Intro: Cognitive Workload

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Multitasking (phoning) while driving can be dangerous.

Now we want to look in a bit more detail at workload and multitasking.

Important questions:

- How are multiple tasks handled in the brain?
  (real parallelims? frequent switching between tasks?)
- What combinations of tasks are good / bad in terms of performance on both tasks?
- How does multitasking affect a) cognitive load and b) performance?

Terminology

Mental workload is the portion of a humans limited mental capacities actually required to perform a particular task.

Mental reserves are the difference between capacity required and capacity available.

Mental effort is the voluntary matching of mental capacities with that needed for task success.

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Increase in Mental Workload often leads to **degradation in performance**, especially if more capacities are required than are available.

Measuring Mental Workload

How can we measure the level of mental workload?

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1. Primary Task Performance
2. Secondary Task Performance
3. Physiological Assessment (more on this on Wednesday)
4. Subjective Response (we'll mostly ignore this here)

Cognitive Load – Primary Task Performance

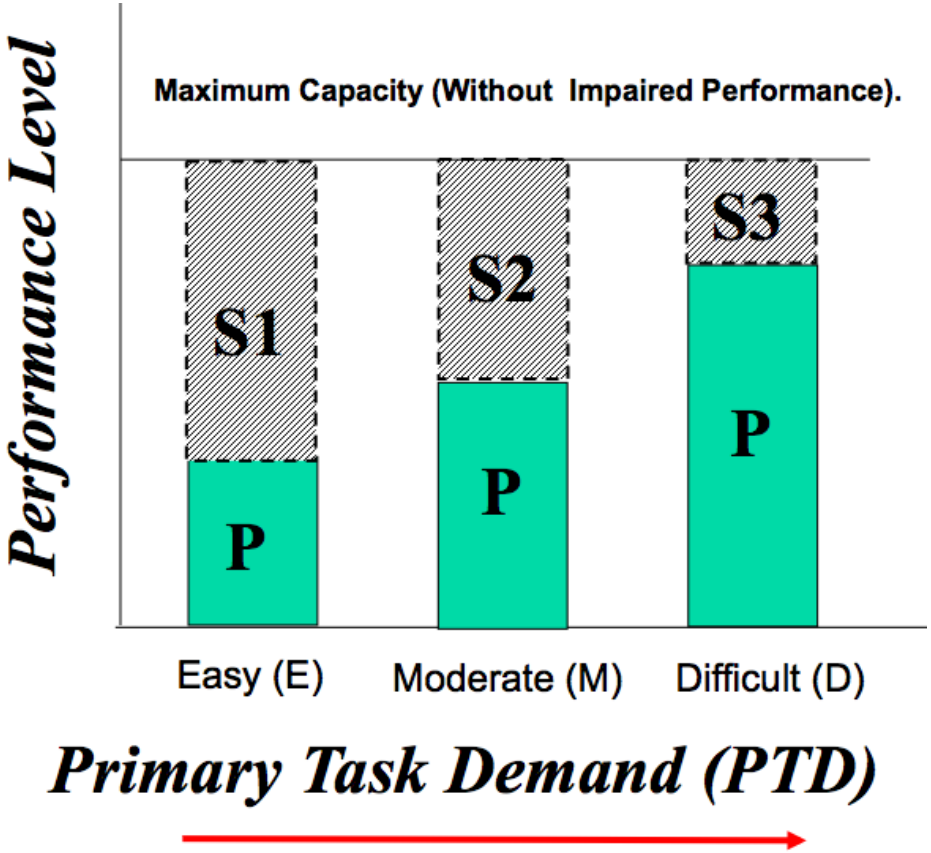
Measure performance: how well is the task done?

Disadvantages:

- “Mental Workload” not distinguishable from performance outcome
- Problem: insensitive to level of mental workload, as long as it is under capacity (performance at ceiling).
- Can’t predict whether making the task a little bit harder will push over capacity.

Secondary task measure

Measuring on a secondary task when interested in cognitive load induced by primary task:



(pic nicked from P. Hancock)

- tell subjects that primary task is more important
- observe secondary task performance
- performance on secondary task as correlate of primary task difficulty.
  (How much cognitive resource is left for the secondary task?)

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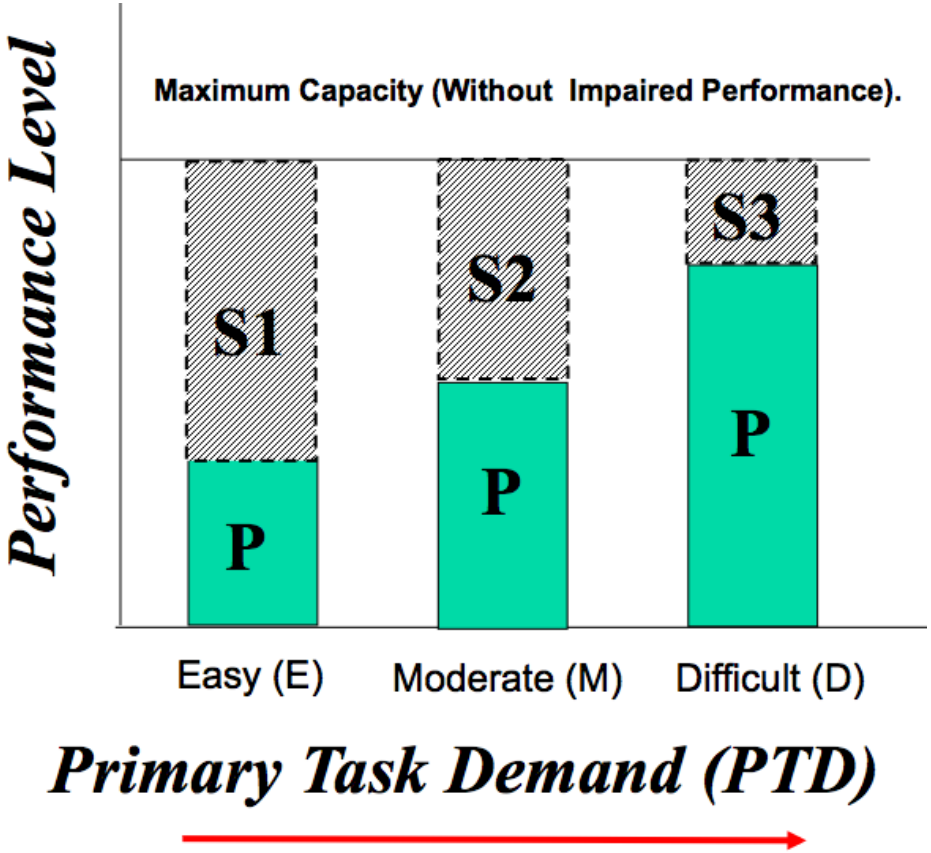

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But how do the two tasks interact with each other?

(and in our case we're not interested in just workload of one task, but the workload of two tasks together.)

How does multi-tasking work?

Experiment with 2 tasks of equal priorities (Schumacher 2001)

1. Visual-manual task
   - circle appears in one of three positions
   - need to press corresponding button on keyboard
2. Aural-vocal task
   - tone in one of three possible pitches is played
   - say “one”, “two” or “three” depending on tone

Possible outcomes:

How does multi-tasking work?

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Possible outcomes:

- answers on one of both tasks slower in dual task condition
- answers to both tasks take same amount of time as if it had been presented as single tasks. (“perfect time sharing”)
- (for tasks where primary and secondary task are correlated such that the signal is partially redundant, could possibly also get faster reaction times in dual task than single task)

Schumacher 2001 results

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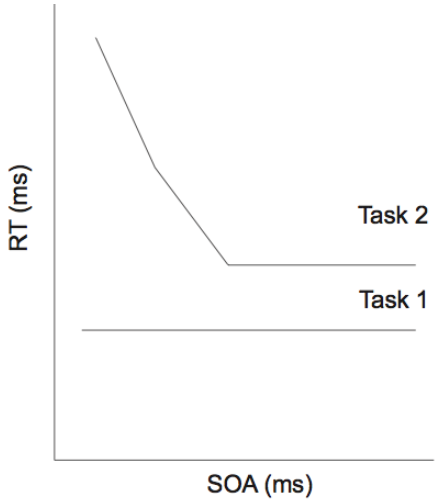
If both signals presented at same time:

- perfect time sharing (after training)

Schumacher 2001 results



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If signals in sequence and additional instruction to respond to first one first:

- additional overhead “Perceptual Refractory Period”: processing of first stimulus not finished when second arrives, therefore delay.

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If signals in sequence and additional instruction to respond to first one first:

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If visual task harder (no direct mapping):

- no perfect time-sharing anymore: overlap in response generation

Effects of practice

- Automatic processes can be executed in parallel
- Controlled processes subject to limitations
- Practice can convert controlled into automatic processes.

Choice of tasks in multi-tasking

Task difficulty:

- harder tasks require more cognitive resources, so more difficult to multi-task
- harder tasks are more difficult to automate.

Choice of tasks in multi-tasking

Try it!

Try to rotate your foot clockwise and your hand counter-clockwise!

Task similarity:

- different tasks are easier to execute in parallel than very similar tasks.
- (similarity of complex tasks may be difficult to asses)

Central Capacity Theory

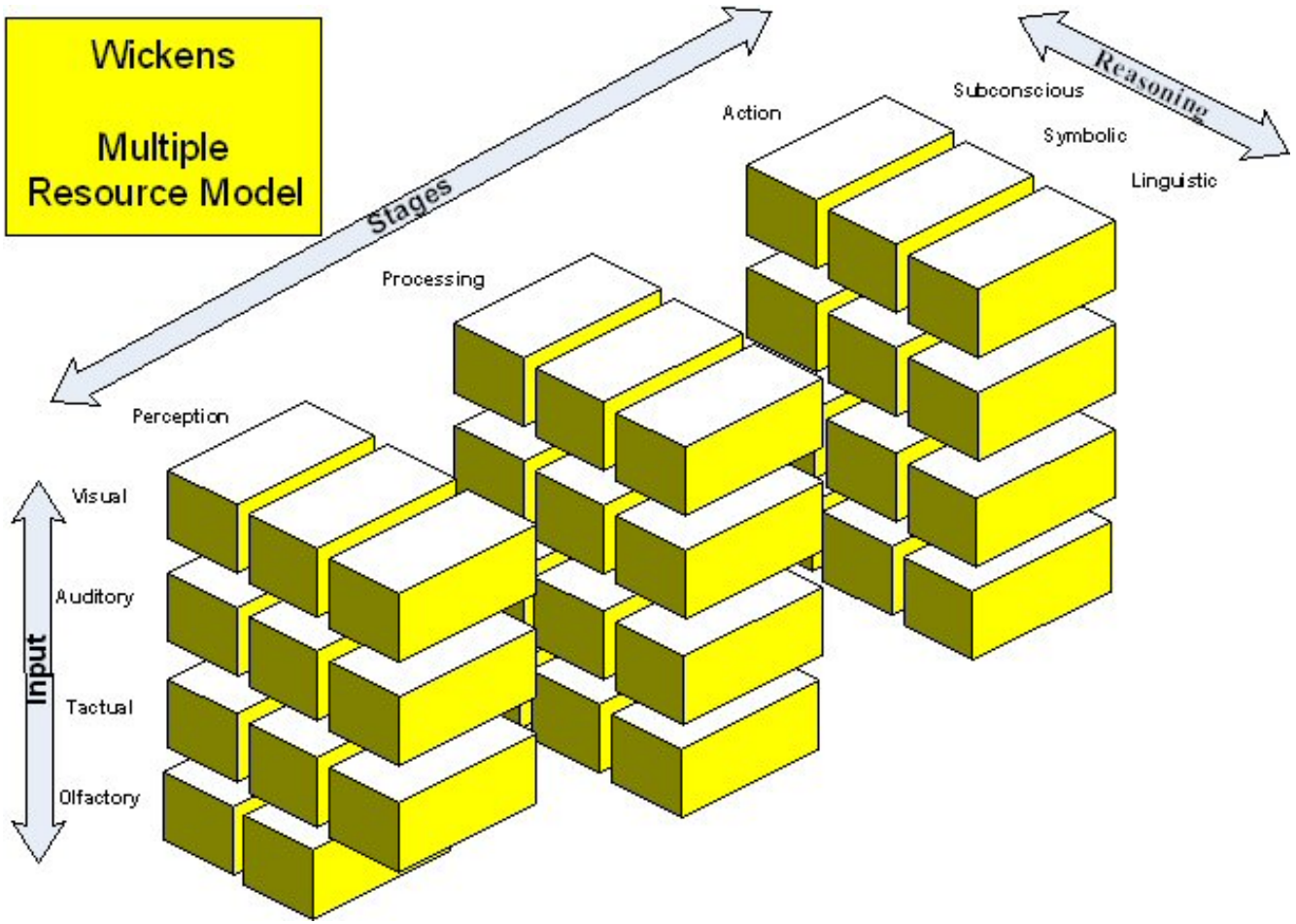
Kahnemann 1973 – basic ideas

- limited resources
- different processes must compete for cognitive resources

Explanatory adequacy:

- explains slow-down or lower performance in dual tasks
- but not why more similar tasks should be more difficult

Multiple Resources Theory



Wickens 1984 - ideas

- each resource has limited capacity
- slowdown if two tasks overlap in terms of resources needed
- complementary tasks should not incur additional cost.

Can explain similarity effects and difficulty effects, but possibly a bit too parallel.

Serial Bottleneck

Some agreement that there is parallel processing to some extent, but that there are also “serial bottlenecks”.

Bottleneck 1: Psychological Refractory Period (PRP)

- response selection is limited
- Why?
  - effect of sharing limited resources?
  - a serial bottleneck (some part of the process that can’t be done in parallel)?
- neural correlates: PRP is thought to occur at time between stimulus consolidation in working memory and motor preparation (Marois & Ivanov, 2005)

Definition

Memory consolidation is a category of processes that stabilize a memory trace after its initial acquisition.

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Bottleneck 2: the attentional blink

Capacity limit in explicit visual event detection: the attentional blink

- first stage of massively parallel processing of incoming stimulus
- later stages of processing require attention and are capacity-limited
- task: identify two targets in rapid succession, frequent failure to identify second target

→ demo

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Bottleneck 3: visual short term memory

- capacity estimate: four items
- also affected by complexity of items
- difficult to detect small changes in complex scenes
- capacity also dependent on attention
- inattention blindness when focussing on something else

→ demo

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Serial Bottleneck

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Conclusions:

- maybe what’s limited is short-term memory consolidation, needed both for AB and PRP.
- Open question: do the observed limits come from limited resources of attention, or limited processing / parallelisation in a specific information channel (visual / aural etc.)?

Definition

Memory consolidation is a category of processes that stabilize a memory trace after its initial acquisition.

Answers to our initial questions

- How are multiple tasks handled? (real parallelims? frequent switching between tasks?)
  $\rightarrow$ not quite conclusive, but full parallelism unlikely
- What combinations of tasks are good / bad in terms of performance on both tasks?
  $\rightarrow$ minimize overlap of resources needed; the more automatic the better
- How does multitasking affect a) cognitive load and b) performance?
  $\rightarrow$ multitasking can lead to an overhead in load, and/or worse performance on one or both tasks.

Back to our task: driving and (remote) conversation

Strayer and Drews (2007)

- Inattention blindness: drivers fail to *react* to relevant objects or events on the road if they are phoning, even if looking at the objects:
  in dual task condition don't react more to relevant objects than irrelevant ones $\rightarrow$ no deep semantic processing
- drivers react more slowly when distracted.
- EEG: brain activity associated with driving related tasks was reduced when driver was speaking on the phone.
- Tunnel vision: when distracted, drivers scan the road and mirrors less; fail to look at important road-side objects.

Overall summary

Users can (and want to) perform multi-tasking

- increased efficiency compared to forced serialization
- but performance CAN suffer
- interference effects dependent on type of tasks and task difficulty
- if we can manipulate the difficulty of one task, we can hopefully increase performance on other task

Plan for the rest of the course

- Tuesday: Linguistic Complexity
  - when do linguistic materials cause higher cognitive workload?
- Wednesday: Workload measurement
  - Task performance
  - Eye-tracking
  - ERPs
  - Heart Rate and Sweating
  - including interactive in-course experiment
- Thursday: Adaptation
  - Why should dialog systems adapt?
  - Adaptation to different user groups (young/old)
  - Adaptation of information presentation
- Friday: Applications
  - Implications for natural language generation in dialog systems.