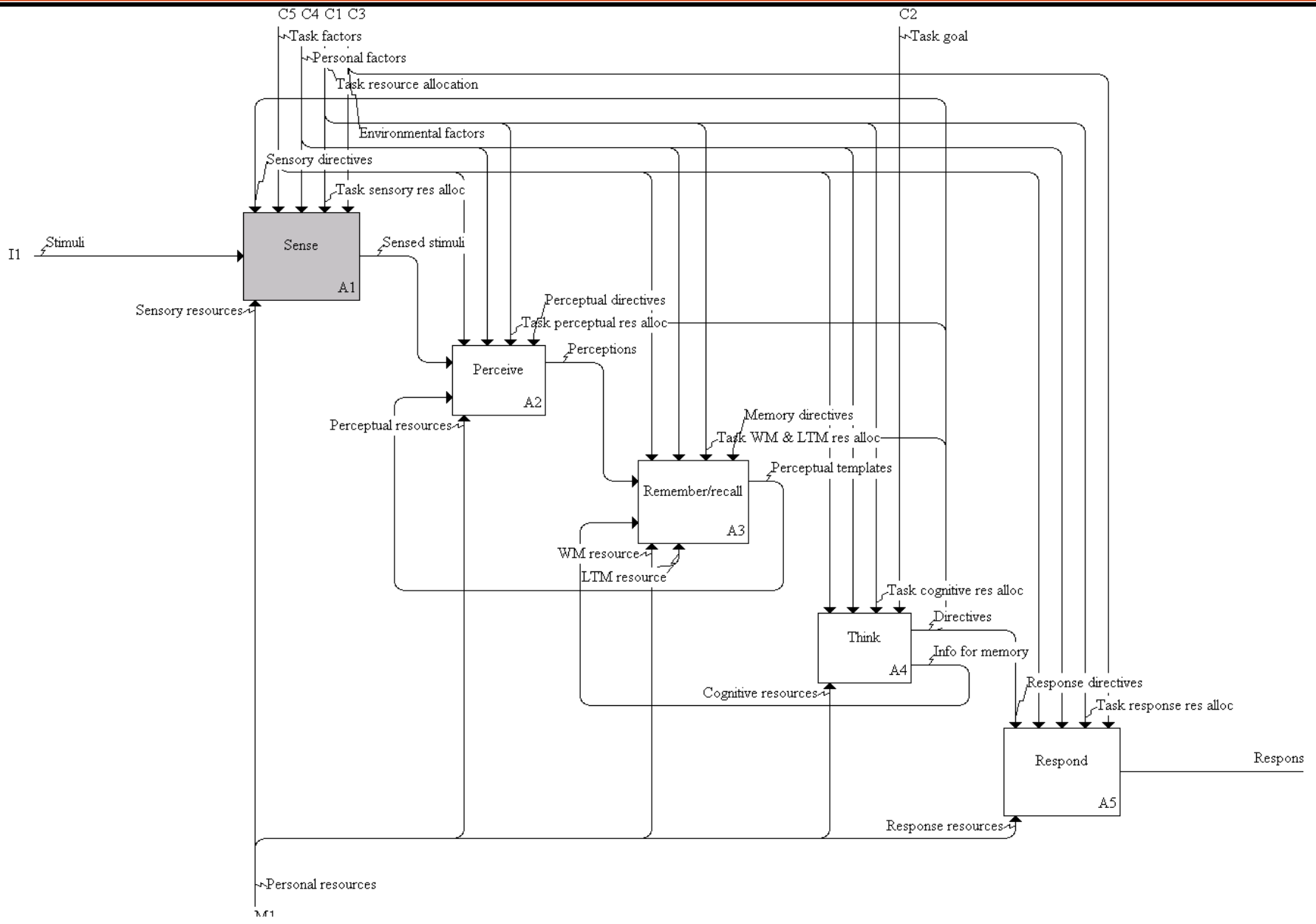
Cognition

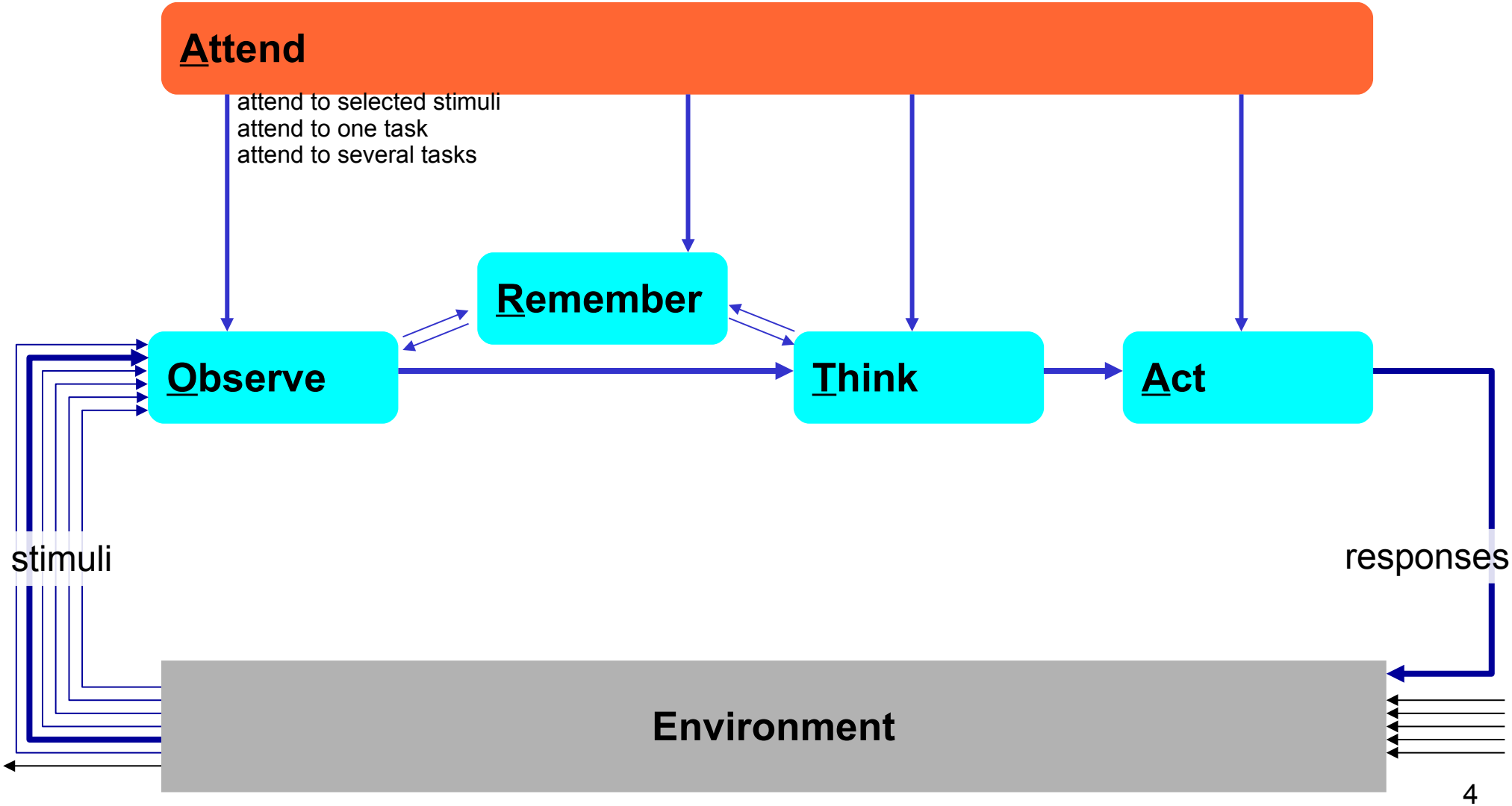
The AORTA (Stage) Model of Human Performance



IDEF0 Version of the Stage Model



Attend (Attention)



Attention

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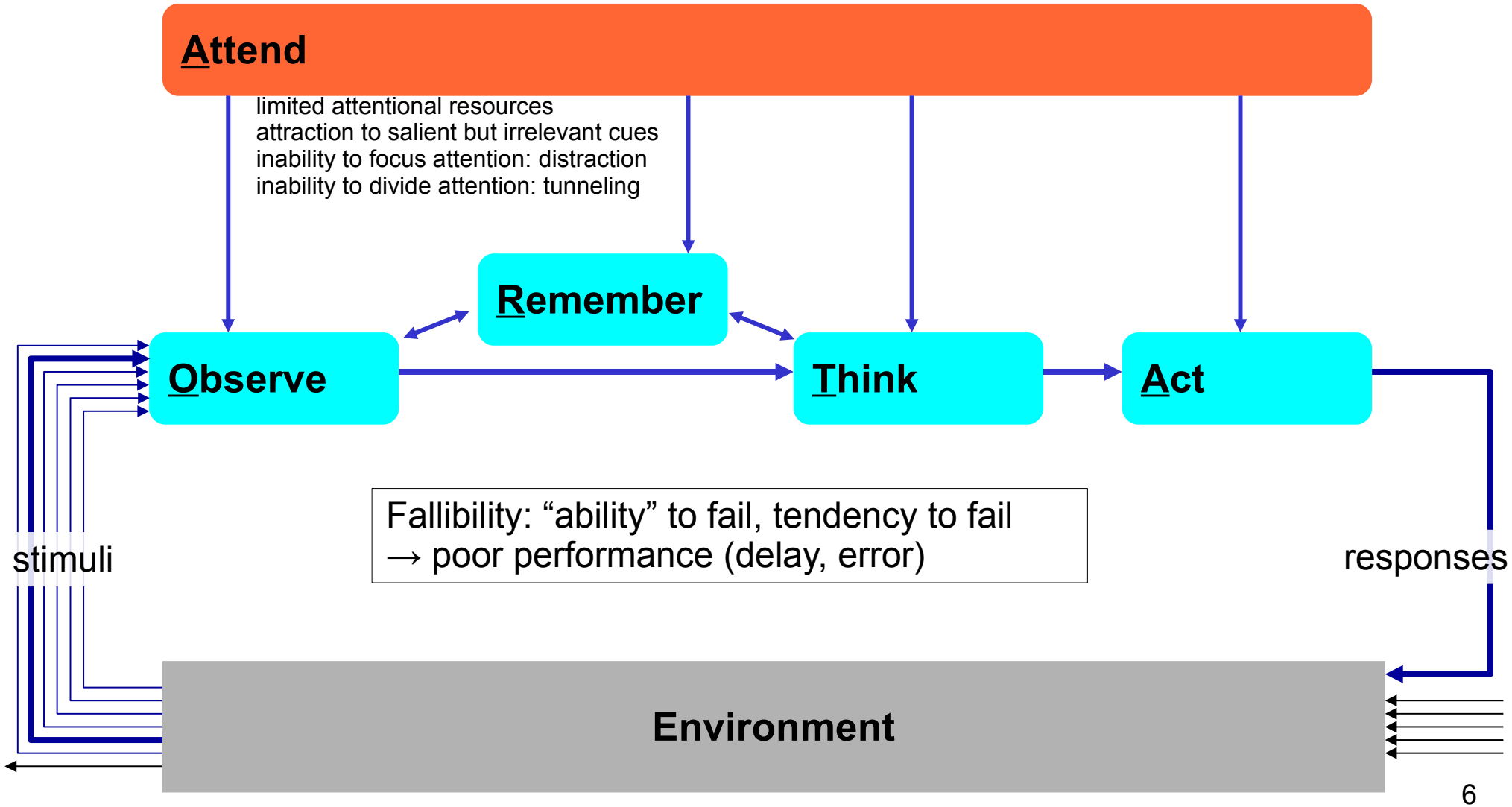
- Types of attention (flashlight metaphor)
  - Selective (aim point)
  - Focused (narrow beam)
  - Divided (wide beam)
- Factors influencing selective attention (SEEV theory/model)
  - Salience
  - Effort
  - Expectancy (where info is)
  - Perceived Value
- Attention in
  - perception: stimuli, information channels

    vs
  - multitasking: tasks

Some Common Human Attentional Fallibilities



Some Attentional Fallibilities and Countermeasures

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- Common Fallibilities
  - limited attentional resources
  - attraction to salient but irrelevant cues
  - inability to focus attention: distraction
  - inability to divide attention: tunneling (often stress-induced)
- Countermeasures
  - Avoid concurrent tasks (multitasking).
  - Limit distractions and interruptions*.
  - Control extraneous environmental stimuli.
  - Match stimulus salience to related task importance/urgency.
  - Reduce stressors (time, environmental, job-related) -- but not all!
  - Provide placeholder cues for complex procedures.
  - Identify critical periods of performance and prohibit distractions.
  - Train operators to be aware of these fallibilities.

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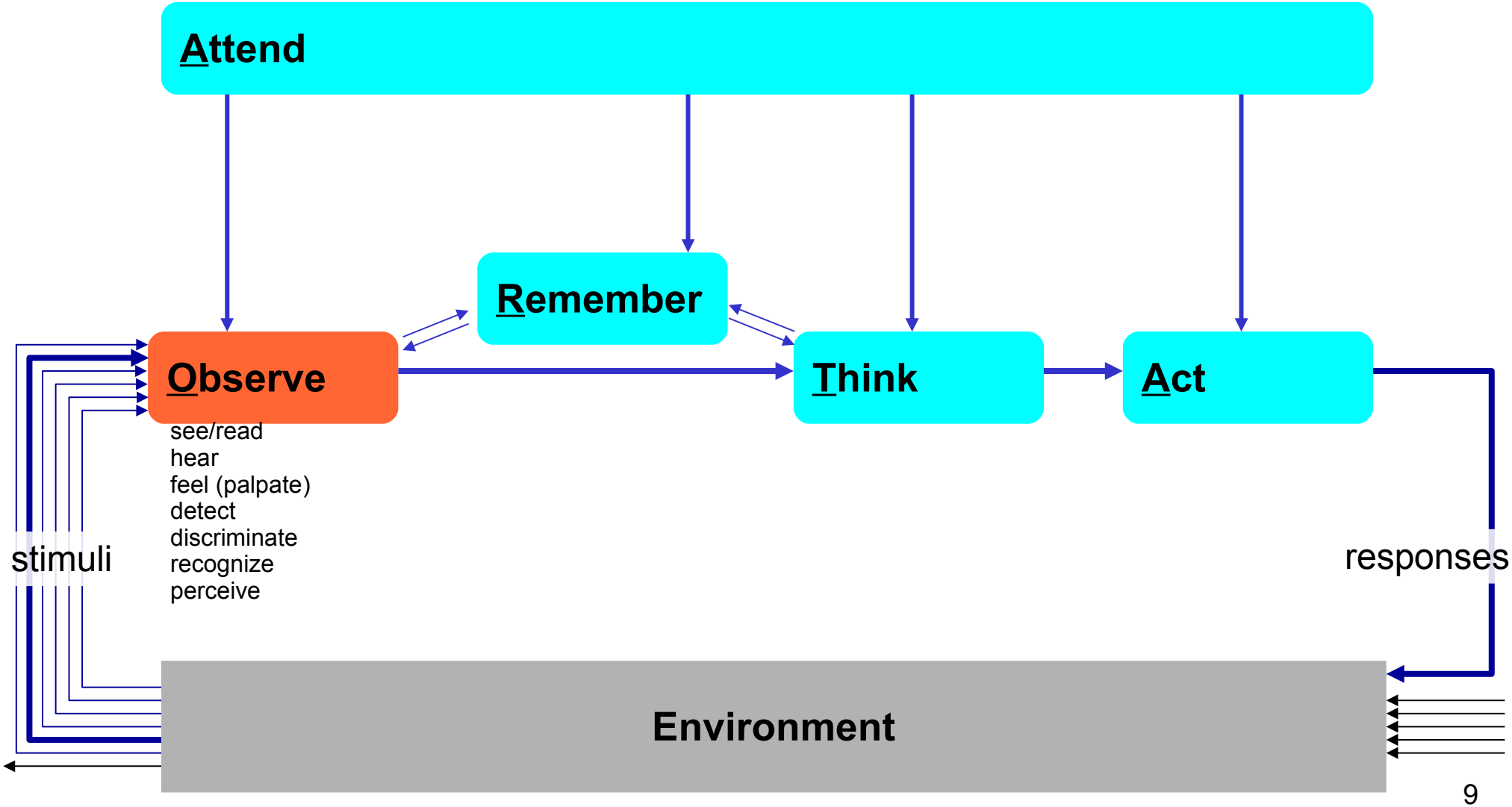
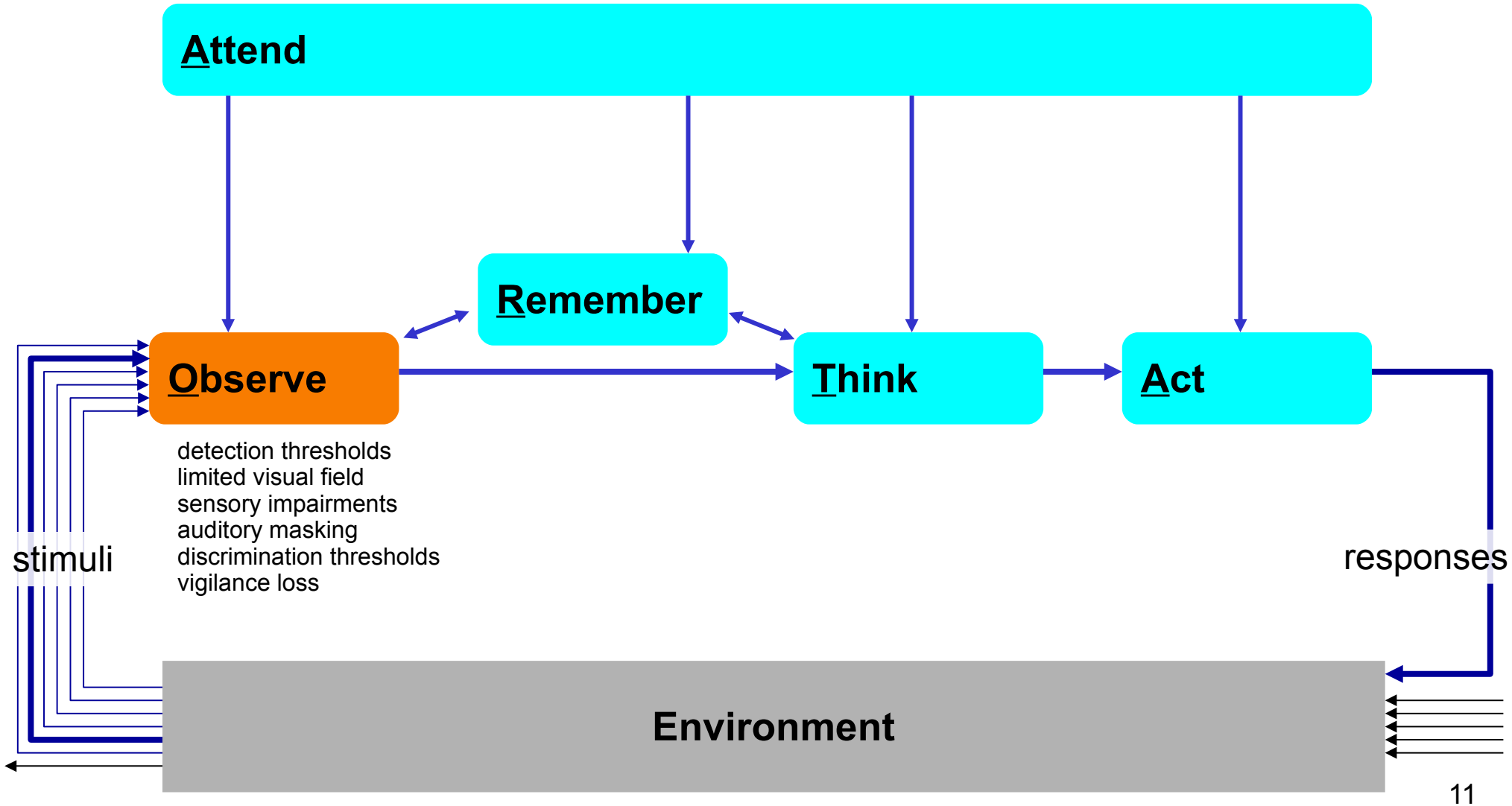
Observe
(Sensing + Perception)



Sensing and Perception

- Sensing (cf. Vision, Hearing and Other Senses)
  - Bottom-up processing
- Perception
  - Perceptual Process
    - Analysis
    - Unitization: recognition of patterns
    - Top-down processing: driven by expectations
  - HF Guidelines for Perception
    - Maximize bottom-up processing
    - Maximize automaticity & unitization
      - automaticity: familiar patterns
      - unitization: perception of commonly occurring combinations of features
    - Maximize top-down processing
      - Discriminable features, small vocabulary, context, redundancy, no illusions/confusions
  - Perception tends to be automatic (except when bottom-up processing is poor)

Some Common Human Sensing and Perceptual Fallibilities



Some Sensory and Perceptual Fallibilities and Countermeasures

- Common Fallibilities
  - detection thresholds
  - limited visual field
  - sensory impairments
  - auditory masking
  - discrimination thresholds
  - vigilance loss

- Countermeasures
  - Provide adequate level and quality of illumination.
  - Provide adequate contrast between stimulus and background.
  - Consider visual impairments (esp. presbyopia).
  - Reduce vibration.
  - Design sounds to be in sensitive frequency range (1,000 – 4,000 Hz).
  - Avoid masking by ambient noise and other sounds.
  - continued ...

Some Sensory and Perceptual Fallibilities and Countermeasures (2)

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- Common Fallibilities
  - detection thresholds
  - limited visual field
  - sensory impairments
  - auditory masking
  - discrimination thresholds
  - vigilance loss
- Countermeasures
  - Design displays well*.
    - Make displays legible (element size, color, discriminability, ...) or audible.
    - Facilitate redundancy gain.
    - Use discriminable elements.
    - Satisfy principle of pictorial realism.
    - Satisfy principle of the moving part.
    - Minimize information access cost.
    - Provide proximity compatibility.
    - Replace memory with visual information.
  - continued ...

Some Sensory and Perceptual Fallibilities and Countermeasures (2)

- Common Fallibilities
  - detection thresholds
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  - continued ...

Some Sensory and Perceptual Fallibilities and Countermeasures (3)

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- Common Fallibilities
  - detection thresholds
  - limited visual field
  - sensory impairments
  - auditory masking
  - discrimination thresholds
  - vigilance loss
- Countermeasures
  - Design auditory alarms* to be:
    - above background sound,
    - not masked by ambient noise,
    - below danger level,
    - not overly startling (longer rise time),
    - should not interfere with other signals,
    - Informative.
  - continued ...

Some Sensory and Perceptual Fallibilities and Countermeasures (3)

- Common Fallibilities
  - detection thresholds
  - limited visual field
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  - continued ...

Some Sensory and Perceptual Fallibilities and Countermeasures (4)

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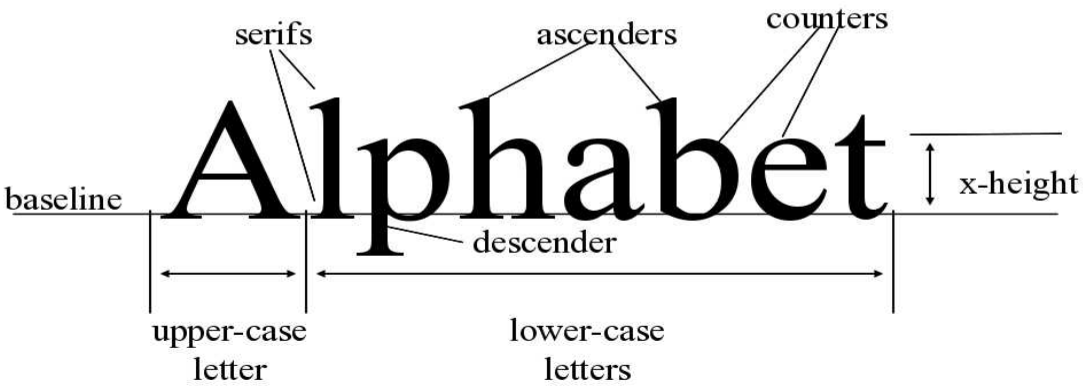
- Common Fallibilities
  - detection thresholds
  - limited visual field
  - sensory impairments
  - auditory masking
  - discrimination thresholds
  - vigilance loss
- Countermeasures
  - Design text well (typography)*.
    - Use sans-serif font (as opposed to serif font, like this).
    - Use mixed (upper/lower) case.
    - Use adequate font size (> 10 pt).
    - Provide spacing between lines ≥ 25 - 33% overall font size.
    - Use appropriate line length (single-column ~ 4 in, double-column ~ 3 in).
    - Avoid long passages in *italics*.
    - Use *font* **face** to emphasize, distinguish, but don't use too many.
    - Use dark characters over a light background.
    - Use color coding (highlighting) to emphasize (but not black over dark red, dark green, or dark blue)

Some Sensory and Perceptual Fallibilities and Countermeasures (4)

- Common Fallibilities
  - detection thresholds
  - limited visual field
  - sensory impairments
  - auditory masking
  - discrimination thresholds
  - vigilance loss



- Countermeasures
  - Design text well (typography)*.
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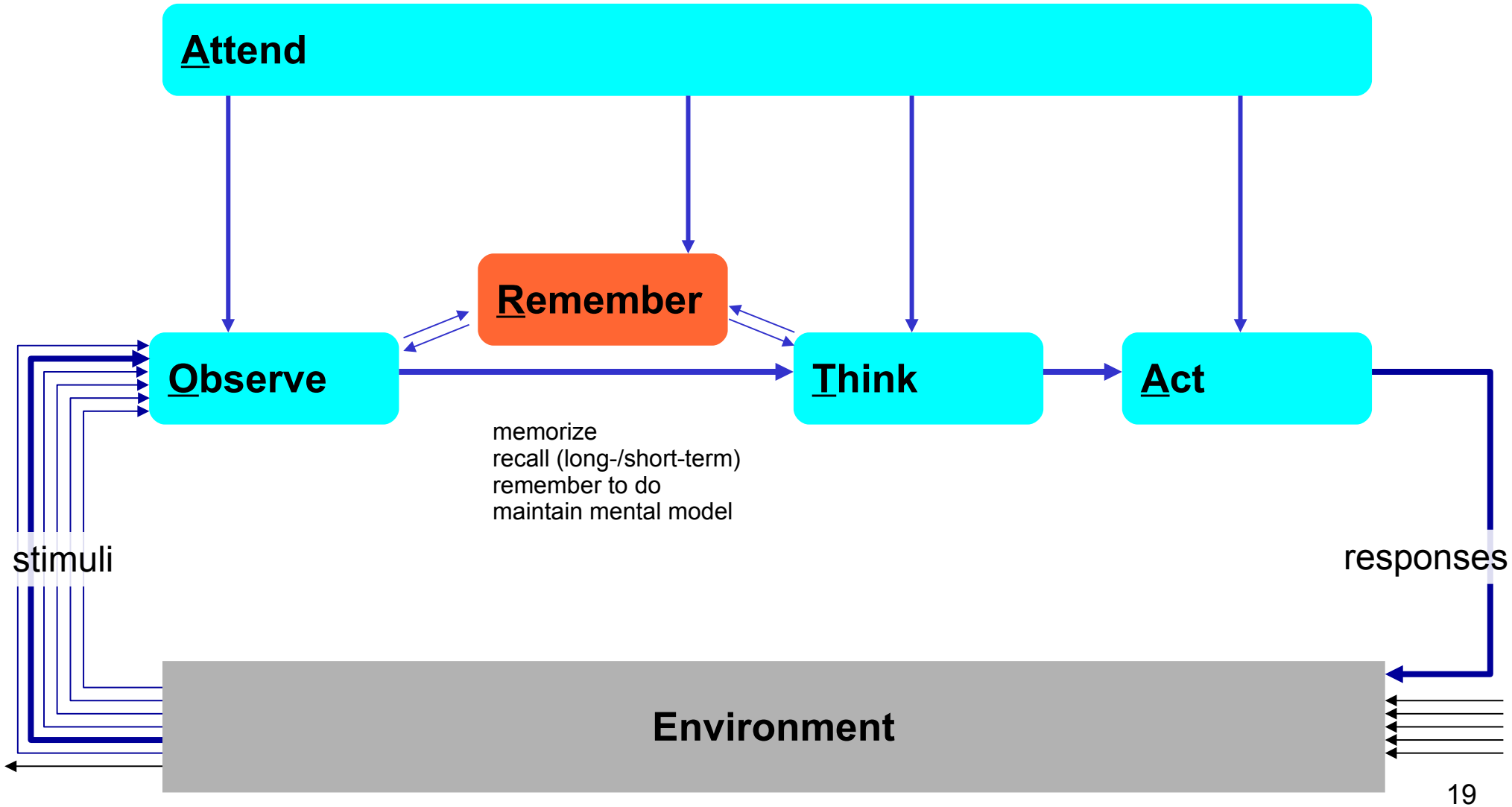
Remember
(Working Memory + Long Term Memory)



Working Memory

- WM Components
  - Central executive: attentional control & coordination
  - Visio-spatial sketchpad
  - Phonological loop
- WM Limits
  - 7 ± 2 chunks
  - < 20 sec (7 sec ½-life for 3 chunks, 70 sec for 1 chunk)
  - Maintenance rehearsal
  - Confusability, similarity reduce performance

Long Term Memory

- Types of LTM
  - Semantic memory
    - Declarative knowledge (facts)
    - Procedural knowledge (procedures)
  - Event memory (episodic memory)
- Basic Mechanisms
  - Features of knowledge in LTM
    - Strength = f(frequency, recency)
    - Associations (links)
  - WM vs LTM
    - WM as area of activation
    - Role of WM in learning, forming associations
  - Forgetting
    - Low strength
    - weak/few associations
    - Interfering associations

Long Term Memory (continued)

- LTM Organization
  - Associative/semantic network (e.g., Forward Observer's knowledge about targeting devices – see next)
    - Schemas: prototypical memory structures
    - Scripts: “typical” activity/event sequences (e.g., restaurant script)
    - Mental model: mental “simulation”
    - Cognitive maps (spatial information, e.g., my “map” of Albany)
- Episodic memory for events (see p. 139 ff)
- Prospective memory: remembering what to do
- Situation Awareness
  - Level I: awareness of objects in environment
  - Level II: comprehension, understanding
  - Level III: prediction of future situation
  - Measurement (e.g., SAGAT = SA Global Assessment Technique)

LTM As Associative Network:

Part of a Forward Observer's knowledge of targeting devices

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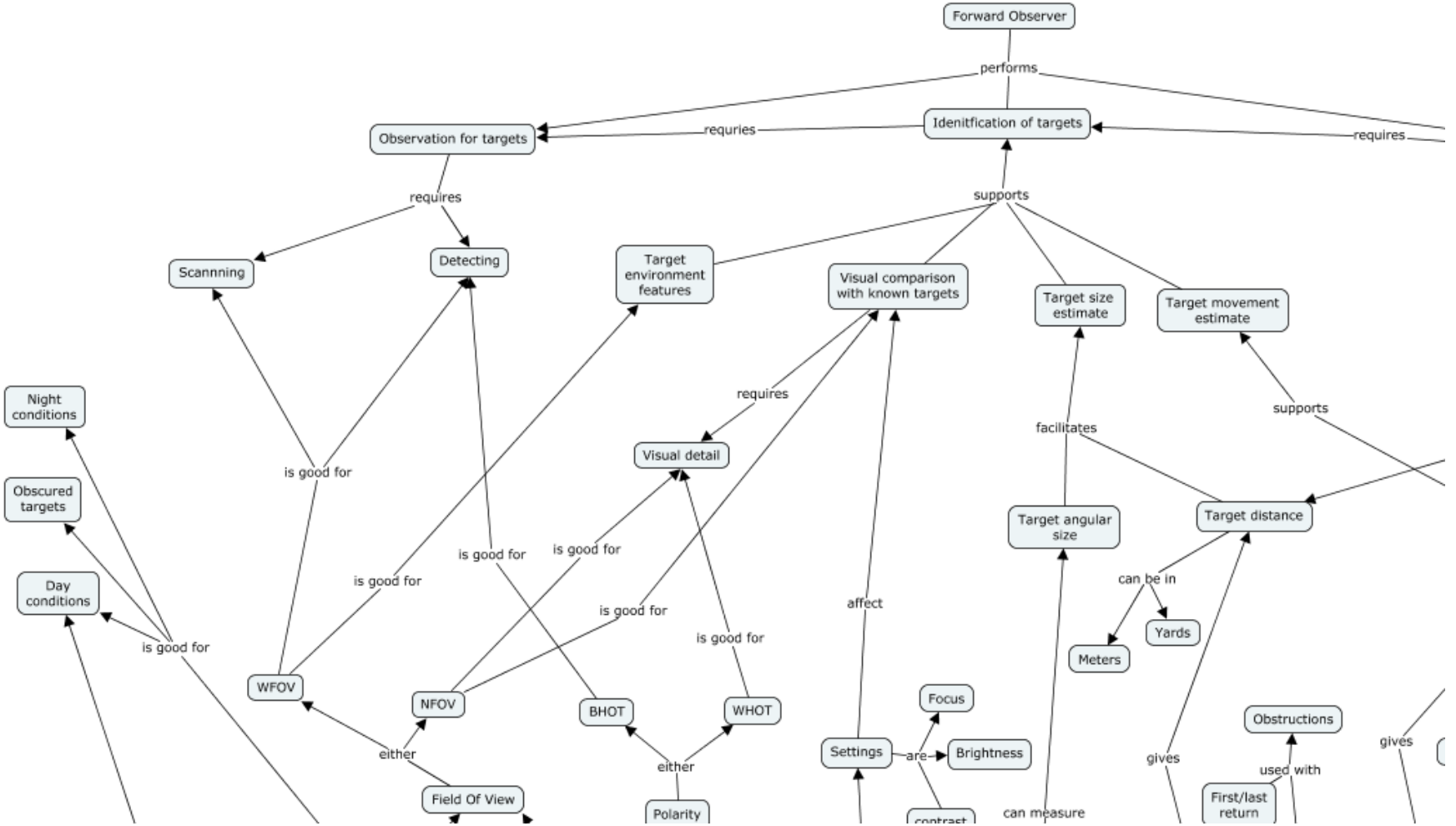
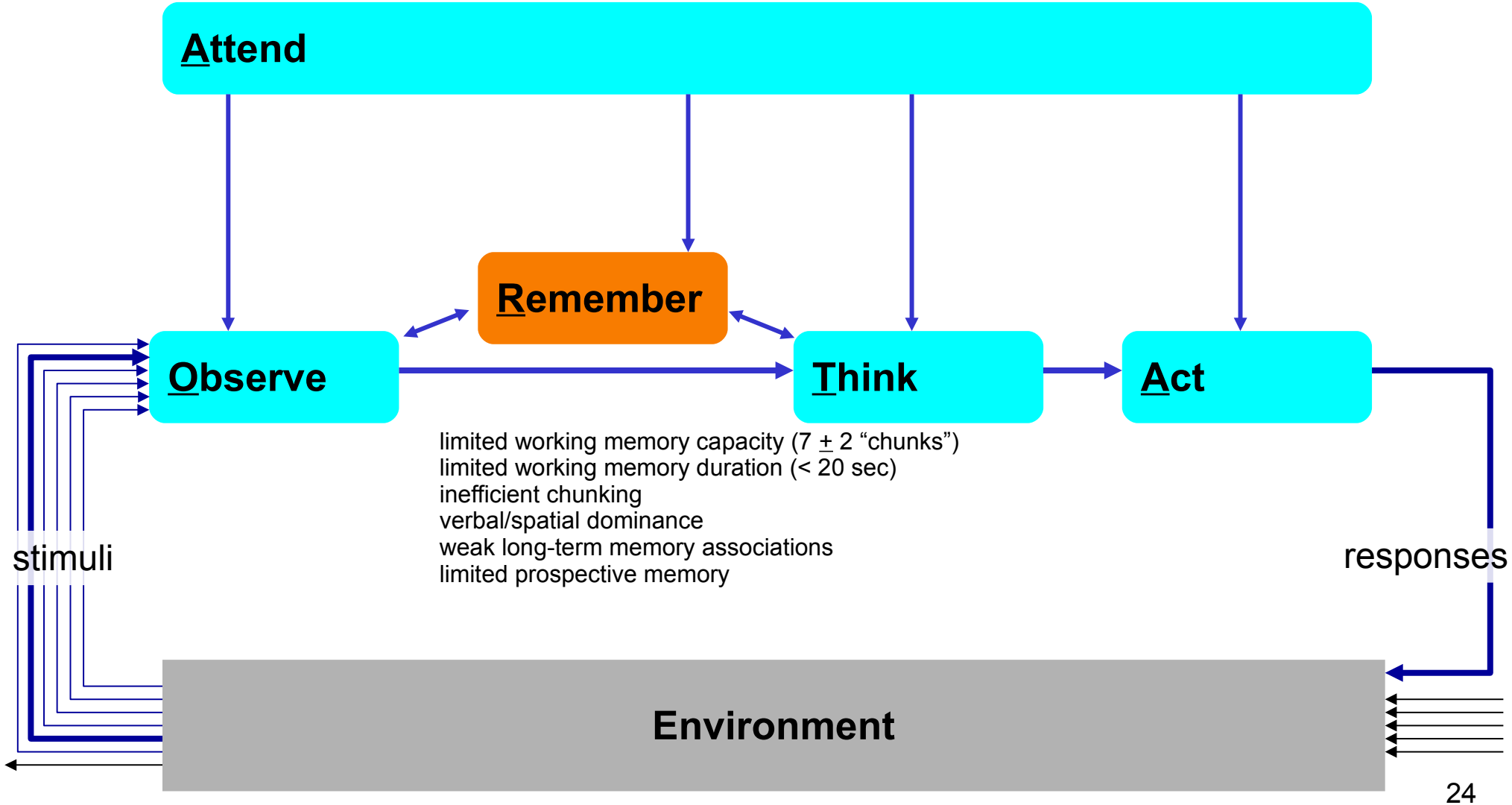


Some Common Human Memory Fallibilities



Some Memory Fallibilities and Countermeasures

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- Common Fallibilities
  - limited working memory capacity (7 + 2 “chunks”)
  - limited working memory duration (< 20 sec)
  - inefficient chunking
  - verbal/spatial dominance
  - weak long-term memory associations
  - limited prospective memory
- Countermeasures (Working Memory)
  - Minimize working memory load.
  - Provide placeholders for sequential tasks.
  - Provide other mnemonics*.
  - Exploit chunking.
    - 3-4 characters/chunk (e.g., 1-541-737-2357)
    - Meaningful sequences (e.g., SFO)
    - Letters > digits
    - Digits separate from letters (PQG 929 vs P9Q2G9)
  - Minimize confusability (e.g., 7-2357 [Funk] vs 7-5237 [Helvie])

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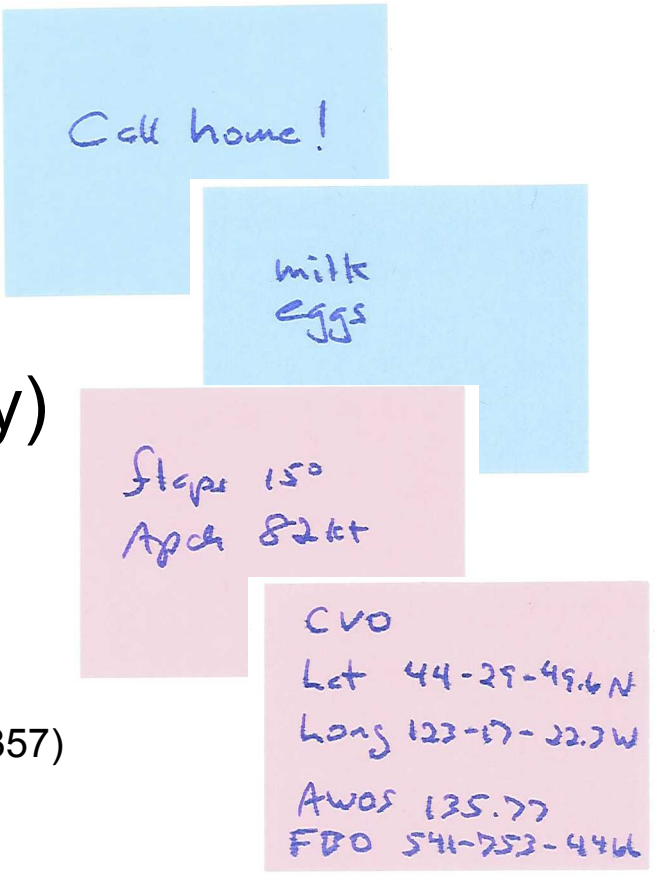

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- Countermeasures (Long Term Memory)
  - Encourage regular use (↑ frequency, ↑ recency)
  - Encourage active verbalization or active reproduction (repeat, take notes, etc.)
  - Standardize
  - Use memory aids (e.g., GUMPS*)
  - Design information to be remembered:
    - Meaningful
    - Distinctive
    - Well organized
    - "Guessable"
    - Little technical jargon

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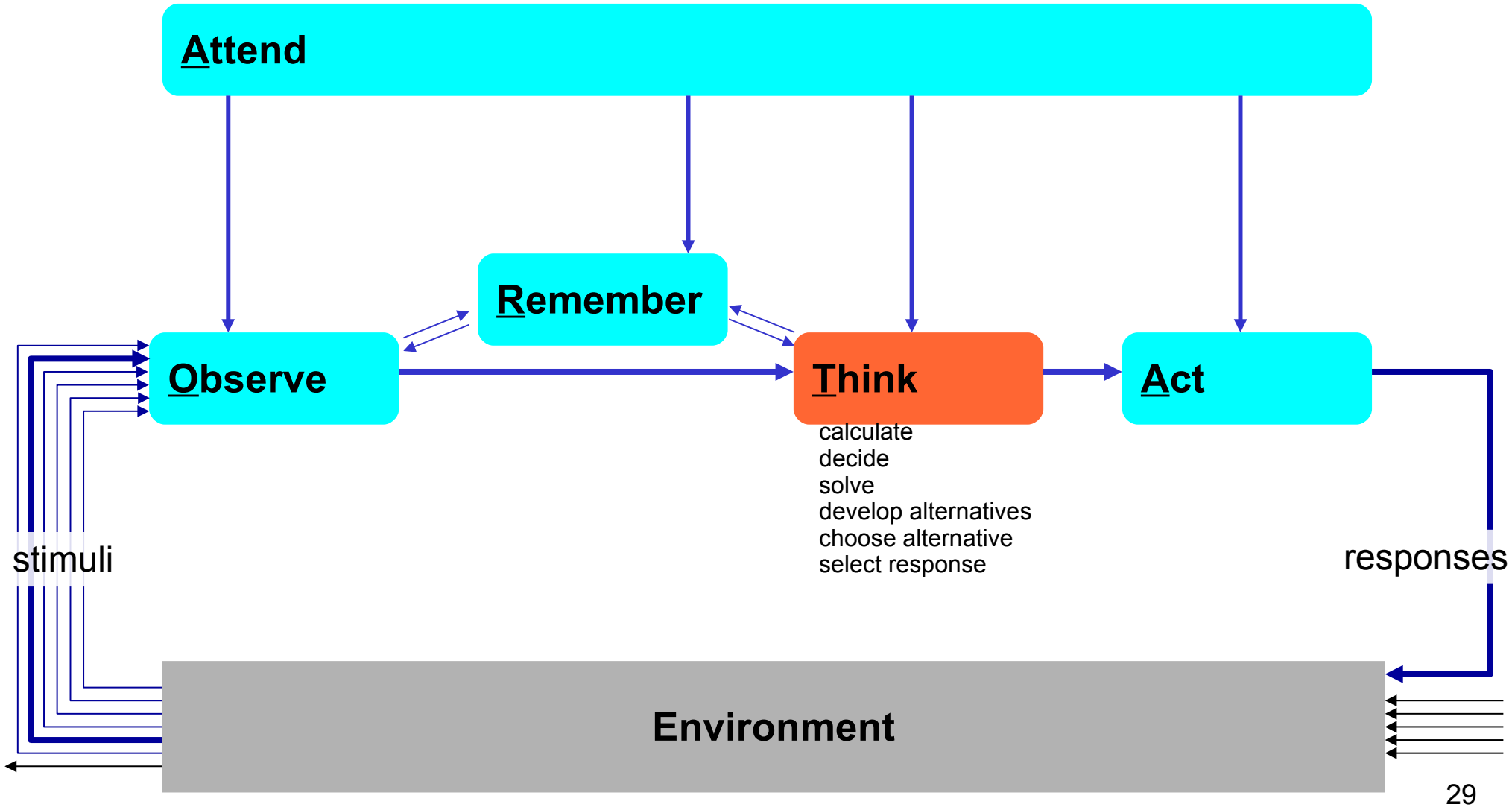
Photo by P Miller <pmiller@nkn.net> ,
downloaded 15 Oct 2010 from http://www.tomzap.com/plane.html.

Gas
Undercarriage
Mixture
Prop(s)
Systems

Also
Undercarriage
Speed
Trim
Airbrakes (glider)
Look
Landing

Think

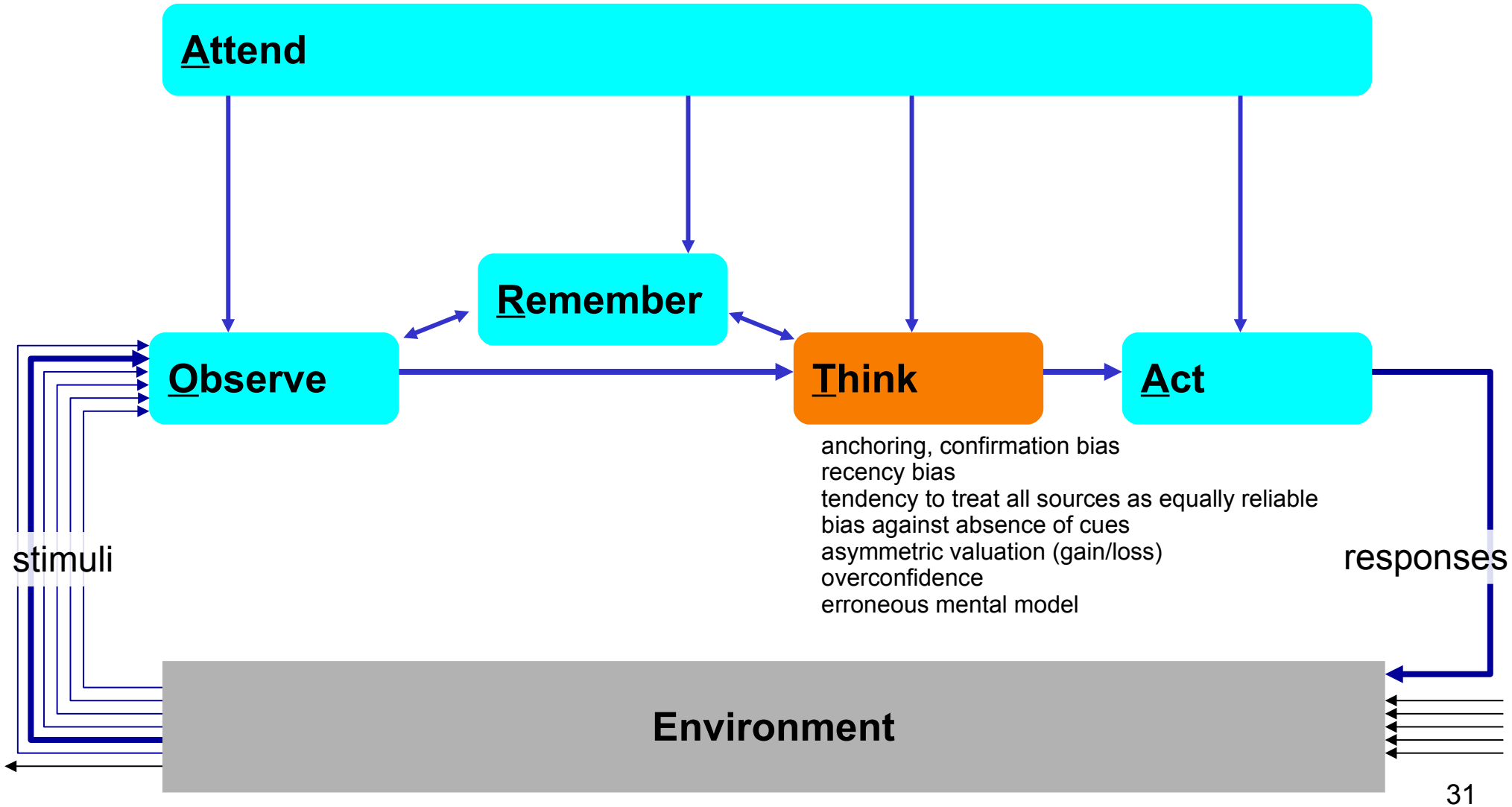
(Decision Making, Problem Solving, Trouble-shooting, ...)



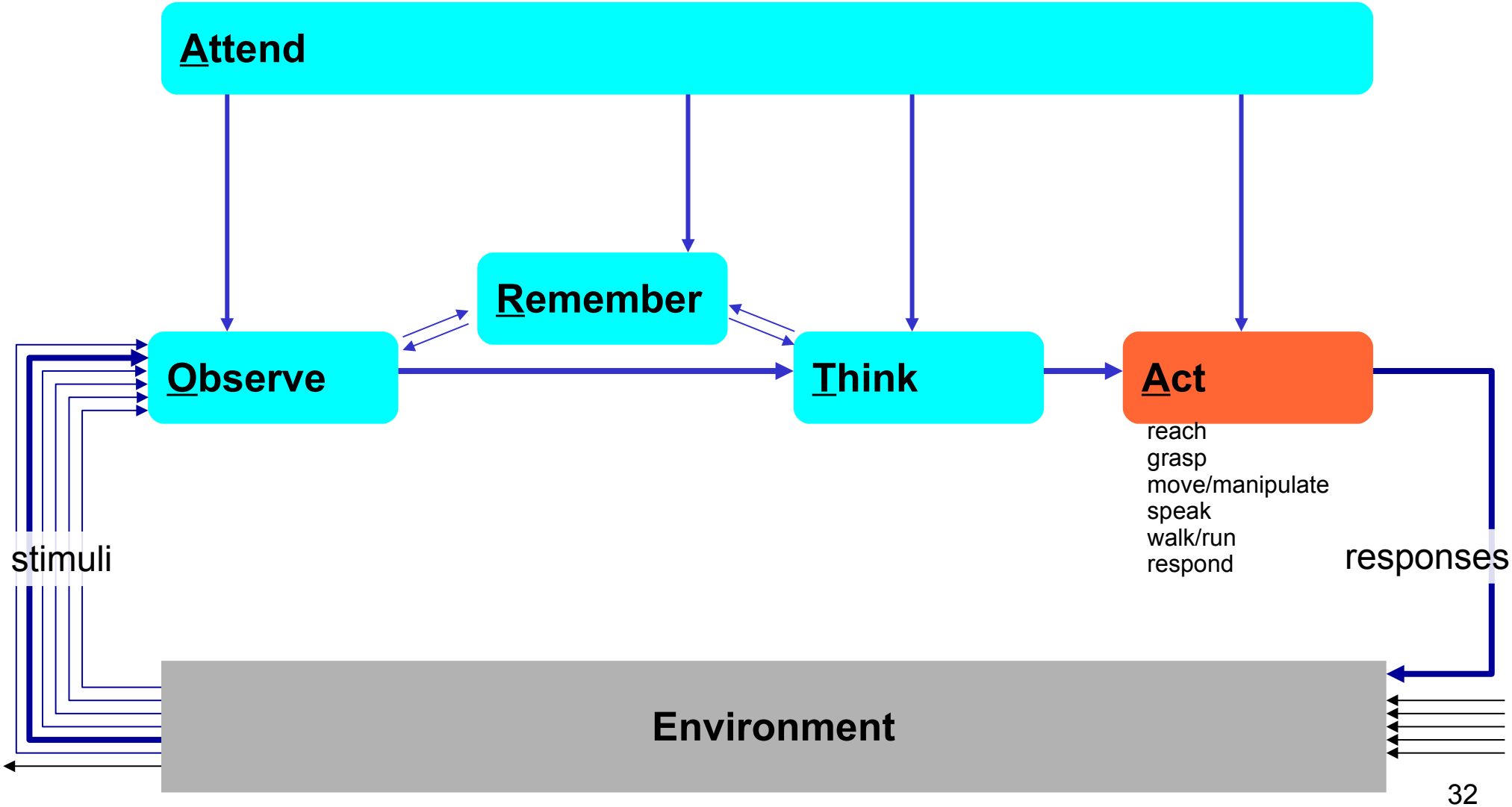
Decision Making, Problem Solving, Troubleshooting, etc.

- Decision Making
  - Formulate decision problem
  - Generate alternatives
  - Eliminate alternatives
  - Evaluate alternatives
  - Choose final alternative
- Problem solving: initial state → goal state
- Troubleshooting: diagnosis
- Planning and scheduling
  - Command state, predicted state
  - Mental simulation (mental model)
  - Plan continuation error

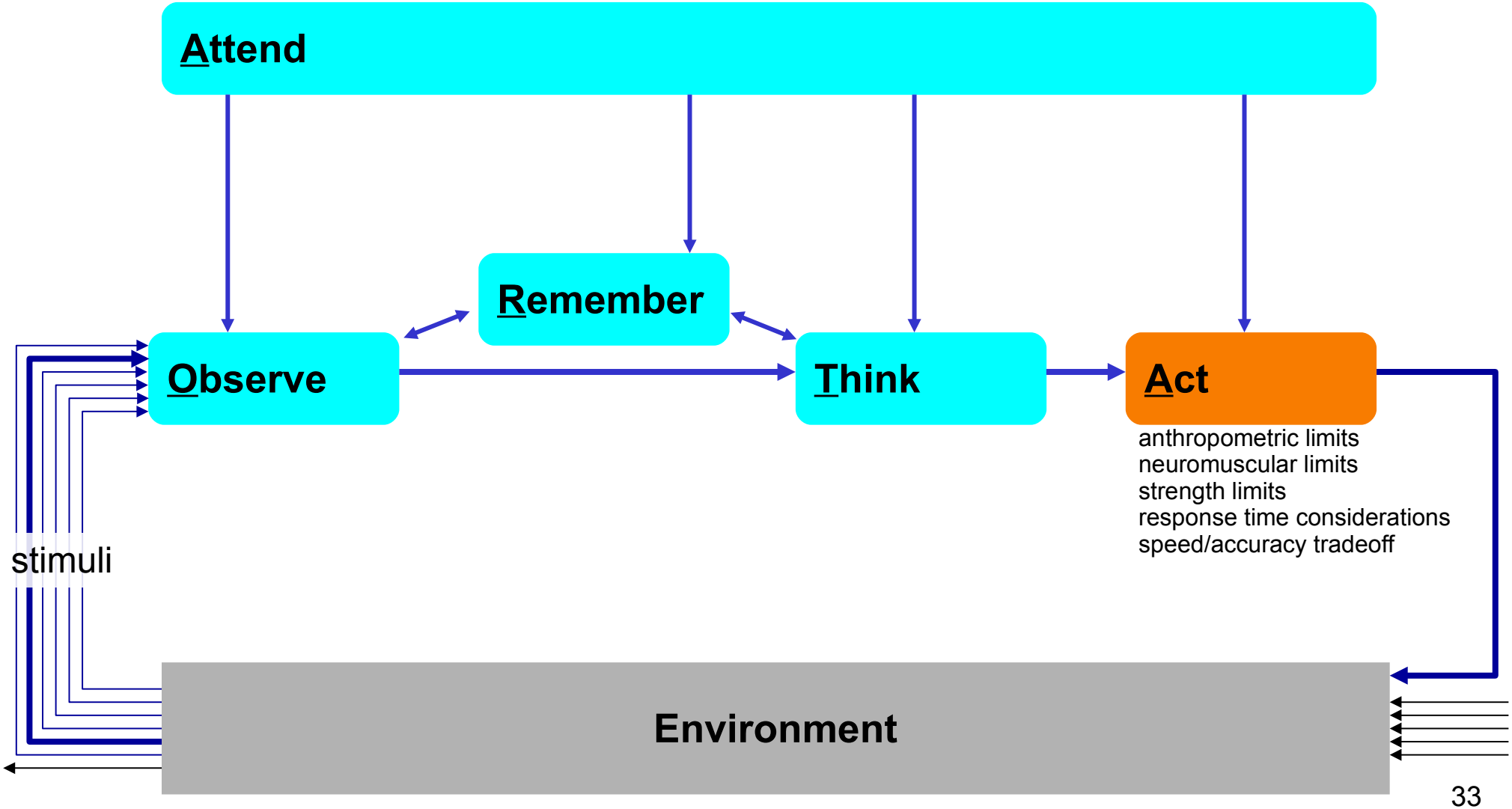
Some Common Human Decision Making,..., Fallibilities



Act (Response)



Some Common Human Response Fallibilities



Some Action Fallibilities and Countermeasures

- Common Fallibilities
  - anthropometric limits
  - neuromuscular limits
  - strength limits
  - response time considerations
  - speed/accuracy tradeoff
- Countermeasures
  - Select/design controls for good performance.
    - Use discrete/continuous controls appropriately.
    - Use multi-rotation controls for precise settings, long ranges.
    - Design for movement compatibility (e.g, up/right/CW + down/left/CCW -).
    - Design controls to be easily identified (location, shape, color, type).
    - Do not overburden any one limb.
    - Combine functionally related controls.
    - Consider the least capable user WRT force, speed, accuracy, geometry.
    - Design for natural movement.
    - Keep control movements short.
    - Design for feedback.
    - Design control surfaces to prevent slipping.
    - Provide enough resistance to prevent inadvertent activation.

Some Action Fallibilities and Countermeasures (2)

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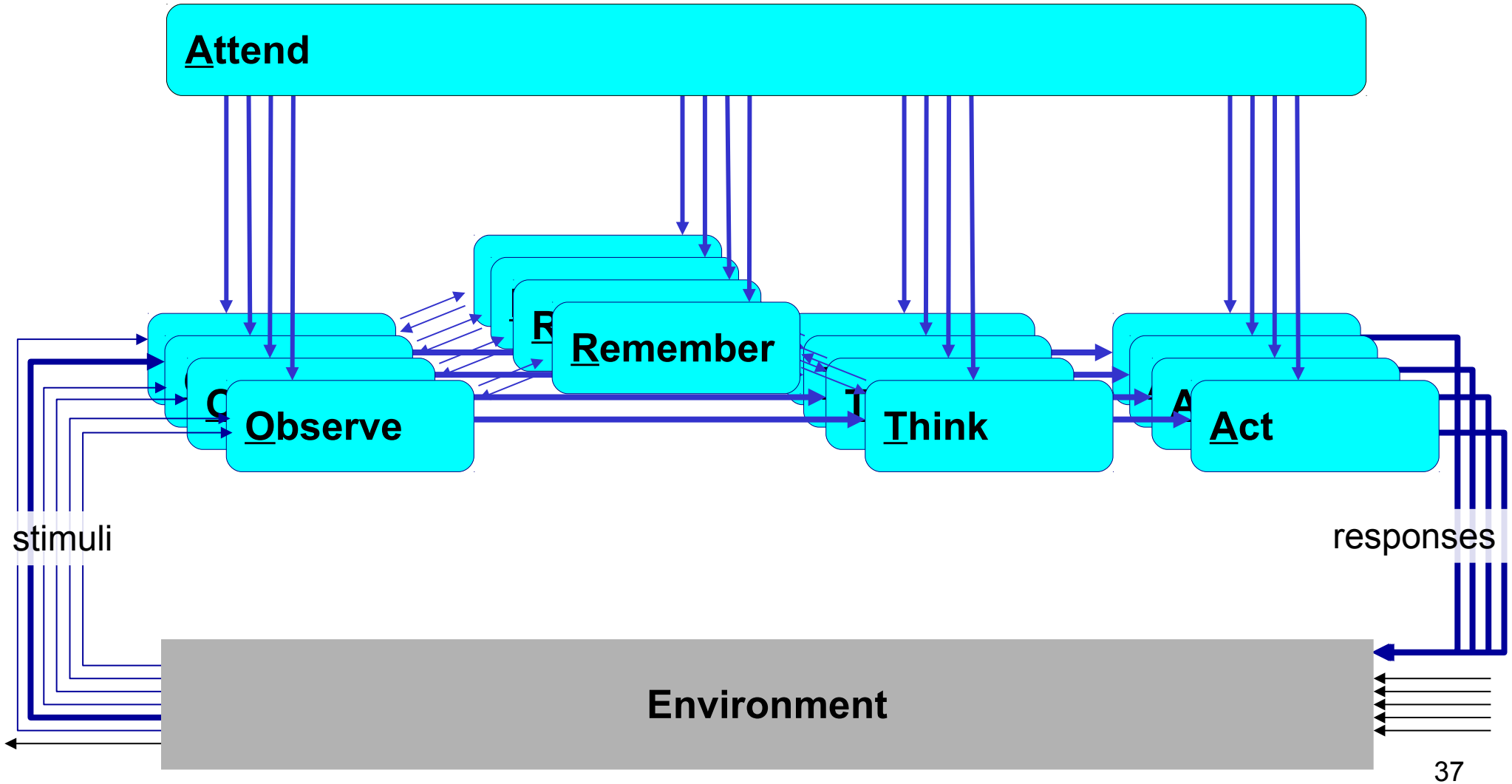
- Common Fallibilities
  - anthropometric limits
  - neuromuscular limits
  - strength limits
  - response time considerations
  - speed/accuracy tradeoff
- Countermeasures
  - Design workstations for:
    - visibility outside workstation (if appropriate)
    - visibility inside workstation (displays, controls, etc.)
    - accessibility of controls, tools (“let the small person reach”)
    - body member support (arm/foot rests, etc.)
    - body member clearance (“let the large person fit”)
    - clearance for clothing & personal equipment
    - restraint (if appropriate)
    - protection from injury
    - ease, speed, safety of entry & exit
    - consistency throughout

Metacognition

- Knowledge about knowledge, thinking about thinking
- Attention and timesharing (attention revisited)
  - Selective, focused, divided attention
- Mental effort and resource demand
  - Automatic vs control processing
  - Resource demand
  - Structural similarity
- Task/Attention management
  - Distractions, interruptions
  - “in-situ” distractions, interruptions
  - Task/Attention Management factors
    - Task importance
    - Task status
    - Task urgency
    - Salience of task-related stimuli

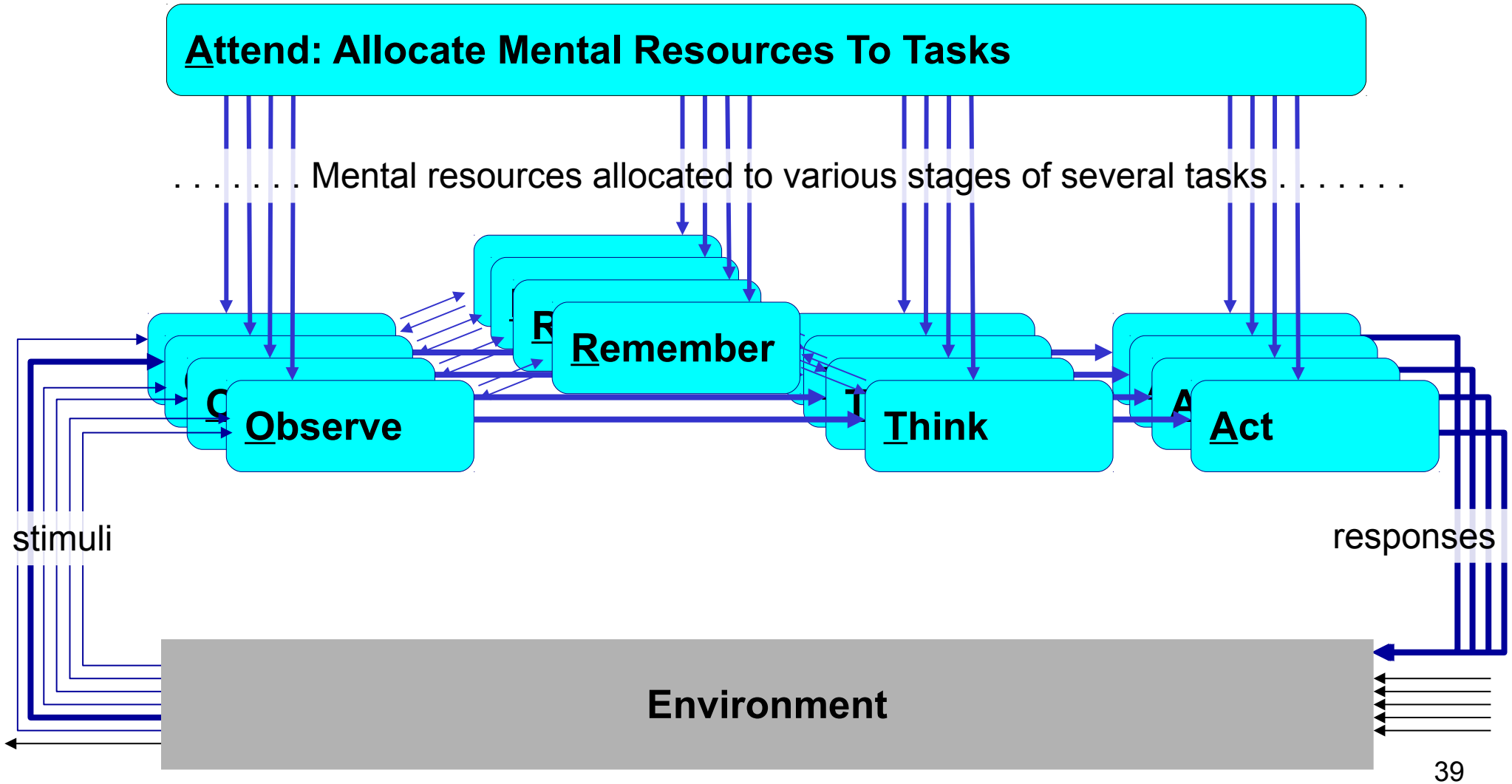
Attention In Multitasking



Attention In Multitasking

- Examples of multitasking
  - driver
  - pilot
  - etc.
- Challenges in multitasking (fallibilities)
  - distractions
  - interruptions
  - reduced performance
- Problems with multitasking: misallocation of attention
  - Driving while talking on cell phone about as risky as driving drunk.
  - 3,154 killed and 424,000 injured in motor vehicle crashes involving distracted drivers in 2013 in US.
  - OSU study of 324 aircraft accident reports: 80 attention errors in 76 (23%) of the accidents.
  - OSU/OHSU surgical simulator study: 8 out of 18 surgeons committed errors when distracted versus 1 out of 18 when not distracted.

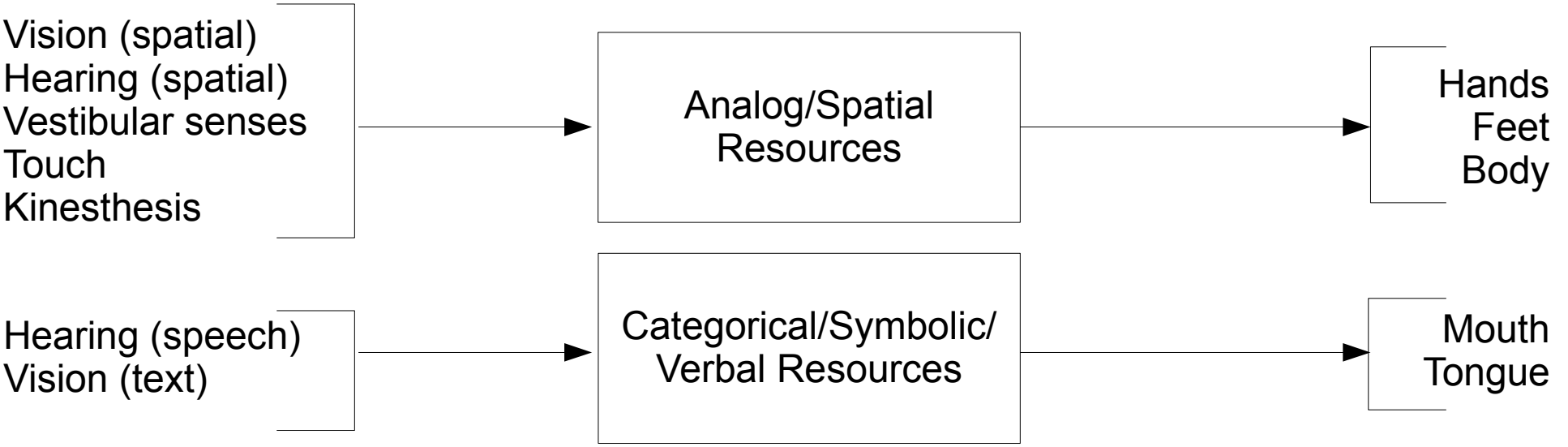
Attention As Resource Allocation



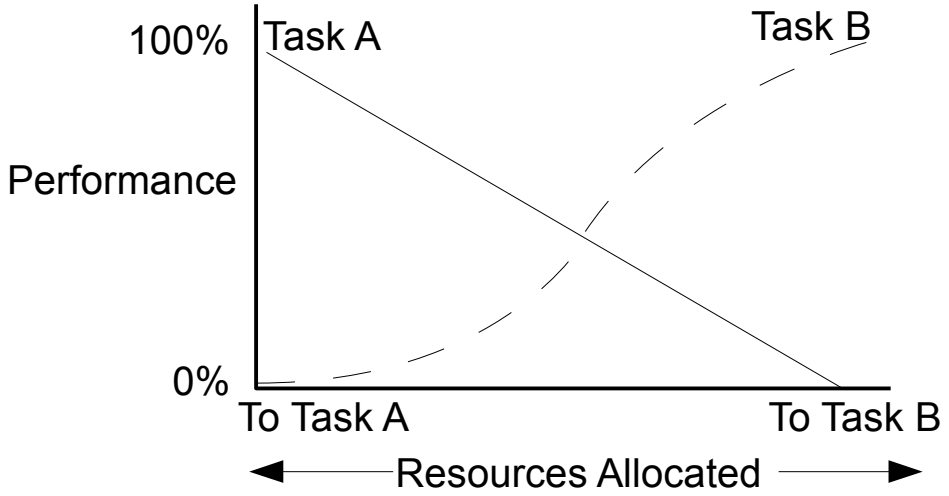
Mental Resources
Multiple Resource Theory (Wickens, 1984)

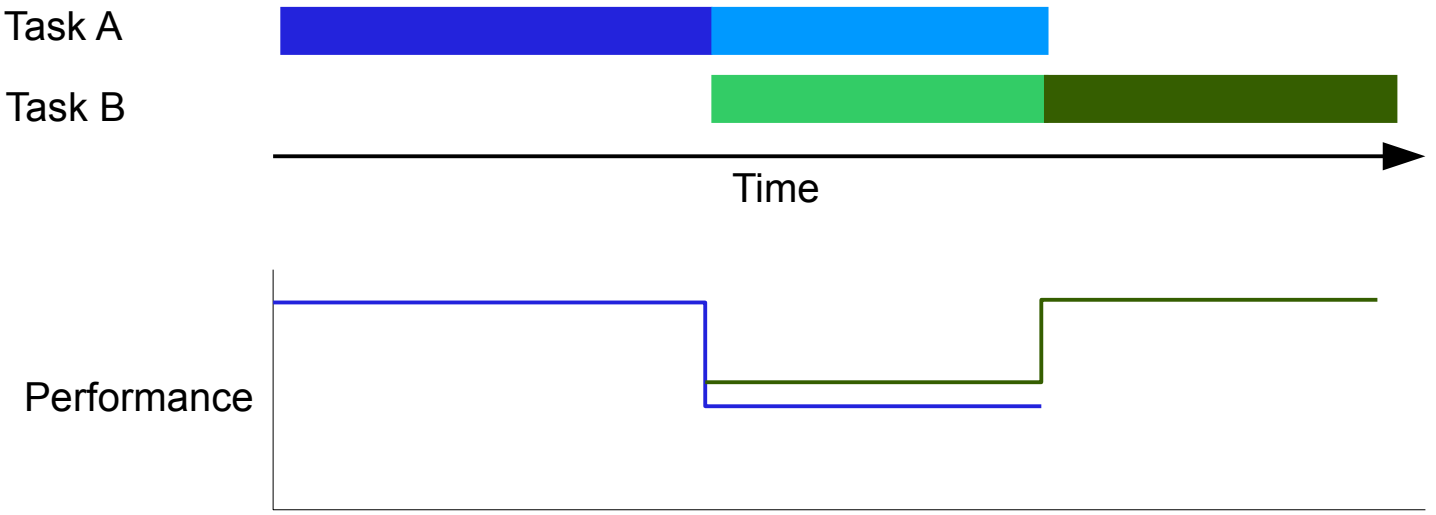
Sensing & Perception → **Central Processing** → **Responding**

Sensing & Perception	Central Processing	Responding
(AORTA Observe)	(AORTA Remember & Think)	(AORTA Act)
Sensory Modalities	Mental Resources	"Effectors"

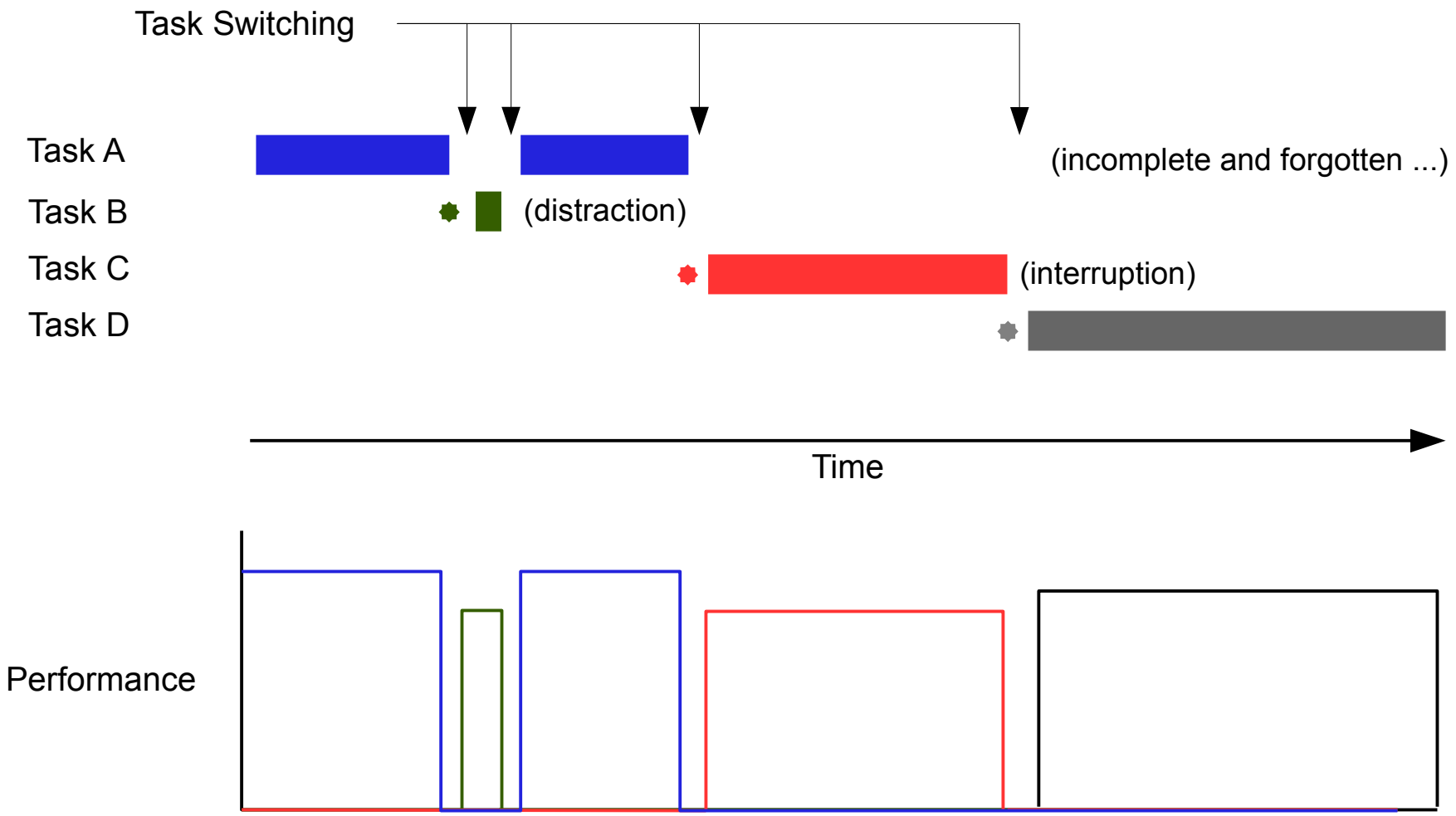


Concurrent Multitasking





Sequential Multitasking



Countermeasures for Poor Multitasking

- Minimize multitasking
  - eliminate unnecessary tasks
  - shift secondary tasks to lower workload periods
  - declare no-distraction periods
  - reduce job scope
- Additional crew-members
- To-Do Lists / Checklists with placeholders
- Task displays salient in proportion to task priority (importance x status x urgency)
- Train primary tasks to proficiency to promote efficient timesharing
- Train operators to manage tasks properly
- Select operators with innate multitasking ability