



HUMAN PERFORMANCE

M6X00915

LECTURE 5: VIGILANCE & ATTENTION

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TODAY'S SESSION

- Techniques to combat loss of vigilance
- Architecture of attention and associated issues
- Divided attention and Workload
- Dual-task performance
- Resource theories

COMBATING THE LOSS OF VIGILANCE

- Vigilance is important in real-world settings
- Thus, techniques have been proposed to combat loss of vigilance:

A. Increase sensitivity: How?

1. **Show target examples to reduce memory load**

- A technique that enhances memory should reduce sensitivity decrements & preserve a higher overall level of sensitivity.
- **Kelly (1955)**: when quality control operators could view an ideal image of stimuli, detection performance improved.

COMBATING THE LOSS OF VIGILANCE

A. Increase sensitivity: How?

2. Introduce false signals

- Reduces beta increment caused by expectancy
 - **Childs (1976)**: Access to visual representations of defective items improves detection performance.

3. Increase target salience:

- Any procedure that differentiates signal and non-signal stimuli.

COMBATING THE LOSS OF VIGILANCE

A. Increase sensitivity: How?

4. Reduce event rate

- **Saito (1972)**: When rate of bottle inspection reduced from 300 p/m to under 200 p/m, efficiency improved.
- **Scerbo et al. (1993)**: giving observers control over event rates improves sensitivity.

5. Training

- **Fisk & Schneider (1981)**: Getting Ps to respond in consistent & repeated manner to target elements reduced sensitivity decrement.
- This technique develops ***Automatic Processing***, thus the target stimulus would “jump-out”.

COMBATING THE LOSS OF VIGILANCE

B. Shifting Response Criterion: How?

1. **Instructions:** Make cost of errors explicit

- But, instruction given will depend on aim to be achieved
 - Difference between seriousness of CR and misses between airport security and sweet factory.

2. **Knowledge of result.**

- **Wolfe et al. (2007):** providing Ps with feedback (& temporary high signal rate) in an airport security x-ray of luggage task was effective at shifting & maintaining response criterion at a lower levels.

COMBATING THE LOSS OF VIGILANCE

B. Shifting Response Criterion: How?

3. Introduce False Signals

- **Baker (1961); Wilkinson (1964):** keep beta low
- If false signals are similar to target signals, a refreshing of standard of memory should occur along with a reduction in the sustained demand of the task.
- But subsequent acting on false warnings could be dangerous.

COMBATING THE LOSS OF VIGILANCE

B. Shifting Response Criterion: How?

4. Confidence level responses

- **Broadbent & Gregory 1965; Rizy, 1972.**
- Allowing observer to report detection of signals with different confidence levels decreases vigilance decrement – why?
- The likelihood alert technique (fuzzy SDT).

COMBATING THE LOSS OF VIGILANCE

- **Other techniques:**
 - Provide rest breaks (Parasuraman, 1986) to interrupt continued demand on resources.
 - Meditation training (MacLean et al., 2010).
 - Increase arousal levels – e.g., by engaging observers in a secondary task
 - Verbal task while driving - Chan, 2011.
 - Acknowledging entry of aircraft to flow corridor to help detect failures of aircraft self-separation (Pop et al., 2012).

ATTENTION

- Critical for vigilance tasks.
- Recognised as factor involved in general human performance.
- Involves selecting particular stimuli from vast amount of stimuli that we could attend.
 - Those stimuli that we do focus on receive intensive cognitive processing.
- But, things can go wrong leading to different types of errors.

ATTENTION

- However, sometimes stimuli we do not believe we have attended to are actually processed and can affect subsequent behaviour.
- So, how does attention, or lack of, impact performance?
- We need to consider different types of attention:
 - Selective
 - Focused
 - Divided
 - Sustained

ATTENTION

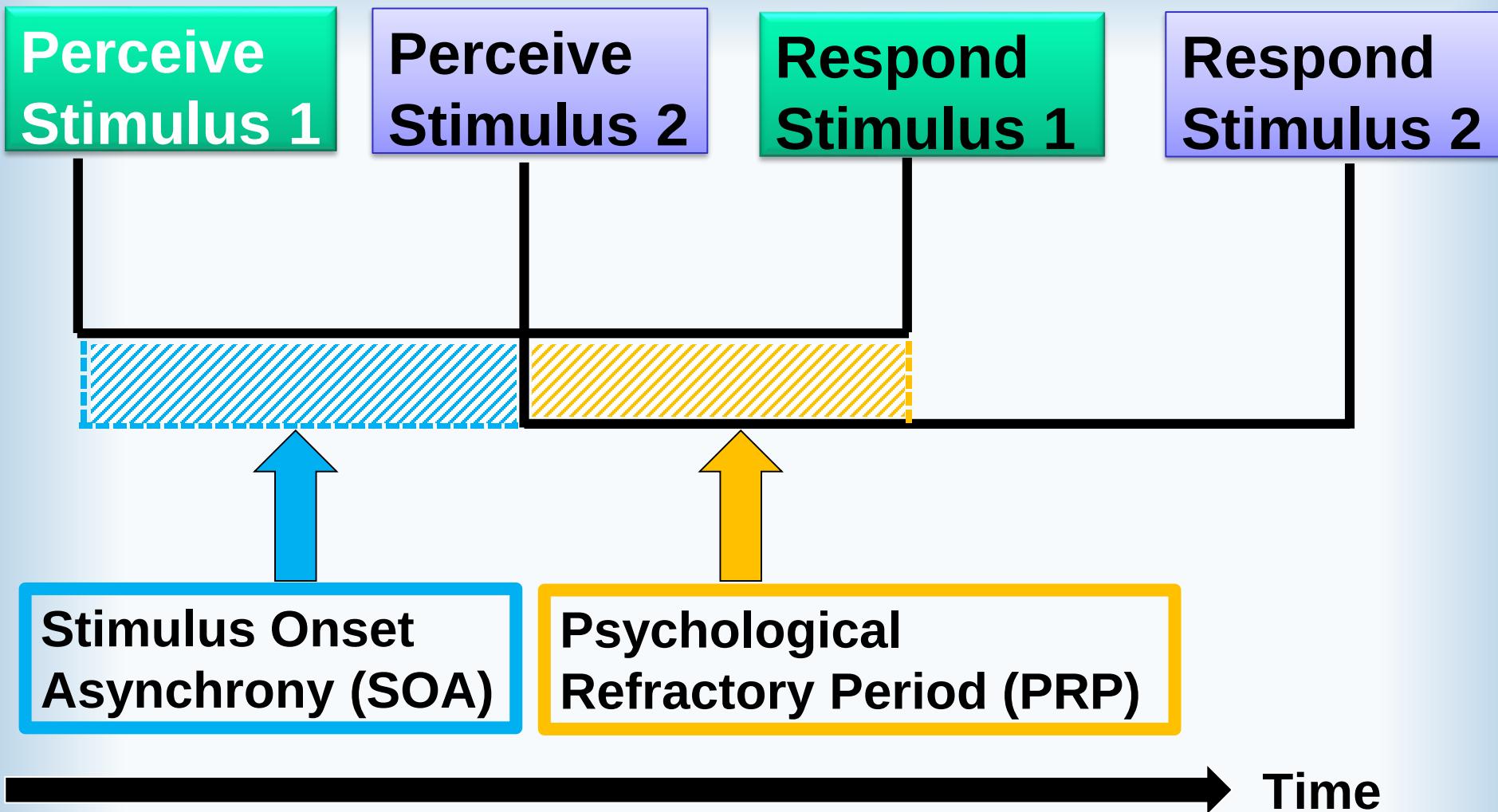
- Important empirical & theoretical precursor to the study of selective attention was the concept of the “Bottleneck”.
 - Narrowing of info so only certain aspects pass.
- Information will eventually pass.
- The issue is that the processing of the second bit of info is going to be slower because the first bit is still being processed.
 - Welford (1952) termed this the **Psychological Refractory Period (PRP)**.

ATTENTION

- Evidence: Ps presented with 2 stimuli, one after the other really quickly, and they respond by pressing a key for each stimulus:
 - Time lapse between presentation of each stimulus is known as **stimulus onset asynchrony (SOA)**.
- Speed Ps respond depends on the SOA:
 - If SOA is reduced, 2nd stimuli is presented while 1st is still being processed and before P has been able to respond to it.

ATTENTION

- This has knock-on effect to how fast P is able to respond to 2nd stimulus
 - I.e., longer (slower), because they are still processing 1st stimulus, responding to it, and then they are able to process and respond to the 2nd
- What do you think happens when SOA is increased?
 - Response times to the second stimulus were shorter (quicker).



These findings suggest there was a bottleneck in cognitive processing between seeing a stimulus and then responding to it.

Practical Application

Using PRP to an advantage:
“Fake pass”



Disadvantage of PRP:
slower reaction time



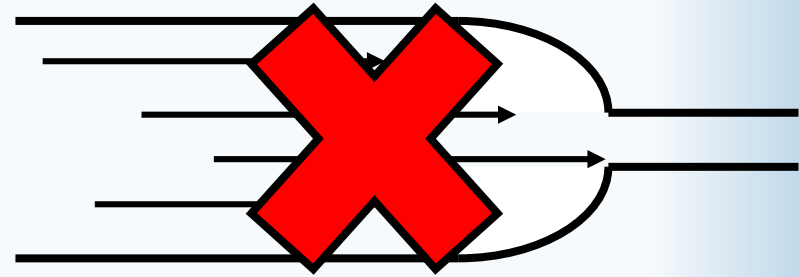
- Easier to manipulate external stimuli to examine selective attention, but internal stimuli (relating to thoughts & knowledge) also influences selective attention by guiding what we expect.
- Research must consider how much semantic analysis is required on incoming stimuli before it's selected for attention

ATTENTION

- Early selection models (e.g., Broadbent Filter model):
 - Bottleneck occurs early & operates on physical characteristics of stimuli.
- Deutsch and Deutsch (1963): semantic processing required for all stimuli before response can be made.
- Treisman's attenuation model (1964): some but limited semantic info processed before item selected for attention
 - Early selection models: processing is bottom-up, data driven, selection made on basis of characteristics.
 - Late selection models: allow top-down processing with semantic content of stimuli being related to semantic content of LTM, so they are conceptually driven.

ATTENTION

- Is the bottleneck metaphor useful for explaining processing of attention in the real-world?
- In real world there is a flow on what we attend
 - E.g., when driving would you just attend to the road and nothing else?
- Attention in real-world is dynamic
- Thus, the bottleneck metaphor falls short
- Instead, channels of attention is a useful explanation



ATTENTION

- But, examining channels of attention in lab is restrictive (in real-life our focus of attention needs to be shifted continuously for us to perform).
- So, we may only ever end up sampling a channel depending on its relevance to what we aim to achieve.
- This sampling strategy is based on Ps expectations about frequency and importance of info in the different channels.
- Ideally the sampling strategy should be adaptive:
 - So, can quickly and easily switch or change to optimize taking in important info.

ATTENTION

- In real-world, training people in certain occupations (pilot), involves them acquiring an adaptive model of attention in order to perform specialist tasks.
- Bellenks et al. (1997): expert pilots scan across their equipment much quicker and more flexibly than less experienced pilots.
- This type of research leads to specific training programmes based on how mental operations are performed.
- But first we need to understand how attention operates and is structured

THE ARCHITECTURE OF ATTENTION

- There is no uniformity among theorists of the architecture of attention or on what types of questions should even be examined.
- **Issue 1:** What is attention for/What is the purpose?
 - The function of visual attention is to select objects for recognition - ***selection for recognition.***
 - However, attention prepares us to act on the environment - ***selection for action.***

THE ARCHITECTURE OF ATTENTION

- These two functions correspond to two challenges:
 1. Perceptual overload:
 - too many stimuli requiring processing.
 2. Response incoherence:
 - performing incorrect action as a result of too many incompatible responses being simultaneously activated.

THE ARCHITECTURE OF ATTENTION

- **Issue 2:** Do attentional selection mechanisms exist at all?
 - Early selection theories:
 - when there is overload of processing, there must be a special purpose selection mechanism that filters out irrelevant stimuli
 - Attention operates as a cause:
 - It needs to be done
 - For others attention is an effect:
 - A phenomenon we see happening, not from specific selection mechanism.

THE ARCHITECTURE OF ATTENTION

- For others the purpose of the visual system is to control action through two types of selection:
 - The intention mechanism:
 - Chooses which skill or action should be implemented (relates to strategies/goals)
- Attention in the sense of selecting the stimulus information that will control the intended action.

THE ARCHITECTURE OF ATTENTION

- **Issue 3:** What is the structure of the attention architecture?
 - For some, this can only be addressed once the first two issues (functional & causal aspects) are fully understood.
 - All of this has a subsequent influence on *what* & *how* experimental research is conducted.
 - If some are characterising attention as selection for recognition, then they will develop models revolving around the selection process.

THE ARCHITECTURE OF ATTENTION

- For those who think attention is the output of multiple mechanisms operating in a parallel processing system, the way they conceive the architecture will be very different.

“to pursue a general ‘theory of attention’, without first specifying the computational functions that the theory is to account for, would appear to be a likely recipe for disaster.” Allport (1989)

- Neuropsychology is used to work out when processes in the mind take place based on the time course of neurological activity (through ERP studies).

THE ARCHITECTURE OF ATTENTION

- Hillyard & colleagues: if selection happens early, differences in ERP produced by attenuated & un-attenuated stimuli should happen straight after stimuli is presented.
 - Support for late attentional selection models would come from no difference in the early ERP components.
- When Ps completed dichotic listening task with tones, results supported early selection, with differences between attenuated & un-attenuated seen in N1 component of ERP.
 - Conclusion: difference in processing of info they were meant to be focusing attention on and info not for focused attention was happening earlier than 100ms after the stimulus was presented.

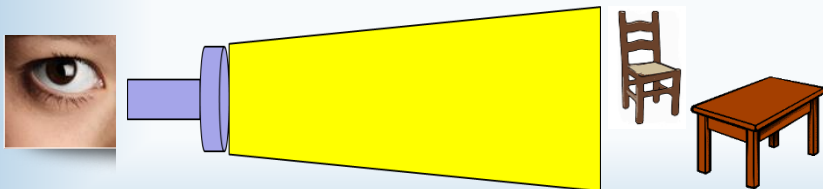
THE ARCHITECTURE OF ATTENTION

- However, we cannot be confident of where selective attention within the processing system occurs.
- “Breakthrough” of info disrepute's early models.
- Reason why different studies show variations:
 - Particular parameters of task: even in dichotic listening tasks, different types of stimuli are being examined:
 - Spoken words (P has to attend to meaning, which involves semantic processing)
 - Tones (P attends to physical characteristic of the sound)

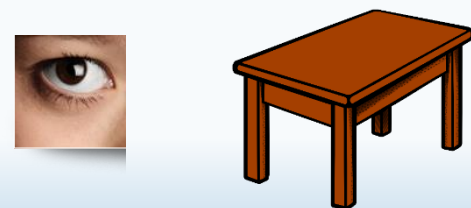
THE ARCHITECTURE OF ATTENTION

- Different conditions lead to varying levels of demand & resources placed on attentional system.
- Likely to be the reason why there is no all-encompassing model of selective attention because it depends on what the stimuli is, which changes how we process it.
- Even if the time-course of selective attention was agreed, we still need to work out what is selectively attended.

Space-based theories



Object-based theories



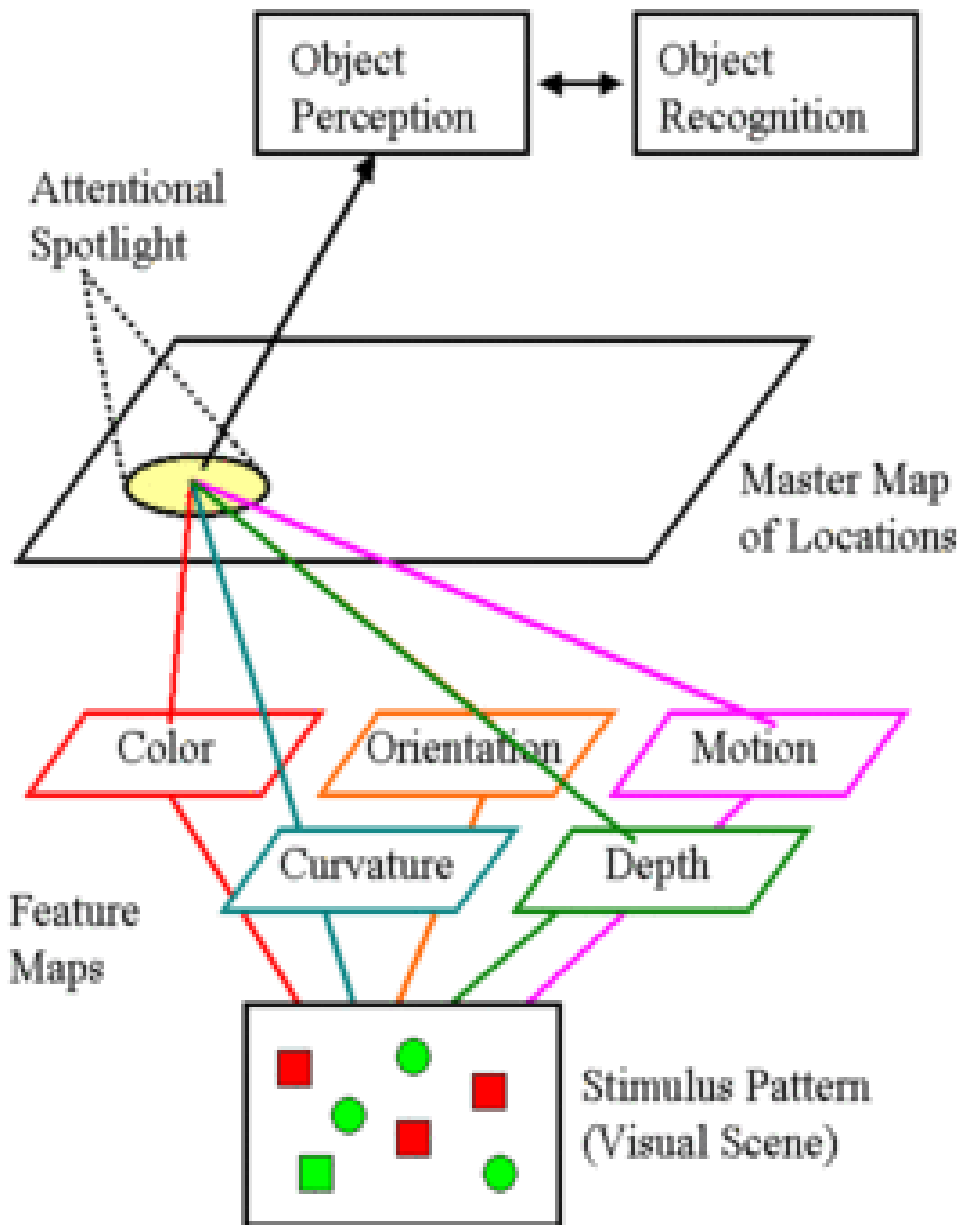
THE ARCHITECTURE OF ATTENTION

- Johnston & Dark (1986): highlighted characteristics of attentional spotlight:
 - Size & shape of area, that a single spotlight results in more effective processing but there is the possibility for attending to two locations, and that there is a link with eye fixation (dependant on fovea).
- If spotlight area is narrow, processing efficiency would be better because there is less information to have to process.
- Treisman: attention acts as a moving window.
- **Feature Integration model (FIT)** suggests *pre-attentative segmentation* (processing before we actually attend), influences area of space that we then attend.

THE ARCHITECTURE OF ATTENTION

- Parallel processing of features in the visual field produce maps of where specific features are located.
- E.g., colour map shows where a particular colour is and the type of “red” there.
- Then there will be a different map of a line edge.
- Attention then uses a master map to show the features binding into a construct of the object in a representation format, which enters an object file in STM.

Feature Integration Theory (Treisman)



Predictions of the model:

- Searching for single feature (e.g., any red letter) is parallel.
- While search for object defined by conjunction of features (specifically a red K), requires serial search with attention moving from one location to the next until the target stimulus is found.

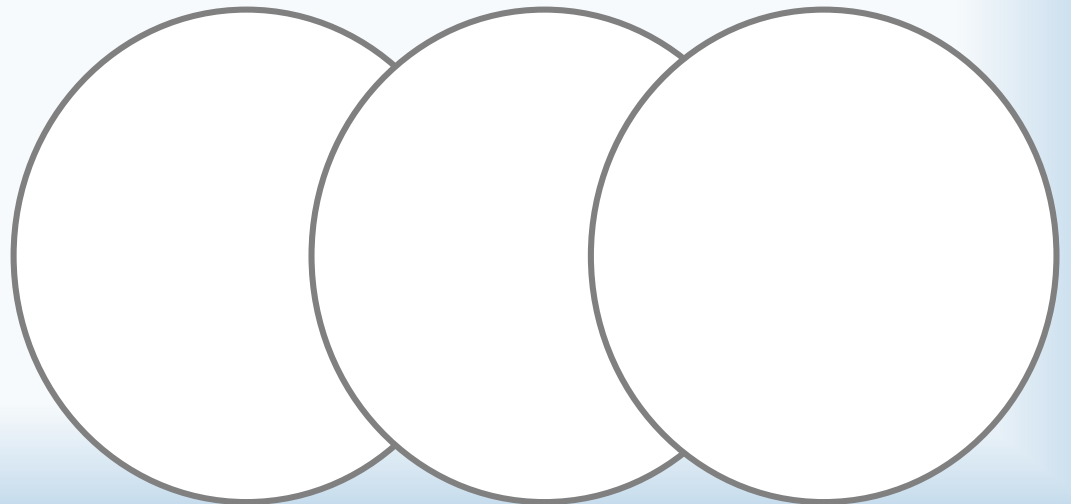
THE ARCHITECTURE OF ATTENTION

- Suggests humans can make *illusory conjunctions*: errors in binding features from different objects.
 - Think of examples when this might happen.....
 - Why should we consider this for performance?
- Criticism: No top-down mechanism
 - Do we not use our knowledge of the world to guide where we search?
- Cave & Wolfe (1990); Wolfe (1994)
 - Modified the model by introducing a top-down activation of feature maps, which allows the implementation of a search strategy.

THE ARCHITECTURE OF ATTENTION

Issues with space-based models

- They rely on elementary features of objects within space.
 - But: visual search may not access feature-level representations
 - Main reason why objects themselves are thought to be the important factor in selective attention comes from studies looking at occlusion of objects.



THE ARCHITECTURE OF ATTENTION

- We can identify occluded objects despite pre-attentative processes being unable to segregate elements of each.
 - Likely depends on top-down processing.
- Neisser (1976): selection is guided by a schema that actively cross-examines the environment which operate within a perceptual cycle.
- Any information taken in can modify the schema, which can then modify what is selected.
- Studies have shown that there is a processing cost to attending to two stimuli simultaneously.
- Alternative = **Object-based models.**

THE ARCHITECTURE OF ATTENTION

- Duncan & Humphreys (1989, 1992): Attentional Engagement.
 - Two-stage architecture:
 - (1). Perceptual description: detailed representation of visual input produced, including codes for the meaning of objects.
 - (2). Segmentation of the visual-field structures the representation in terms of object-like units.
 - Selection controls access of input to a visual STM (serves as the focus of attention).
 - Object representations compete for access to VSTM on the basis of activation levels (mainly affected by top-down control).

THE ARCHITECTURE OF ATTENTION

- Efficiency of search impaired if targets and distractors are similar to each other.
- Searching for a target is easier if all distractors look similar to each other:
 - **Perceptual grouping effect**
- No qualitative difference between searching for features & searching for conjunctions
 - Instead there is a continuum of search difficulty from target-distractor similarity and distractor-distractor distinctiveness.

Evidence from Neuropsychology

- Patients with unilateral visual neglect suggest attention operates on object-based selection.
- Neuropsychological evidence suggests object-based attention is associated with enhanced neural firing in V1.
 - This supports early pre-attentive processing.



ATTENTION

- Other approach: combine exp. studies with cognitive neuroscience.
- Attempt to work out brain structures involved in specific processes.
- Posner et al: 3 neural networks contribute to selective attention -
 1. Posterior system: controls orienting to stimuli – directing attention to a location where something has happened.
 - Components such as engagement, disengagement, & shifting attention studied through spatial cueing tasks – a valid or invalid cue informs Ps where they should direct attention.

ATTENTION

2. Anterior network: controls the detection of events and is active during tasks where visual targets must be detected.
 - PET scans have shown this system is more active when the task is more demanding but activity is reduced if something is practiced.
3. Control of alertness/vigilance: located in right frontal lobe.
 - Plays a role in variable-foreperiod reaction time tasks: Ps receive a warning that a stimulus that they must respond to will be presented but the time until it is shown can vary so the P must remain alert.
 - The 3 systems deal with different challenges in attention: 1. deciding what the object is, 2. deciding where it is, 3. dealing with uncertainty of presentation timing.

SUMMARY OF SELECTIVE ATTENTION

- Understanding underlying architecture of selective attention is very complicated.
- There is a distinction between stimulus-driven and expectancy-driven control of attention (Yantis, 1998).
- The focus of attention may be guided by both voluntary and pre-attentive processing and by search strategies (Wolfe, 1994)
- Activation based models integrate the 2 types of control.
- Remaining architectural issues:
 - Early vs. Late selection
 - Space vs. Object based attention
 - The role of inhibitory processes.
- Evidence from cognitive neuroscience may help.

DIVIDED ATTENTION & WORKLOAD

- Ability to attend/perform 2 or more tasks simultaneously.
- Research examines theoretical issue of attentional capacity:
 - *Mental workload* refers to attentional demand experienced during performance of cognitive task.
- When capacity is overloaded, performance deteriorates:
- Capacity limits of attention examined in dual-task studies through levels of interference.
- Experimental lab work uses 2 different methods to examine effects of divided attention.....

DIVIDED ATTENTION & WORKLOAD

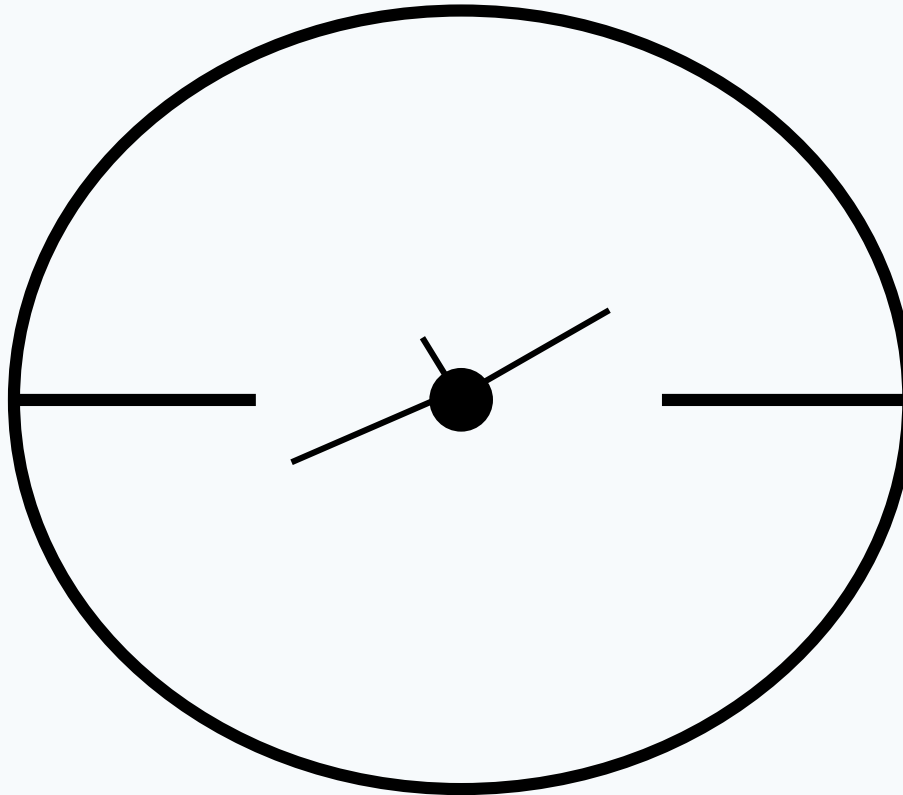
1. Discrete-trial tasks: Present 2 stimuli in a RT paradigm
 - Is response to one slowed by presence of other.
 - Based on Welford's (1980) single channel model:
 - Processing can only be performed serially
 - Supported by PRP studies: processing a given stimulus may slow response to a second stimulus.
 - But single-channel models cannot explain shifting of visual attention or how info is stored in VSTM (Pashler, 1998a).
- Instead examine interference in ***continuous performance***.
 - Representative of real-world tasks such as driving.
 - E.g., “tracking” task: Monitoring target and controlling tracking device impose continuous demand on attention.

DIVIDED ATTENTION & WORKLOAD

- Research shows successful dual-task performance is constrained by 4 main factors:
 1. Task difficulty: interference is worse when task components are demanding (see Wickens, 1980).
 2. Skill: being skilled can protect the performer from dual-task interference, possibly through automatization processes reducing the need for resource allocation (Allport et al., 1972; Hatano et al., 1977; Hirst et al., 1980).
 3. Task similarity: interference increases when tasks are similar or involve same sensory modalities (Wickens, 1984b; McLeod, 1977).
 4. Emergent properties: as an example tapping your head while rubbing your stomach – timings and directions make them incompatible (Duncan, 1979; Wickens, 1992).

DIVIDED ATTENTION & WORKLOAD

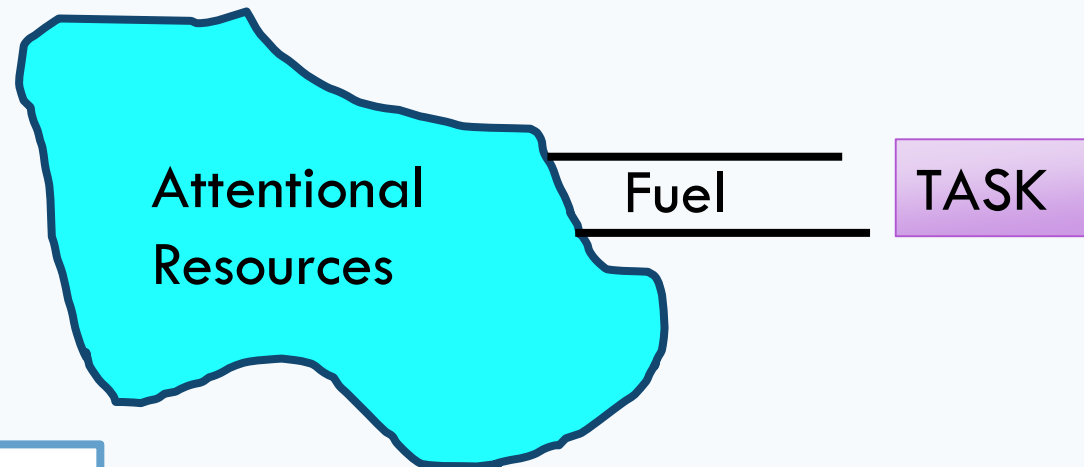
Emergent properties: In relation to real-world scenarios, far easier for a pilot to see this in relation to the spatial altitude of the aircraft.....



Than the same information being presented in numerical form.

DIVIDED ATTENTION & WORKLOAD

- **Resource theory:** dual-task interference emerges from an insufficiency of processing “energy”.
 - Attentional resources can be flexibly allocated to more than one task at a time, until all attention is allocated.
 - Hypothesises a “pool” of attentional resources and “fuel” to perform a task is taken from central reservoir.



**Kahneman, 1973;
Moray, 1967**

DIVIDED ATTENTION & WORKLOAD

- More difficult task = more resources & fuel required.
- Relationship represented in “performance-resource function” (PRF) graph.
- But: formula cannot always be applied
 - Highlights **data limited processing**.
 - If two tasks “compete” for limited attentional capacity, resource allocation can only go to one task.
 - But if demands of both tasks do not exceed attentional capacity, there can be a sharing of resources.
- Problems with resource theory:
 - Cannot account for all processing limitations.
 - Needs to explain what resources actually refer.
 - Hypothetical model - does not provide direct way of assessing assumptions.

DIVIDED ATTENTION & WORKLOAD

- But task procedures have been designed that require resource usage to be inferred.
 - Can examine resources when a task is performed in isolation
 - Enables us to distinguish how much spare attentional capacity the person performing the task has available.
 - E.g., if a pilot was able to deal with an emergency, there must be spare resources above performing basic task of flying.
- By changing task difficulty we can assess performance.
- Can anyone see any issues here?....
 1. Do not know if P will devote all resources to a task or not.
 2. Research is very specific & has little generalisability.

DIVIDED ATTENTION & WORKLOAD

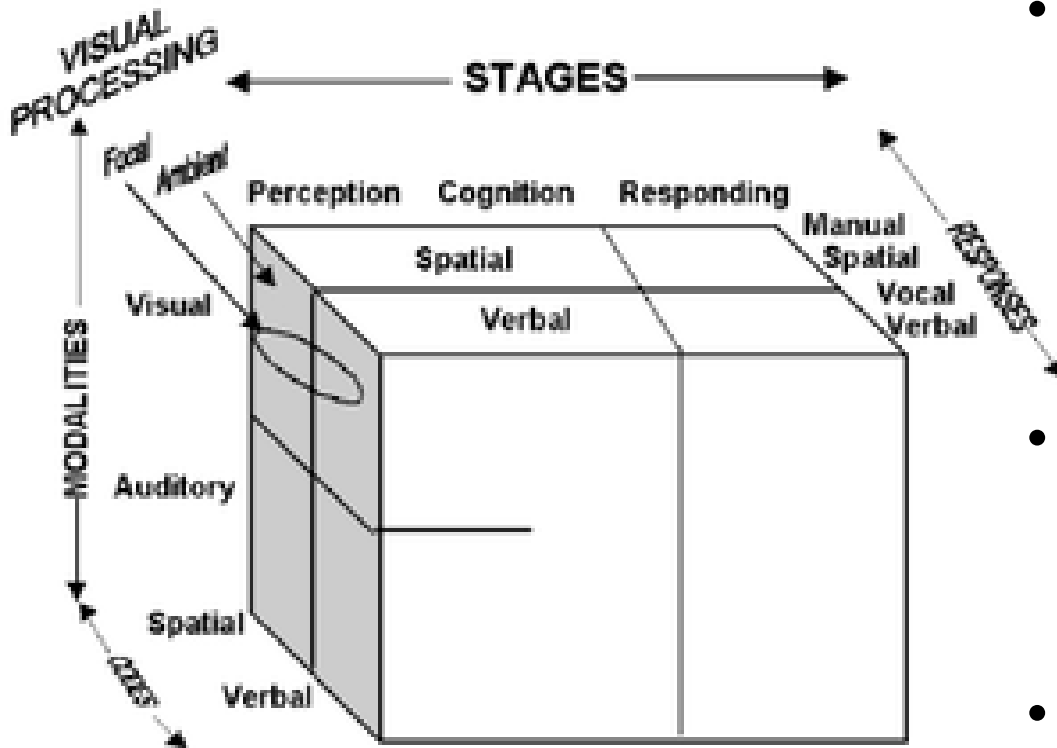
- To add backing to theories/models, researchers use physiological measures (association between cognitive and physical processes).
- However, there are issues with this:
 - (1) it is only a correlation
 - (2) there could be a range of other factors involved.
- Nevertheless, two physiological indicators of mental workload have been identified through....
 - (1) pupil diameter (Kahneman, 1973) and
 - (2) event related potentials (Kramer, 1991).
- Pupil diameter: linked to differences in task difficulty and effort.
 - But findings are mixed & factors not related to task (illumination) produce larger change in dilation than task manipulations.
- ERPs give the averaged recording of electro-cortical activity following the presentation of a stimulus or a response.

DIVIDED ATTENTION & WORKLOAD

- Wickens: For some dual-task combinations:
 1. The difficulty-sensitivity trade-off does not occur
 2. Performance on one task could be improved by changing the response format on the other task.
 - E.g., on tracking & tone detection task, performance would improve if response was vocal to the detection task rather than manual.
- Wickens (1980; 1984a; 1991): human attentional capacity should be viewed as having multiple resource pools.
- Dual-task interference greatest when tasks compete for similar resources, and least when they draw from different resource pools.

DIVIDED ATTENTION & WORKLOAD

- Wickens' model identifies dichotomies across each of the 3 orthogonal attentional resources (stages, modalities, codes).



- Stages: Tasks requiring early & central processing draw from different pool of resources than tasks requiring response selection.
- Processing codes: spatial & verbal draw from different resource pools.
- Processing modality: auditory and visual tasks drawn from different resource pools.

Also a distinction between Manual spatial and vocal verbal responding.

DIVIDED ATTENTION & WORKLOAD

- Issue with model:
 - Studies have shown an association between dual-task interference and semantic similarity of dual tasks.
 - Suggests findings from dual-task performance studies may be better described in terms of “crosstalk” between tasks rather than competition from resource pools.
- Processing in dual-tasks may be result of outcome conflict between two independent streams of processing.
- Stroop test provides an example of such an outcome:
 - Irrelevant word meaning activates colour naming response.
- But there is also evidence to suggest increases in task similarity can result in reduced dual-task interference,
 - Because similarity of 2 concurrently performed responses reduces competition.

DIVIDED ATTENTION & WORKLOAD

- Criticisms of the resource theory: Methodological issues.
 - Navon (1984): criteria for resource limitation could just be consequence of demand characteristics.
 - Uncertainty over how many dimensions of resources should be distinguished.
- Allport's (1980) architectural argument:
 - Serial processing assumption of resource theory is not compatible with parallel functioning of the brain.
- However, there are 2 counterarguments to the above:
 1. Software and hardware refers to different levels of explanation, so processing may operate serially even if hardware components operate in parallel.
 2. Seriality and resource limits in processing are distinct from one another.

SUMMARY OF DIVIDED ATTENTION AND WORKLOAD

- Attentional resource theory of capacity
 - Inspired the development of workload measures.
- Dual-task studies suggest “single-pool” theories do not account for the empirical data.
- Therefore, multiple resource theories were developed – e.g., Wickens’ model.
- However, further understanding is needed to account for task-similarity effects on interference, constraints on executive control of processing, and neuropsychological evidence.

NEXT WEEK

- Lecture: Models of Memory
- Seminar: Considerations for EWT.
- Reading: See module handbook