Attention and Workload

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Lecture 18

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Overview

- Information processing & memory
- Attention
  - What is attention and how do we study it?
  - Models of attention
  - Auditory and visual attention demos
  - Control of attention
  - Multi-tasking and distributed attention
  - Design considerations for attention
- Mental workload
- Wrap-up of recent lectures

Human Information Processing

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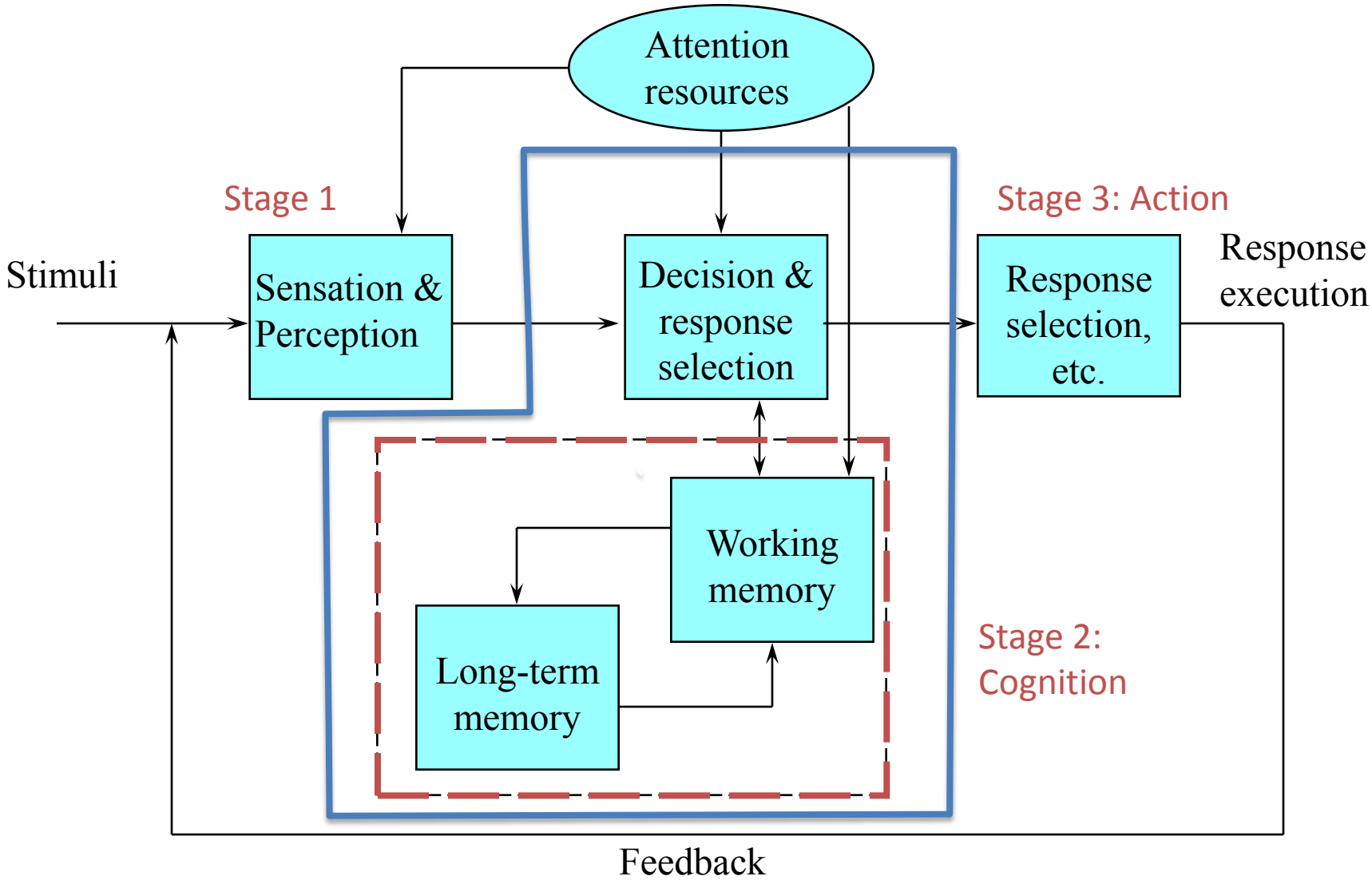

Short-term Memory

- From PV Chapter 10 (not assigned)
- Sensory storage < 1 second
  - Iconic and echoic memory traces
  - Pre-attentive, automatic
- Short-term/Working Memory
  - Verbal & spatial info
    - phonetic loop/visuo-spatial sketchpad
  - Limited by capacity, duration, similarity, attention
    - 7 ± 2 perceptual chunks
    - Info decays over time unless rehearsed
    - Vulnerable to distraction in same modality

Long-Term Memory

- Semantic (general knowledge)
- Knowledge gained through learning and structure
  - Associative networks (activation)
  - Schemas, mental models, cognitive maps
  - Deep processing
  - Frequency and recency
- "Forgetting" occurs due to lack of the above, or interference
- Recall versus recognition
  - Which is harder? Recall

What is Attention?

- Attention is associated with “consciousness” and “awareness”
  - As opposed to “automaticity” or “automatic processing”
- Attention “connects” perception and cognition
  - It is an “executive” function used to select specific information of interest from a busy environment
  - It can also be used to take in a lot of general information at one time from across the environment
- We use metaphors to model attention
  - Filter, bottleneck, spotlight, (limited) resource
- Some words to describe attention
  - Focused, selective, divided, distributed

Studying Attention

- Attention can be studied using different perceptual stimuli and tasks
  - Initially studied auditory tasks, then visual tasks, then multi-modal tasks
- Recent studies in attention use functional MRI (fMRI) to see what areas of the brain are active during the task
  - Attention involves multiple areas of the brain (varies based on task)
  - Damage to parietal lobe is associated with clinical attention deficits

Bottleneck (Filter) Models of Attention

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- Selective attention tasks (typically auditory)
- Where exactly is the bottle neck (early or late) in information processing?
  - Broadbent's filter theory (early)
  - Treisman's filter attenuation theory (late)
  - Deutsch & Deutsch (late)
- Is the bottleneck a structural limitation (bug) or a strategy (feature)?

Selection Attention Models

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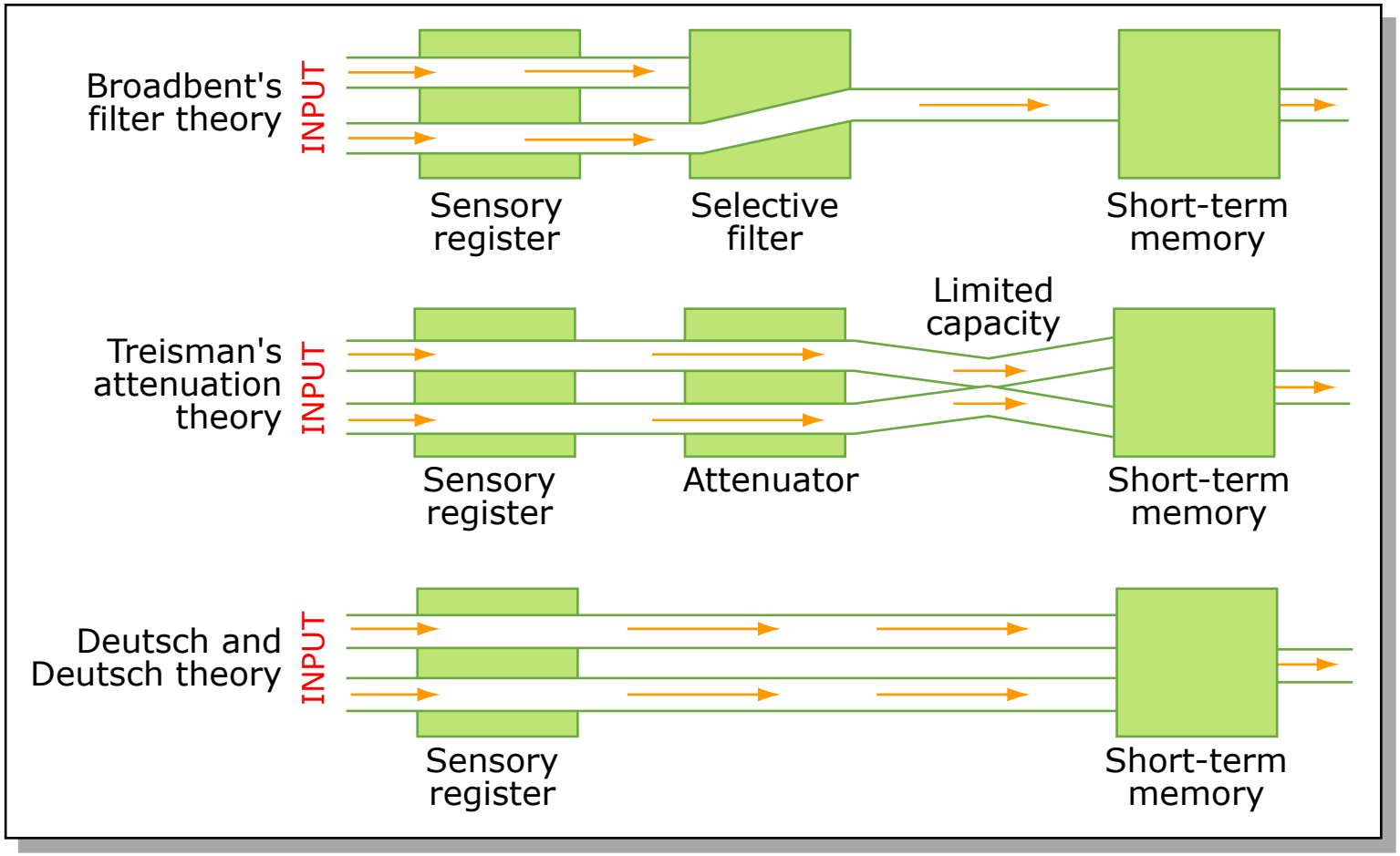

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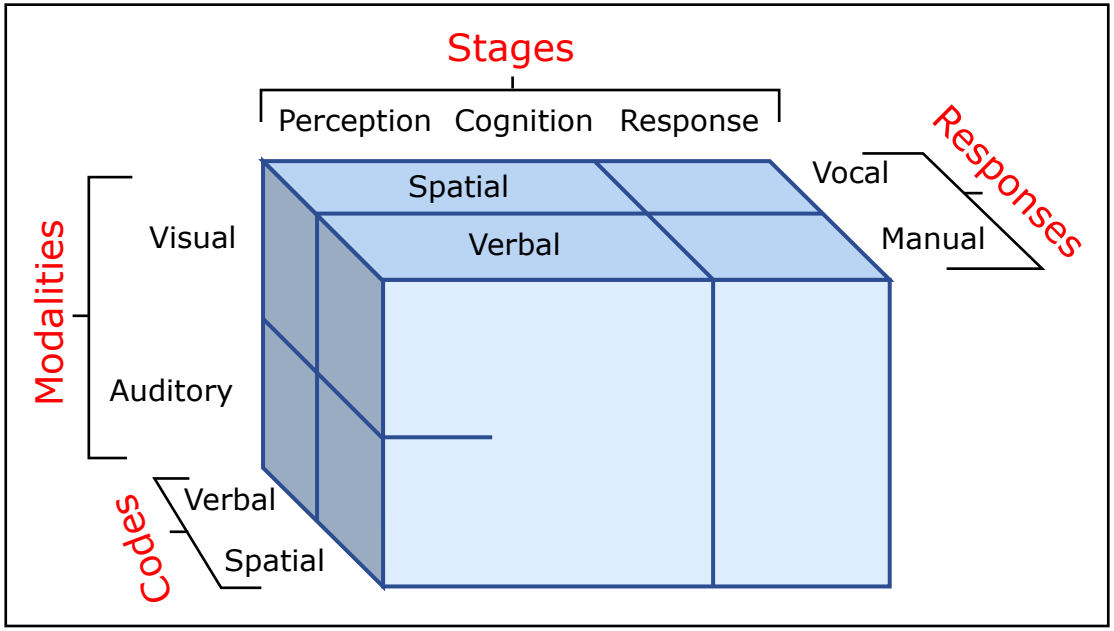
Resource Attention Models

- Single vs. multiple resources
- Multiple Resource Theory
  - Divided attention implications



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Contemporary Models of Attention

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- Spatially-based Feature-Integration Theory (Treisman)
  - Visual search (is a target present in a visual array?)
- Executive Control Model (EPIC) (Meyer & Kieras)
  - Attention is modeled as an unlimited resource
  - Executive strategies (e.g., task scheduling) are the source of decrements in multiple-task performance

Auditory Attention Demo

- http://www.gocognitive.net/demos
- Selective Attention
  - http://www.gocognitive.net/demo/selective-attention-auditory-demonstration
  - cocktail party effect

Visual Attention Demos

- Asking for Directions
  - http://www.youtube.com/watch?v=vBPG_OBgTWg
- Still photo demo
  - http://www.gocognitive.net/demo/change-blindness

- Spotlight Metaphor
  - Attention can be aligned with direction of gaze, or directed to be independent of fixation
  - What you are “attending to” can be different from where your eyes are focused
  - e.g., team sports

Control of Attention

- Involuntary
  - Aka *exogenous*
  - Bottom-up processing, stimulus driven
  - Attention grabbing
    - e.g., flashing lights, sudden movements and sounds, tv images
- Voluntary
  - Aka *endogenous*
  - Top-down processing, under executive control
  - Deliberate
    - Controlled attention as intended
    - e.g., a sign directing you where to look, cocktail party effect

Multi-tasking and Distractions

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- What exactly is “multi-tasking?”
  - Multi-tasking is “task switching” (can be fast, but still switching)
  - Multi-tasking ≠ parallel processing
  - Task switching comes with cognitive “switching costs”
  - Multi-tasking is interrupt-driven
  - Multi-tasking performance improves with practice, but performance on each of the tasks does not match the performance when performed one at a time
  - Tasks that are similar interfere with each other more than tasks that are dissimilar (cf. multiple-resource theory)

- http://gocognitive.net/video/david-strayer-driver-distraction-and-cell-phones (18 min video)
- http://www.npr.org/templates/story/story.php?storyId=95256794&ps=rs
- http://www.npr.org/templates/story/story.php?storyId=95524385&ps=rs
- http://www.apa.org/news/press/releases/2001/08/multitasking.aspx

Distributed Attention

- For global scene registration as opposed to detailed scene analysis
- Parallel processing mechanism
- Better for estimation of overall pattern

- e.g., registering emotion or ‘average’ tilt of several objects in a scene

The Instrument Scan

- Multi-tasking or distributed attention?

- Similar task for auditory attention would be to conduct an orchestra
- Requires practice and proficiency!

Display Design and Attention

- Color Coding
  - Filtering out “relevant” info via color coding
  - Takes advantage of parallel processing
  - But what is relevant depends on the specific task and the number of useful colors is limited
- Flashing
  - Grabs attention, high frequency or extra bright is especially grabby
  - But can be distracting

More on Display Design and Attention

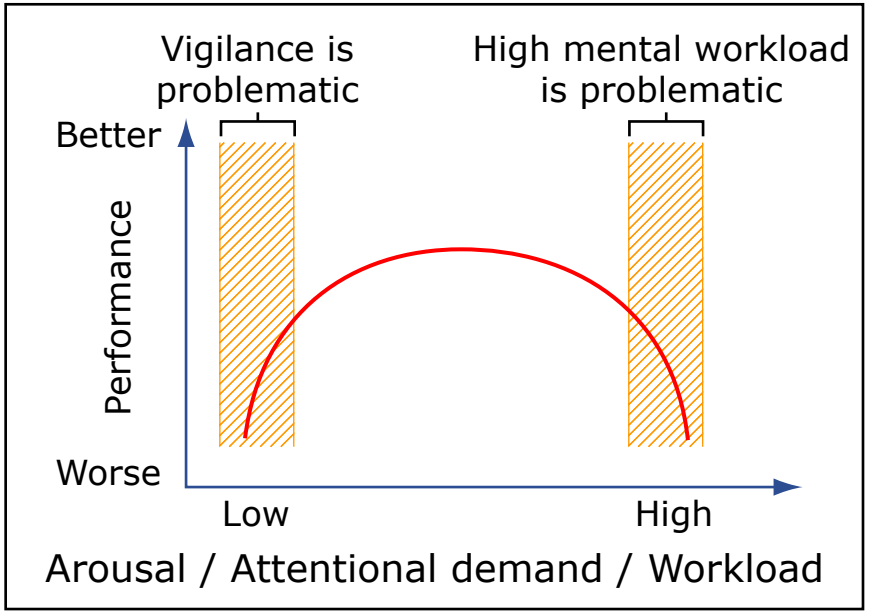
- Size/Loudness
  - Big/loud objects can attract attention
  - But too big or too loud can backfire
  - Distinctiveness from background is more important
- Feature contrast
  - e.g., easy to find a straight line segment amongst curves
  - Difficult when there are many visual objects, all different

"Visual Clutter" and Attention

- Both cognitive and perceptual organization of information affects perceived level of clutter
- Experienced observers see structure where inexperienced observers do not (chunking)
  - e.g., reading (text, math equations, music)
- Some perceptual features are processed in parallel rather than in serial
  - Visual Search Demo (cf. Treisman Feature-Integration Theory)
    - http://www.gocognitive.net/demo/visual-search

Arousal & Vigilance

- The inter-relations between attention and workload
  - Perceptual narrowing (high workload)
  - Vigilance (sustained attention) decrement)



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Workload

- Workload can be physical or mental
- Mental workload refers to cognitive demands over a time period
  - Based on unitary-source or multiple resource models of attention
  - Empirical measures include
    - Task performance (on primary or secondary task)
    - Subjective scales
    - Psychophysiological data
  - Workload that is either too low or too high is not optimal

Secondary Tasks

- Spare/reserve capacity
- Types
  - Detection/monitoring
  - Lexical decision (letters form a word?)
  - Memory-scanning (an item in a memorized set)
    - Sternberg memory
  - Mental arithmetic
  - Problem solving
  - Reading
  - Tracking
  - Can combine
- Problems
  - Testing on same channel as primary task
  - Intrusiveness
    - Counter: Embedded secondary tasks

Subjective Workload Measures

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- High face validity, cheap, and easy to administer
- Types
  - Cooper Harper
    - Bedford, Modified, Honeywell versions
  - NASA-TLX
  - SWAT
- Problems
  - Dependent on short term memory
  - Be careful when using with secondary tasks
  - Individual interpretations

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NASA Task Load Index (TLX)

- 6 dimensions of workload (next slide)
- Rate effort for each along a linear scale
- Rank the 6 dimensions via 15 pairwise comparisons
- Pros
  - Easy to administer, widely used, long history
- Cons
  - Tedious for subject (takes time and patience)
  - Interrupts the task
  - Performance scale may be confusing

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NASA TLX Dimensions and their Definitions

From Hart, HFES 2006.

RATING SCALE DEFINITIONS

Title	Endpoints	Descriptions
MENTAL DEMAND	*Low/High*	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	*Low/High*	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	*Low/High*	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
EFFORT	*Low/High*	How hard did you have to work (mentally and physically) to accomplish your level of performance?
PERFORMANCE	*Good/Poor*	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
FRUSTRATION LEVEL	*Low/High*	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

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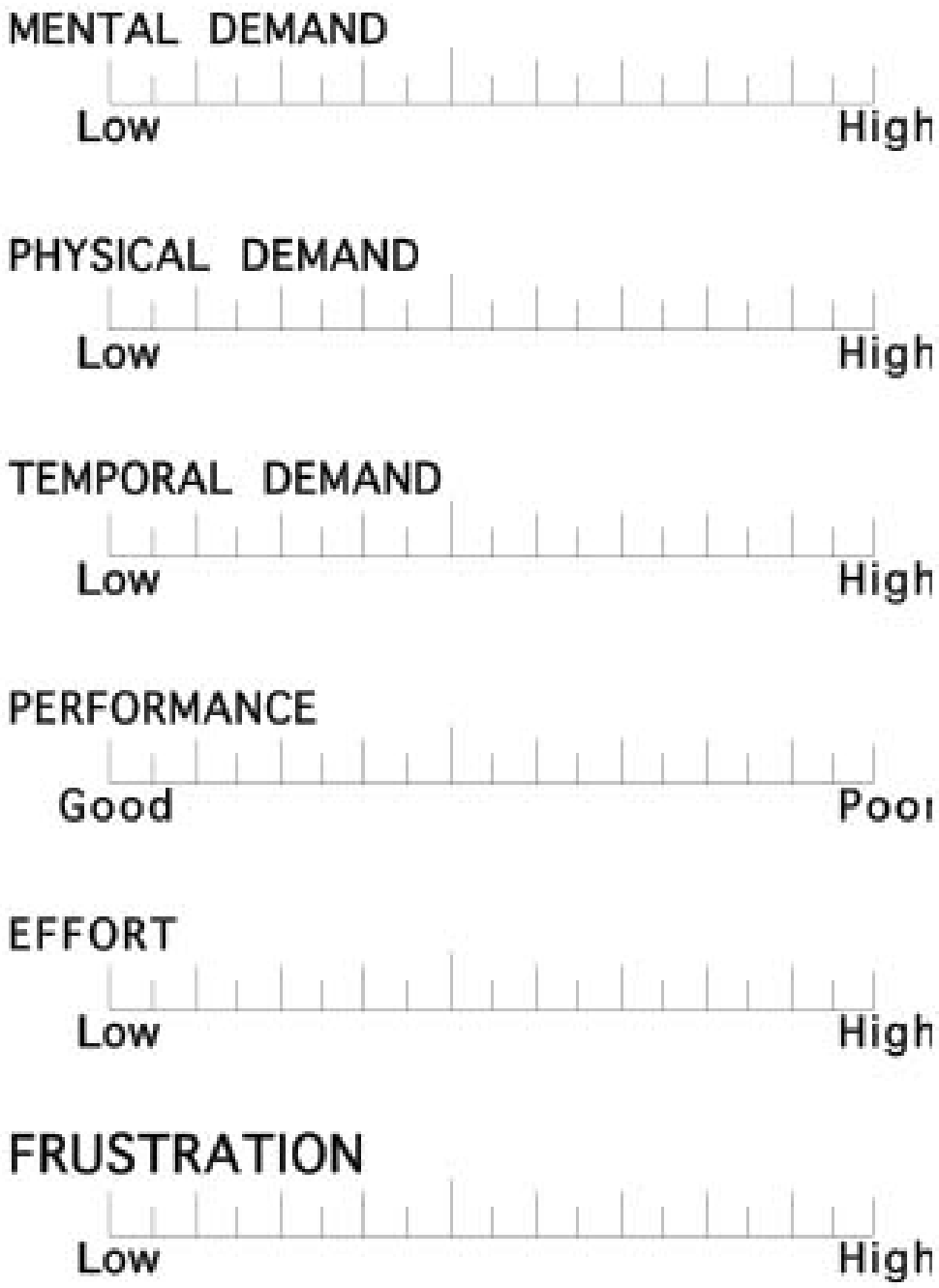
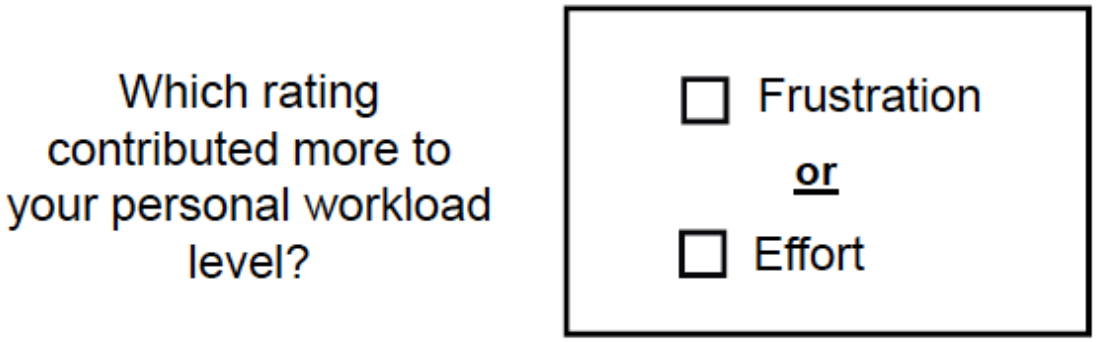
NASA TLX Rating Scales

From Hart, HFES 2006.



NASA TLX Pair-wise Example



Frustration: How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent you felt during this scenario.

Effort: How hard you had to work (how much effort did you put in mentally and physically) to accomplish your level of performance.

NASA TLX Downloads

- http://human-factors.arc.nasa.gov/groups/TLX/tlxpublications.html

- Many software versions available for download

Subjective Workload Assessment Technique (SWAT)

- Subjects rate workload (low, medium, and high) on three dimensions (time, mental effort, & stress load)
- Scale development (27 combinations of 3 & 3) and then event scoring
- Problems
  - Correlations between 3 dimensions
  - Lack of diagnosticity
  - Low mental workload issues

SWAT

1. Time Load
   a. Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.
   b. Occasionally have spare time. Interruptions or overlap among activities occur frequently.
   c. Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.
2. Mental Effort Load
   a. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
   b. Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.
   c. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.
3. Psychological Stress Load
   a. Little confusion, risk, frustration, or anxiety exists & can be easily accommodated.
   b. Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.
   c. High to very intense stress due to confusion, frustration, or anxiety. High to extreme determination and self-control required.

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Physiological Measures of Mental Workload

- Psychophysiological
- Types
  - Blink rate
  - Pupil diameter
  - Galvanic skin response
  - Heart rate
  - P300
  - fMRI
- Problems
  - Stress versus mental workload
  - Often more noise than signal

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Review of Recent Lectures

- Audition
  - Hearing, Stevens' law, auditory displays & warnings, parallels and contrasts with visual displays
- Automation (including Kathy Abbott's lecture & readings)
  - Human information processing
  - Aircraft control loops, types of automation
    - e.g., control vs. information automation
  - Situation awareness (general terms)
  - Risk mitigation, errors, and error management
- Decision making
  - SDT, "Simple" Decisions, Biases, Naturalistic Decisions
- Attention and workload
  - Models of attention, designing for attention
  - NASA TLX

Wrap-up of Recent Lectures

- Technology examples
  - TCAS, EFB, moving map displays, Flight Management Systems (control & display), and Mode Control panels

- Study tips
  - Review PV Chapters (4, 7, 9, 11) and automation readings in parallel with lectures (including Dr. Abbott's lecture)
  - Be able to list the main topics/sections (i.e., covered in lecture) from each chapter and know key points about each
  - Highly recommend trying the SDT demo and Attention demos
  - Be familiar with technology examples (above)
  - Computation of d' and β not required, but should understand meanings and SDT plots (distributions and ROC curves)
  - Slides on FAA (Part 2 from 11/10) will not be tested material. However, content of AC on controls may be helpful to review for Response Selection lecture by LRY.
  - Don't rely solely on previous quizzes. Their content may be different due to lecture order and instructor changes.

Extension Readings (For Fun)

- *The Checklist Manifesto: How to get things right* by Atul Gawande

- *Distracted, The erosion of attention and the coming dark age* by Maggie Jackson

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