IST 605: Human Information Processing

Attention

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Outline

- What is Attention For?
- Functions of Attention
- Perceptual Attention
- Attentional Limits
- Capacity and Automaticity

What is Attention For?

- Attention
  - Means different things in daily speech
    - Attending to a lecture - concentration
    - Attending to a particular conversation in a crowded room - selection
    - Being able to attend to only so many things at one time - limits in capacity
    - No longer having to attend to skills that we perform well – automaticity
      - Conscious monitoring of the skill is no longer necessary

What is Attention For?

- What the Various Facets of Attention Have in Common
  - Recognition of the fact that people cannot do an infinite number of different things at the same time
  - With a lot of practice however, we do get better at doing many different things at the same time
  - Goal of cognitive theories of attention is to explain
    - The types of limitations that people have in processing information
    - How people learn to deal with those limitations

What is Attention For?

- Why are there limits in our attention?
- One possibility
  - We cannot process all the information in the environment as the environment gets complex
  - Example: Finding your guest at the airport
    - If your guest is the only one at the airport, it would be easy to find them
    - But if there are several other persons at the airport (i.e., environment is more complex), then it would be more difficult to find your friend

What is Attention For?

- Why are there limits in our attention?
- Another possibility
  - Our perceptual and cognitive systems are noisy
    - i.e., we do not perceive everything exactly as it appears in the environment, and
    - We do not make decisions about what to respond to perfectly all the time

What is Attention For?

- Ideal observer analysis
  - Tool (method) that psychologists use to investigate how information is processed in a perceptual system.
  - It is also a basic principle that guides modern research in perception
- The ideal observer
  - A theoretical system that performs a specific task in an optimal way
  - If there is uncertainty in the task, then perfect performance is impossible and the ideal observer will make errors

What is Attention For?

- Ideal performance
  - The theoretical upper limit of performance
  - It is theoretically impossible for a real system to perform better than ideal
  - Typically, real systems are only capable of sub-ideal performance

What is Attention For?

- Reasons why cognitive tasks ought to limit the amount of information that it processes
  - (A) There are too many possibilities (too many signals from the environment) for all of them to be considered efficiently
    - Limiting the number of items that are considered reduces the number of combinations to be entertained during processing
    - Keeping the number of possible combinations to a manageable number ensures that we are not overwhelmed by the possibilities

What is Attention For?

- Reasons why cognitive tasks ought to limit the amount of information that is processes
  - (B) Our action systems are limited
    - Examples
      - We have only two legs and arms
        - Hence we cannot grasp more than two things at a time
        - Nor move in more than one direction
      - When we speak, we can only say one word at a time
    - Hence, attention is useful for taking whatever information is being processed in parallel and transforming it in a way that facilitates action

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Functions of Attention

- Focussing
  - Limiting the number of items being processed
- Perceptual enhancement
  - Increasing the gain of a stimulus in the environment
- Binding
  - Combining perceptual information about different properties into a percept of a single object
- Sustaining behaviour
  - Maintaining an action in the presence of potential distractions
- Action Selection
  - Choosing an action to be performed from among a set of possibilities

Functions of Attention

- Focussing
  - Limiting the number of items being processed
- Example
  - Assume the friend you went to look for at the airport has brown hair
  - If you looked carefully only at people with brown hair, then you would be focusing

Functions of Attention

- Perceptual enhancement
  - Increasing the gain of a stimulus in the environment
- This is attention as a type of concentration
  - Analagous to turning up the volume of a car radio in order to hear the station better
  - Only works when the signal in the environment is clear
    - If the radio signal is clear, turning up the volume helps (to drown the noise from car tyres, other vehicles on the road, etc)
    - In the presence of static noise from the from the radio, then turning up the volume also turns up the noise, and perceptual enhancement is no longer an effective attention strategy

Functions of Attention

- Binding
  - Combining perceptual information about different properties into a percept of a single object
- Example
  - In low level visual perception, visual system identifies properties of objects (like edges)
  - At some point, this information must be brought together to create the perception of a coherent object - this is binding

Functions of Attention

- Sustaining behaviour
  - Maintaining an action in the presence of potential distractions
- Attention may be captured by salient events in the environment
  - Loud sounds, flashing lights etc.
  - Even in the presence of these potentially distracting signals, it is possible to concentrate on a single perceptual object to the exclusion of others

Functions of Attention

- Action Selection
  - Choosing an action to be perform from among a set of possibilities
- We are limited by the actions we can perform in the environment
  - Some mechanism must select some possible actions over others and order the actions we are going to perform

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Perceptual Attention

- We now look more in-depth at the functions of attention at the perceptual level

Perceptual Attention

- From experience, information about the immediate sensory environment persists for a while
- Example
  - Looking out of the window of a moving car
    - You perceive quite a lot
    - But after a few seconds, you can hardly recall what your perceived earlier on, as more new signals are perceived
    - This suggests limits on what information is taken in
      - This is confirmed by experiments (read on relevant experiments: Full Report Technique and Partial Report Technique)

Perceptual Attention

- Research points to the idea of a sensory store
- Sensory store
  - Records sensory information automatically, but the information decays after a brief period
  - Has a very high capacity
  - For visual perception, the sensory store is iconic memory
  - For auditory perception, the sensory store is echoic memory

Focusing: Selecting Channels

- At what point do we start to select some of the information in the environment for deeper processing?
- Imagine you are having a conversation with someone next to you in a crowded room
  - You succeed in filtering out other nearby conversations
  - Yet you are still able to process other auditory information
    - e.g., the loud sound of a jet flying
  - You are also capable of selecting and attending to other conversations
    - Example, a conversation far from you in which your name is mentioned

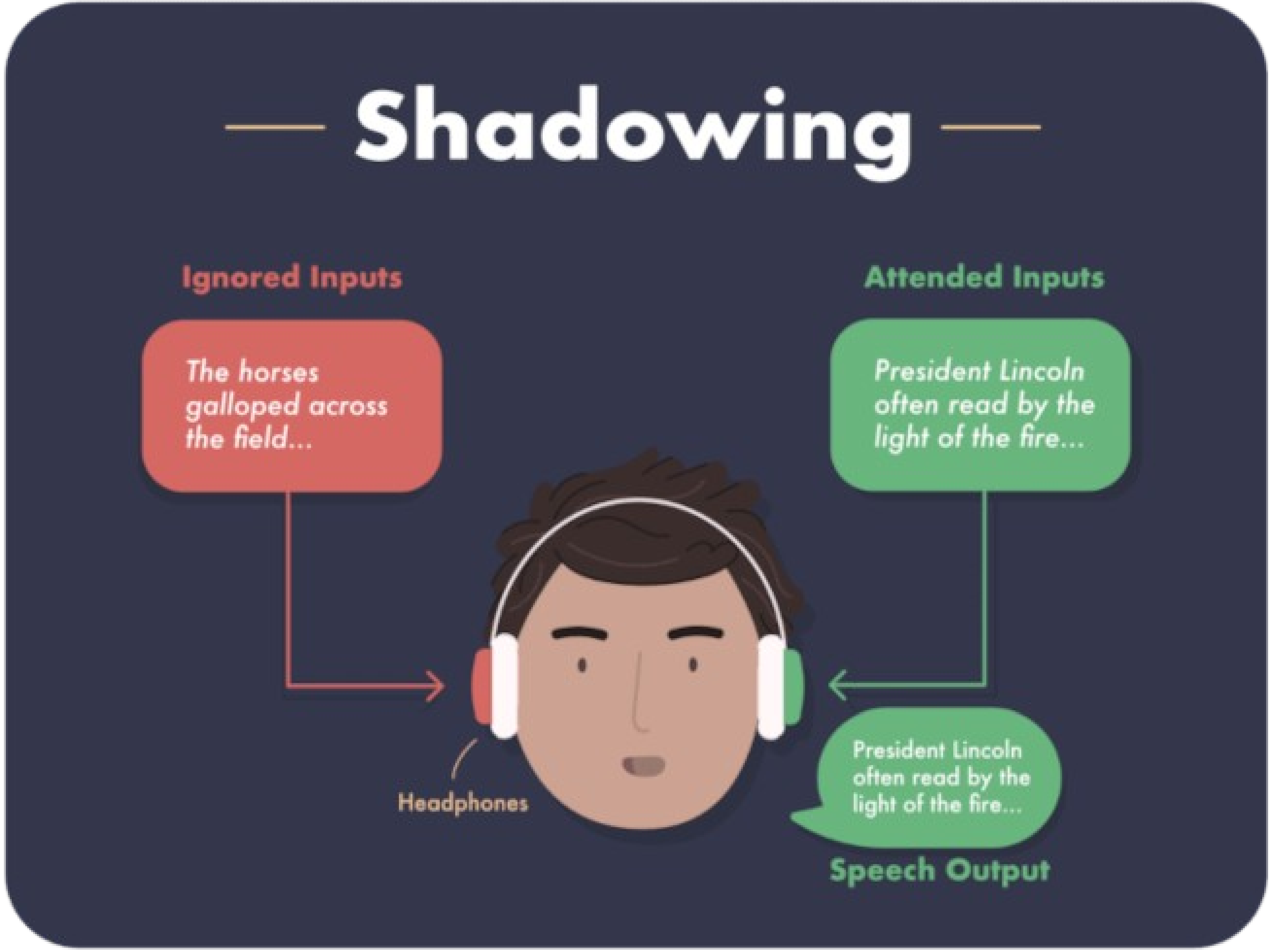
Focusing: Selecting Channels

- Clear from the above example that focusing attention does not mean other input is suppressed
  - Research suggests that salient stimuli like loud noises, flashing lights, etc. command attention by virtue of their extremeness
  - But how do you get to recognize your name called in a conversation that you were not part of across a noisy room? - Selective attention.
- Fundamental question on selective attention
  - What are the limits on a person's ability to
    - Select the most relevant input to attend to
    - Be aware of a significant event occurring outside their momentary focus of attention

Focusing: Selecting Channels

- Typical studies on selective attention
  - Present information on more than one channel (e.g., both ears)
  - Assess people's ability to track the information on only one (or a small number) of these channels
  - Example: dichotic listening experiment
    - Studies people's ability to localize sounds in space
    - Participant listens to a different recorded message played to each ear through earphones and tested afterwards on the messages heard

Dichotic Listening Experiment



Focusing: Selecting Channels

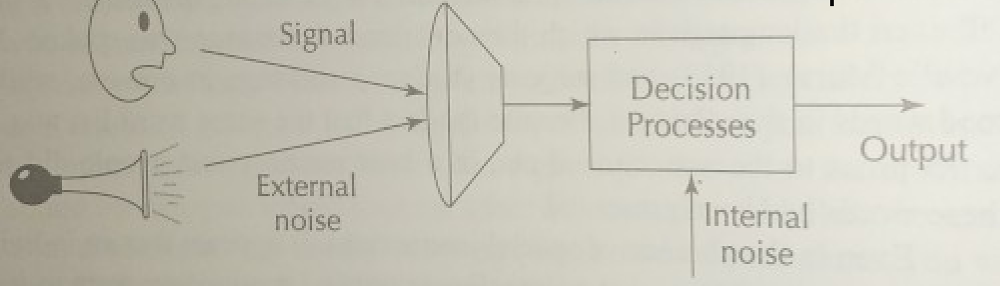
- Results of experiments on selective attention
  - When told to pay attention to the messages on one ear
    - People are aware that a voice was present in the other ear, but unable to say much beyond that
    - Even the language in which the distracting message was spoken

Focusing: Selecting Channels

- Results of experiments on selective attention
  - Even when not given instructions to pay attention to the message played to one ear
    - Individuals appear to attend to only one channel at a time
    - Example
      - The messages {6, 2, 9} played to one ear and {4, 7, 3} to the other ear are recalled as {6, 2, 9, 4, 7, 3}, rather than alternating e.g., {6, 4, 2, 7, 9, 5} even though that would enable one to order the numbers by the time they were heard

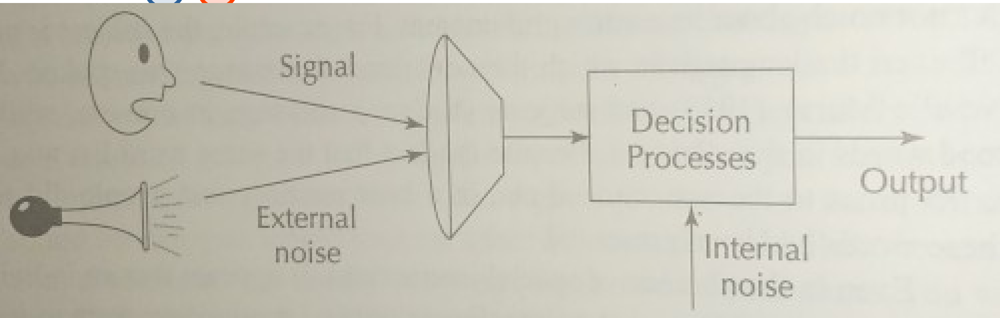
Perceptual Enhancement

- Often when something in the environment is hard to detect, we find ourselves **paying attention** in order to better perceive what is happening
- Perceptual enhancement plays a role
- Consider model below in which an individual is trying to pay attention to an item of interest (signal) in the presence of noise
  - At least 2 ways that attending to a perceptual stimulus might make perceptual processing more efficient
    - It makes the perceptual input stronger (i.e., amplifies both the signal and external noise)
    - It decreases internal noise (like errors in the functioning of neurones), making the internal representation and processing of information more efficient



Perceptual Enhancement

- Evidence from relevant research points to the following
  - Attention makes the perceptual input stronger
  - The processing is helped with reduction in the external noise (which is now not amplified by the attention system together with the signal)
  - Examples
    - By increasing the contrast between objects and their backgrounds
    - By shutting a car window to filter out external noise as the radio is turned on



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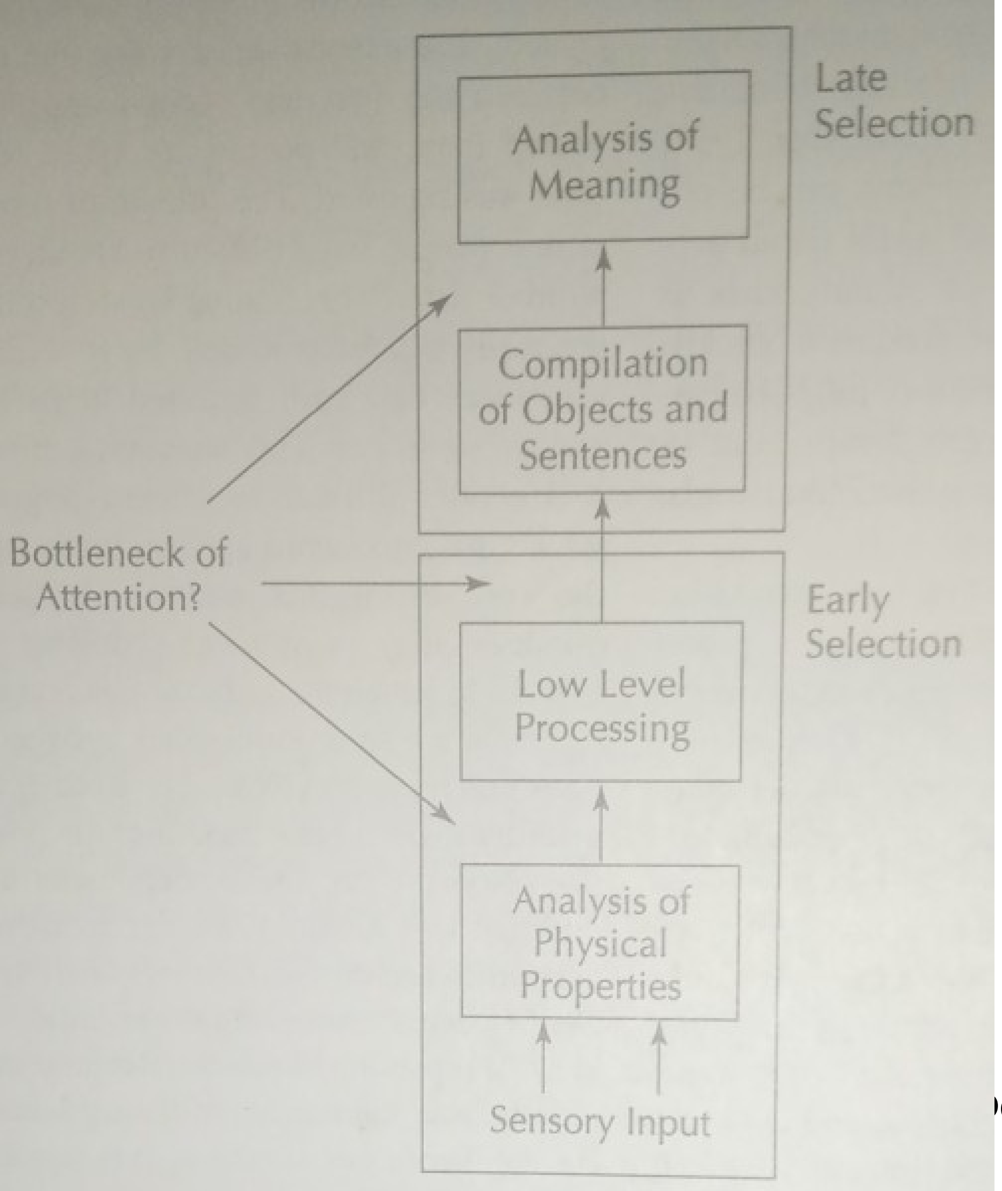
Location of Attentional Limits

- Previous discussion has considered
  - Focusing attention on a limited number of perceptual information (sensory stores)
  - Boosting the strength of the perceptual input (perceptual enhancement)
  - Need to also consider at what point in information processing do we start experiencing limits



Location of Attentional Limits

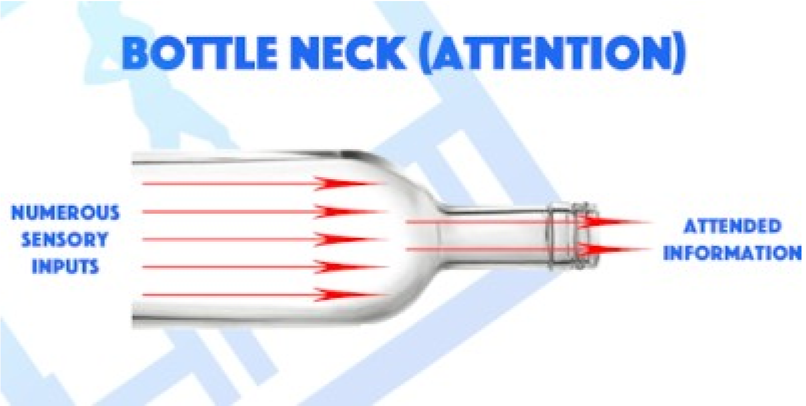
- Possible locations for limits shown in diagram
- What we already know
  - Sensory stores provide a vast amount of storage
  - Dichotic listening experiments suggest that eventual processing of the sensed signals is limited

Location of Attentional Limits

- Bottleneck theories of attention
  - Assume that all inputs are processed completely up to a certain stage
  - Only attended channels are processed more fully after that
- Capacity theories of attention
  - Assume that information processing requires cognitive resources
  - Limited resources can be allocated across the cognitive tasks that need to be performed

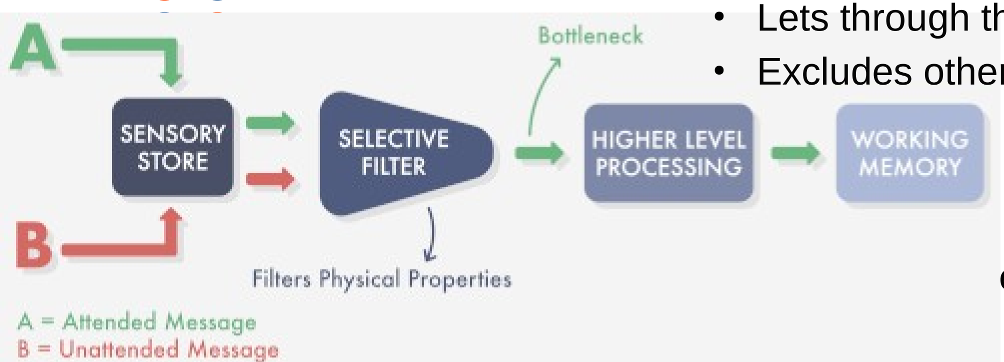
Bottleneck Theories of Attention

- Broadbent used findings from dichotic listening experiments to formulate a filter, or bottleneck model of attention



Broadbent’s Bottlenect Theory of Attention

- An individual’s mental apparatus includes a central processing system
  - Receives inputs from sensory channels
  - Compares them with items stored in memory to determine their meaning
  - Overload of central processor is prevented by means of a selective filter between the central processor and the outside world
    - Filter sifts incoming stimuli
      - Lets through those that have certain properties
      - Excludes others



Broadbent’s Bottlenect Theory of Attention

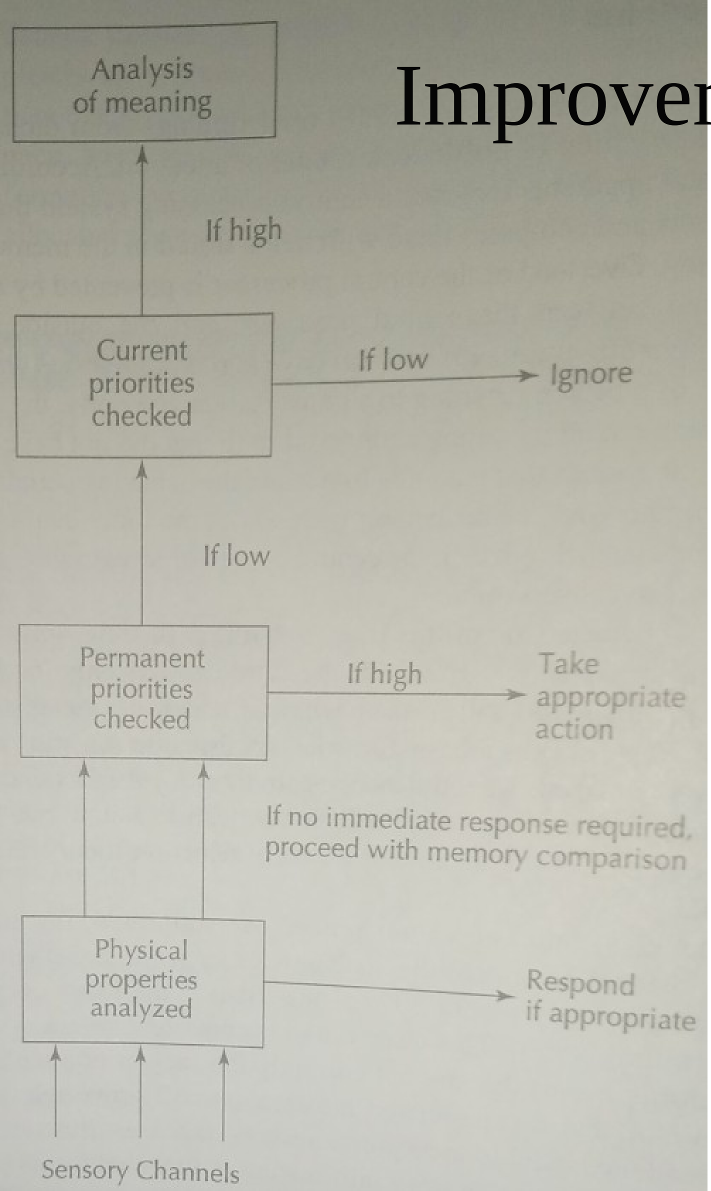
- Application to the person listening to a conversation at a party
  - Filter screens out all incoming auditory stimuli that did not have the properties of speech sounds
  - Of the sounds that pass the filter
    - Those having certain properties (e.g., voice of the conversation partner) are admitted to the input channel that the central processor is attending
    - Hence, individual can follow the conversation

Broadbent’s Bottlenect Theory of Attention

- The selective filter
  - Is flexible - one can readily shift attention to a different conversation
  - However, can only use lower level auditory characteristics
    - e.g., loudness, but not the meaning of the message
  - Bottleneck is produced by the fact that the filter cannot shift back and forth across sensory channels fast enough to follow two conversations at once
  - Broadbent’s theory is an example of an early selection theory of attention

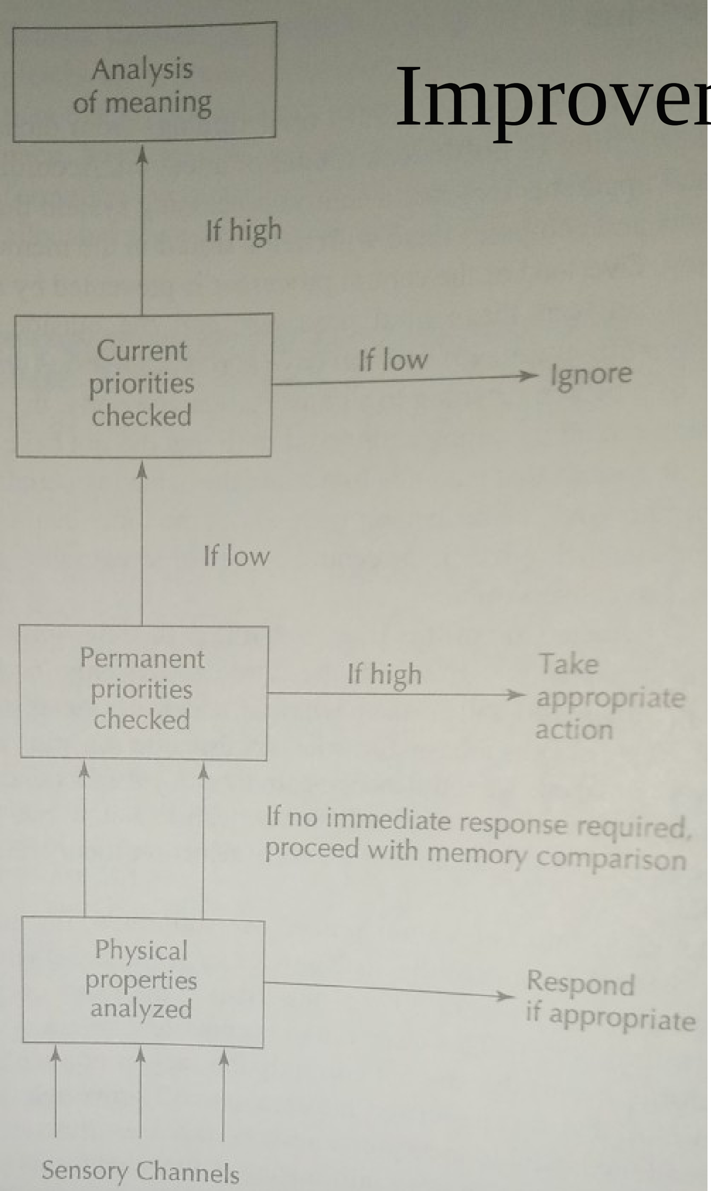
Improvements to Original Bottleneck Theory

- Conception of filter was oversimplified
- Example
  - Subjects overshadowing one channel in a dichotic listening experiment were able to notice their names with a significant frequency if the name occurs in an unattended channel
  - Observation suggests that our attention system is sensitive to high priority events that are not currently the subject of attention



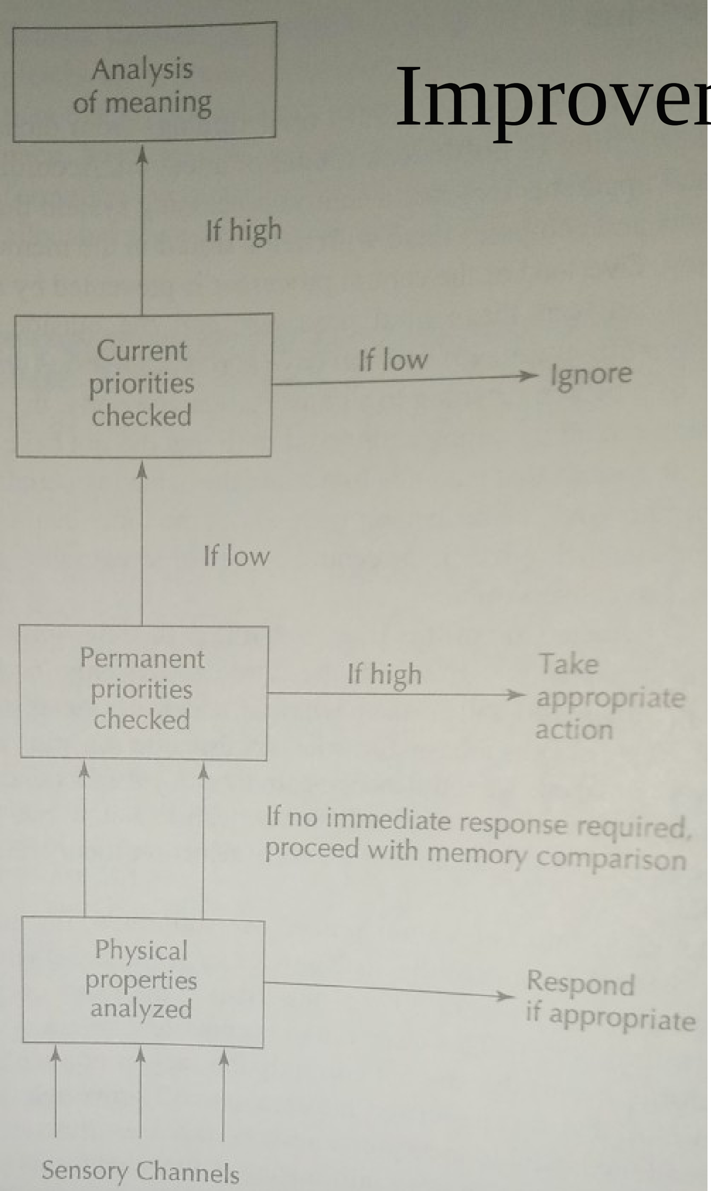
Improvements to Original Bottleneck Theory

- Model expanded to incorporate several stages
- Stage 1
  - Incoming stimuli analyzed for physical characteristics (pitch, speech vs non-speech properties, etc.)
  - If required by the task at hand, a decision or response can be made
    - Example: determining who is speaking



Improvements to Original Bottleneck Theory

- Stage 2
  - Stimuli checked against a list of high priority messages maintained in permanent memory
  - Examples
    - Danger signals
    - Vocal patterns of the individual's name
  - Such stimuli are attended to, at this stage

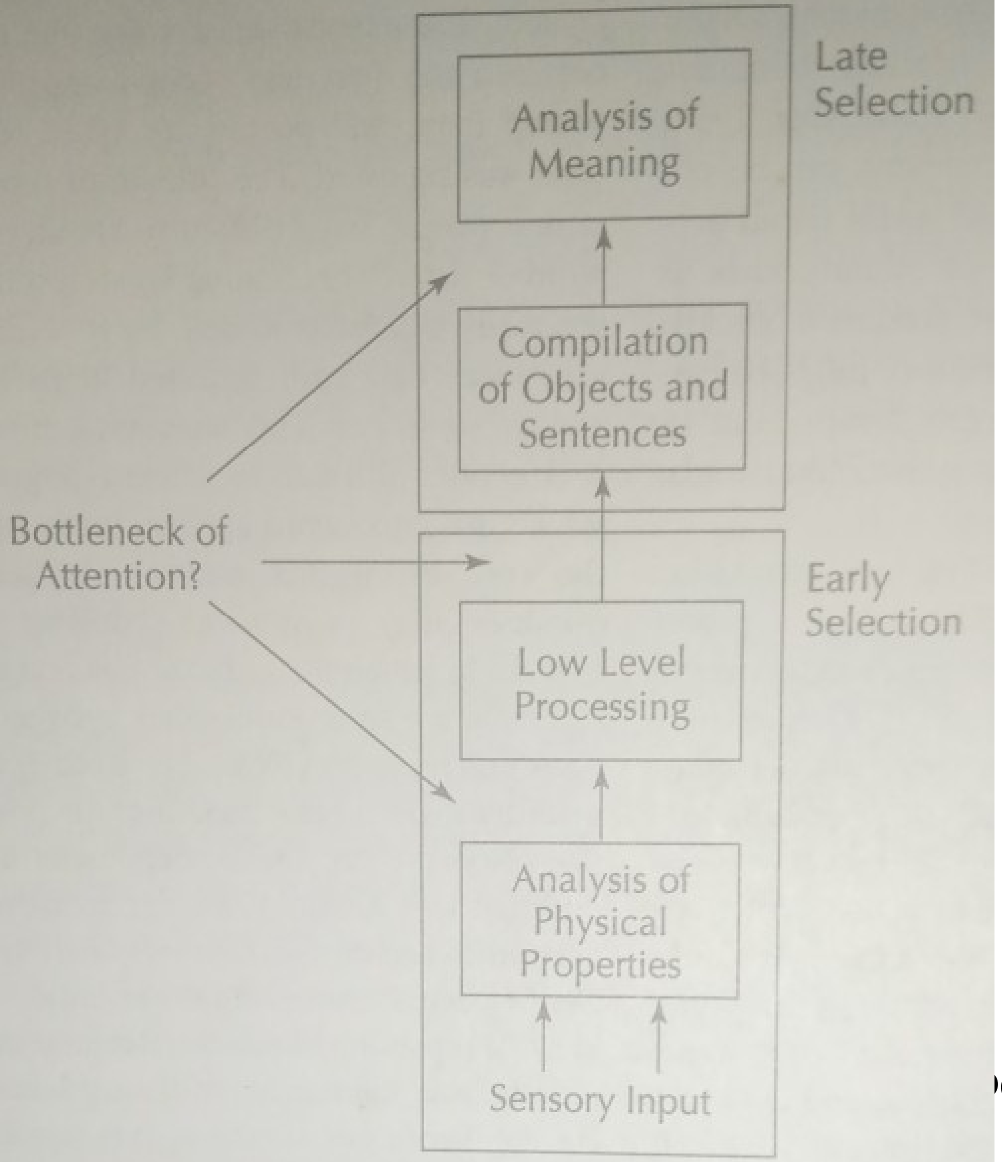


Improvements to Original Bottleneck Theory

- Stage 3
  - Stimuli not selected at Stage 2 (permanent priorities) matched against a list of Current priories
    - High priority stimuli would include things like sounds that match the voice of the conversation partner
    - Low priority stimuli would include voices of other people, or non-speech sounds
  - At this stage
    - Low priority signals are ignored
    - High priority signals are moved up for further processing, leading to comprehension of the meaning of the message

Role of Expectation

- Discussion above on Broadbent’s Bottlenect Theory of Attention suggests that a person’s expectations influence what information is processed
- Research confirms that, that is indeed the case



Late Selection

- Broadbent’s theory is an example of an early selection theory of attention
- Other research suggests that there are similar bottlenecks after stimuli have already been recognized and placed in short term memory
    - Information in short-term memory that is not rehearsed or elaborated is likely to be forgotten

Capacity Theories of Attention

- Basis
  - We have a limited pool of attentional resources
  - These resources are depleted as information is processed
  - Hence
    - Two tasks that do not need too much cognitive effort should not (are not expected to) interfere with each other
    - Whether or not two tasks interfere with each other depends on how much they draw on the same resource pools
    - Because resources can be allocated, if one task is more important than another, resources can be devoted to the more important task at the expense of the less important one

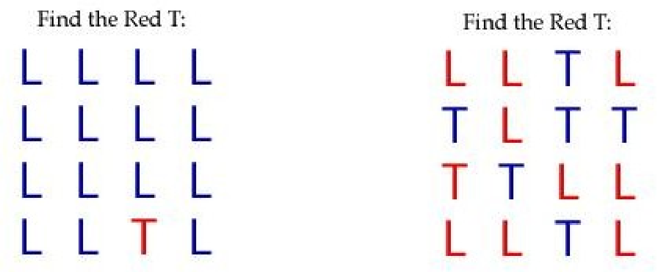
Capacity Theories of Attention

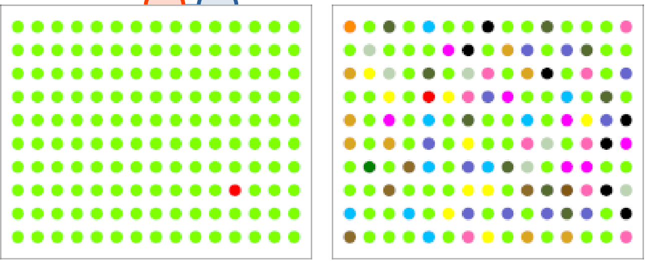
- Resource pools
  - Evidence suggests that there are multiple pools of resources
    - Example, a pool for visual tasks and a pool for auditory tasks
  - This could explain why auditory and visual tasks can be performed more easily together than two visual or two auditory tasks

Binding

- Binding perceptual features together into coherent representation of objects
- An object in the world consists of a number of properties that occur at a single spatial location (e.g., colour and shape: a red triangle)
  - These properties are initially processed independently – as a shape and as a colour
  - At some point, this information is brought back together – this is binding

Visual Search Task





Find the red circle. It is easier in the left panel.
This is called the "pop out" effect.

- Provides support to the proposal that attention influences creation of object representations, i.e., binding
  - A set of objects is presented in a display (Display size = Number of objects)
  - People are asked to search for a target object, e.g., red circle (the non-target objects are distractors)
    - Searches for a single distinct object (e.g., red T in a sea of blue letters) is quite easy
      - Consistent with the idea that if we focus on a single dimension (e.g., colour), it is easy to distinguish between distinct values (red and blue)
    - However, searching for a red **T** against a background of red **L**s and blue **T**s is quite difficult
      - It is more difficult searching for a conjunction of properties: colour and Letter T

Visual Search Task

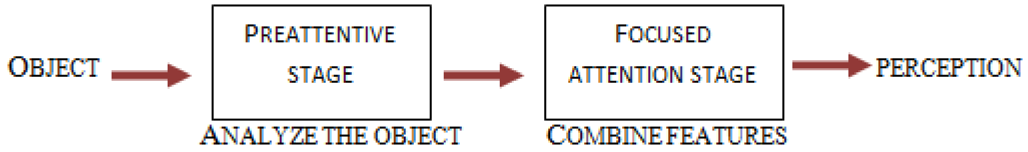
- Index of difficulty: the time it takes to search
  - Search time does not increase when a single feature is searched, irrespective of display size
  - Search time increases with display size when search is for conjunctions
    - To understand why, need to consider what it means for a conjunction of features to be part of the same object

Conjunction of Features in Vision

- 2 features are part of the same object if they they occupy the same location in space and time
  - Green triangle
    - Co-occurrence of the colour green and the shape triangle in the same location in space
    - We must combine information about ***what*** is in the world (triangle, green thing) and ***where*** it is located
    - (there is neuropsychological evidence that the **what system** and the **where system** of the brain are neuroatanomically separable, parallel systems
      - i.e., they appear to operate in parallel rather than sequentially

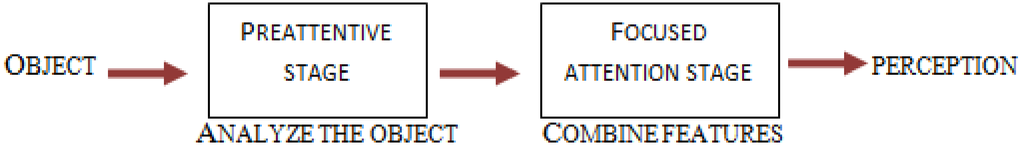
Conjunction of Features in Vision

- Feature integration theory of attention
  - One of the most influential psychological models of human visual attention
  - Suggests that when perceiving a stimulus, features are "registered early, automatically, and in parallel, while objects are identified separately" and at a later stage in processing
  - Pre-attentive stage
    - Different parts of the brain automatically gather information about basic features (colours, shape, movement) that are found in the visual field



Conjunction of Features in Vision

- Feature integration theory of attention
  - Second stage (focused attention stage)
    - Individual features of an object are combined to perceive the whole object
    - This requires attention, and selecting that object occurs within a "master map" of locations
    - The master map of locations contains all the locations in which features have been detected
    - When attention is focused at a particular location on the map, the features currently in that position are attended to



Attention in Complex Tasks (i.e., Higher Level Attention)

- As tasks that people carry out become more complex, how are different tasks and different perceptual modalities coordinated?
- An important line of research here is the influence of learning on attention
  - How does learning decrease the the amount of attention required to carry out cognitive tasks?

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Capacity and Automaticity

- We have all experienced the fact that with practice, we need less mental effort to do a task, e.g., driving a car
- Automaticity
  - Most stringent view: a process is automatic if it requires no cognitive resources to carry out
  - In most cases though: automaticity means that there is a significant reduction in the perceived difficulty of the task
- There is experimental evidence that whether practice leads to a reduction of attentional demands depends on type of practice and on the structure of the task

Research on Automaticity

- Typical scenario: Visual search task
  - Subject asked to tell if a target (say T) appears in a display (e.g., of letters BKQR), that is shown briefly on a screen
  - Typical result (Sternberg, 1966)
    - The time it takes to say that a target is in the display increased by 35-40 ms for each item in the display
    - So, if it takes 320 ms to plan and make a response, for a display with 2 items in it, it would take 390-400 ms
- What would happen if people were able to practice (i.e., learn) the task?

Visual Search Task with Practice

- 2 scenarios: Consistent mapping and Varied mapping
- Consistent mapping
  - If an item is a target on one trial, it never appears in the display unless it is a target
  - In the example above, the letter T would only appear in a display on trials when T is the target, but not when some other letter is the target
    - i.e., T would never be a distractor (the target set and distractor set do not overlap)
  - Example of consistent mapping
    - Detecting a letter among digits (or a digit among letters)
- Varied mapping
  - The distractor set and the target set overlap
    - Example: Detect a letter among other letters (or a digit among other digits)
    - A given letter may appear on some trials as target, on others as a distractor

Visual Search Task with Practice

- When people are given a lot of practice with a search task, consistent and varied mapping yield different results
- Varied mapping
  - Time to respond that a target was in the display increased with number of letters in the display
  - But the reaction time was lower, evidence that learning helped
  - However, the amount of time for each additional item increased by a constant amount, as in Sternberg (1966)
- Consistent mapping
  - Reaction time was similarly lower
  - But search time per additional item was substantially lower