Auditory Attention

Hearing – unlike vision – is not directional. We can't avoid hearing things that are in the environment, but we can avoid looking at them.

Disentangling sounds

Hearing makes use of both intensity and wave-position differences – the size of inter-aural difference indicates the direction a sound is coming from.

Both are used as neither are effective for all types of sounds – long wavelength (low pitch) sounds that are longer than the width of the head are not shadowed by it (unlike short wavelength, high pitched sounds.) This means intensity cues are only available for sounds of short wavelength. In contrast, detecting that the direction of long wavelength, low pitched sounds comes from inter-ear comparisons.

The two methods complement each other – the change from one to the other occurs when wavelength=head width. Problems occur if the wavelength is around head width size as neither process is then fully effective.

Attending to sounds

Ability of auditory system to separate sounds based on their source direction => possible to listen to a particular sound without confusion - our '**spotlight of attention**' can be directed to the sound we want to listen to.

Broadbent – **dichotic listening** experimental technique was one of the earliest researchers in this area (early 1950s); results have been repeated and built on by others – e.g. **Treisman** (1960s).

Dichotic listening – headphones used to play a different sound to each ear. Shown that attending to a message in one ear, participants could recall virtually nothing of the unattended message – even language.

Two exceptions to this finding:

(a) If messages short (3 words), participants could report both messages => short lived storage mechanism present.

(b) If the attended message was more than a few seconds long, unprocessed material from the other ear is lost.

The auditory system's ability to hold onto a sound for a short while is termed **echoic memory**.

Was also demonstrated that the gender of an unattended voice could be identified as male or female; this distinction can be used to follow a message – shown by alternating a message between ears.

Explanation for findings: the brain is processing sound into speech **serially**, but the earliest stages of processing must take place in **parallel** – or how would we know what we wanted to attend to? **Broadbent**'s 1954 theory was therefore that a 'gate' operated – opening to one stream of information but closed to everything else.

Application – **Broadbent** addressed the difficulty pilot had in understanding a message from interfering stations. Rather than play the same sounds to each ear, inter-aural differences used to direct attention to the desired message by playing it through both sides and the interference through just one side of the earphones. To the pilot, interference now appeared to come from both sides and the wanted signal in the middle of them – dichotic listening in action. So good the MoD rejected it as being a falsified result! **Naish**, 1990, demonstrated using stereo, therefore giving a directional quality to aircraft warning sounds in the cockpit, pilot response times became significantly shorter – e.g. if direction of warning can be made to come from where the approaching missile is, it helps!

Eavesdropping on the unattended message

More sophisticated research mechanisms suggested flaws in **Broadbent**'s theory. The often reported **cocktail party effect** is an anecdotal rebuttal – how does your 'serial' brain know that someone who you weren't listening to has said your name across the other side of the room?

Treisman suggested instead of the all or nothing process described by **Broadbent**, the ability to pick out your name could be explained by an **attenuation** process. This acts as a **filter**, 'turning the volume down' for everything except the attended signal. For an unattended signal for which we are very sensitive too (our own name), sufficient residual information would be being processed and so get our attention.

Shadowing (dichotic listening technique) experiments demonstrate this effect. Participant repeats aloud everything said in one ear, demanding concentration. When the shadowed message ends, the participant appears ignorant of what was said in the other ear.

If the storyline swaps ears during shadowing, participants tend to swap ears too as they follow the sense of the story (**Broadbent**'s original theory is deficient in this regard – how could this happen if the other ear was being totally ignored?)

Treisman's explanation for this phenomenon is that the story sensitises the listener to the next possible words – an effect known as **priming** (similar to the permanent sensitisation we have to our own name, for example.) Has been demonstrated to exist experimentally – e.g. through **lexical decision tasks**. If participants are asked if a string of letters spells a word they respond faster if a word is preceded by one related to it.

Follow up work by **Corteen and Wood** (1972) showed a wider variety of stimuli could gain our attention too. One experiment used a mild electric shock when a word was presented from a specific category (eg city.)

Associated formed between the shock and category, leading to a **galvanic skin response** (changes in arousal) when subsequent words of the same category were then presented - e.g. applied in lie detectors.

The second part of the experiment showed that if one of the category words was presented to an unattended ear, then there was still such a response even if nothing could be consciously remembered about what had been presented to the unattended ear.

Such research led psychologists to question the 'serial' nature of the brain w.r.t. auditory attention. **Deutsch and Deutsch** (1963) suggested all messages are processed, attended or not; **Norman** (1968) proposed unattended messages must get sufficient processing to activate relevant semantic memories (**See Ch. 8**).

Shows that people can be influenced by material of which they have no conscious knowledge. Modern computer based research (**See Ch. 16**) can now emulate brain-like parallel processing - not possible at the time the original research was conducted. However, recent studies also show that early stages of analysis are modified by attention - **Broadbent** would have recognised this as an example of filtering.

Visual Attention

We don't see everything around us at the same time, but we can see more than one thing at once. As we appear to be able to receive visual information in parallel, perhaps similar attention problems are present in vision as in hearing - as if visual information is handled in the same way, various items in the field of view will activate representations in memory simultaneously. If so it would lead to similar effects as for hearing - e.g. we could be influenced by things which we did not know we had seen.

We have to disentangle overlapping speech streams and similarly, visual objects overlap and obscure each other - the brain therefore has to work out what parts of images 'go together. (*See Ch. 3*)

Heads-up displays demonstrate visual attention can be linked to specific objects (not just regions of space) - pilots have the sensation of focussing on the information it provides or on the foreground scene.

Knowing about unseen information

Sperling (1960) - grids of 3 rows of 4 letters - participants shown for 50ms - recall of 3 or 4 letters typical.

Explored further - auditory cue (different for top, middle, bottom) played after letters had been removed. Typical report of 3 or 4 letters from the specific row. Result implies that participants registered nearly all the 12 letters to be able to report on a specific row - **partial report superiority effect**.

Effect also observed if letters printed in two colours and the tone used to cue for which colour to report.

The brief moment when all letters appear to be accessible termed **iconic memory** (c.f. **echoic memory**.)

Like auditory attention, selection and serial processing concept has been challenged subsequently.

Use of **backward masking** and **priming effects** to study this. **Stimulus onset asynchrony** (SOA) of between 10 and 50ms often leaves participants unable to say if a target was present, let alone what was on it.

Evett and Humphreys - sequences of stimuli containing two words, both backward masked. If second word related to first (e.g. tiger to lion) it was more likely to be reported accurately - a priming effect.

Cheeseman and Merikle - challenged by demonstrating even though participants say they cannot see the first word, they are better than chance at saying if a word had been presented. Argued a conclusion could only be reached if participants could identify if a target had been presented at chance - and under such conditions, no evidence for priming found.

Pecher et al used the same technique with two changes - (i) with priming word shown for a short or long (1s) duration; (ii) two sets of trials used - one with 10% related words; the other with 90% related.

Found: On long duration primes, priming effect produced a 15% advantage in the 10% condition and a 40% advantage in the 90% condition - as participants often able to guess correctly.

On short duration primes, advantages were 7% and 9% respectively - but still statistically significant. However, small increase from 7 to 9% between conditions is not.

Conclusion: In short duration condition, participants unable to guess, but a small priming effect is present, suggesting some information from the masked words gets through.

Towards a theory of parallel processing

Sperling-type experiments show that participants can name an additional one or two letters when pressed, but do not know position and colour information. Interesting as the more complex (letter identity) information is remembered but the 'simpler' colour/position information is not.

Coltheart - suggested items do not reach conscious awareness unless both semantic and episodic information is detected. You can't have an 'N-feeling' in the absence of the letter, even if position/colour is in the field of view. Attention is therefore not selecting material for complex serial processing but the joining of two parallel processes - **identification** and **episodic characterisation.**

Rapid serial visual presentation

Backward masking operates in one of two ways - **integration** and **interruption** - **Turvey**.

SOA between target & mask v. short => integration (both items perceived as one.)

SOA between target & mask longer => interruption Occurs even if target and mask presented to different eyes - so such a dichoptic interaction must take place in the brain.

Contrasts with integration which does not occur dichoptically when target & mask presented to different eyes => early in analysis, maybe on the retina. Therefore:

Turvey - integration = peripheral masking
interruption = central masking

Broadbent - RSVP procedure. A series of (say 20) stimuli in rapid succession, SOAs short (display time of 100ms; gap of 20ms between each stimulus typical.) Participants look for two stimuli - T1 and T2.

One variant is a single target of a white letter on a black background; all others inverse. Asked to look for an 'X'(T2) after seeing the white letter(T1). T2 seen if immediately after T1, then less likely to be detected unless 5 or 6 items separate T2 from T1. A report of T2 does not mean semantic analysis carried out - **Vogel** demonstrated this by using words as targets rather than single letters. Before stimuli presented, a context is presented to prime T2 (e.g. context=shoe; T2=foot) Some T2 presentations not in context. EEG monitoring shows a 'signature' when such a mismatch occurs. The participants produced the effect even if they could not report the T2 word they had been presented with. Therefore, something about T1 is causing the problem.

It is the **attentional blink** (**refractory period**) - 500-700ms needed to prepare to process something new.

Raymond found time is not the only factor - removing the item after T1 and leaving a gap of 100ms (reducing the backward masking) improves T1 report rate (not surprising) and also T2 report rate - more surprising - the AB had disappeared.

Giesbrecht and Di Lollo - made T2 the last item on the list. Found T2 could always been seen (regardless of how T1 was presented) if this was the case - again, no AB.

Two stage model of visual processing developed to explain this result and that making T1 easier to see helps T2 detection.

Stage 1 - Information on identity, size, colour, position etc. of target captured in parallel.

Stage 2 - Serial processes prepare the information for awareness and report.

While stage 2 is operating, later information cannot be processed so is held at stage 1. Disruption to T1 of any kind makes the T2 information wait longer - allowing it to be overwritten by a later stimulus. The wait is most damaging to episodic information e.g. an item cannot be both white and black. Semantic information survives better. Even if there is insufficient information for T2 to be fully processed, it can reveal its presence through priming effects or EEG.

There is some similarity to **Coltheart**'s idea - both require the need to join semantic and episodic detail.

Masking and attention

Merikle and Joordens conclude that tasks made difficult by masking (the evidence in this chapter) are comparable to giving participants two tasks so they cannot focus on the target (the issue of attention) - the same underlying processes are at work - therefore, the results of masking experiments are useful for investigating the nature of attention.

Integrating information in clearly-seen displays

Serial and parallel search

Harder to find an odd target out if the difference is colour and shape, rather than just colour or shape (**Treisman.**) Two differing dimensions require more effort than one, even though the features are simple and picked up in the early stages of visual processing. However, the different analysis types (shape, colour) takes place in different areas of the brain - so have to be integrated together - c.f. the way attention appears necessary to integrate semantic and episodic information. Conclusion is that processing is serial and takes longer when there are more items to process.

Known that the parietal region of the brain is involved in attention. **Triesman** investigated with a participant who had been impaired through a stroke in that region. Shown two letters from (T,X,O) in a choice of three colours (Red, Blue, Yellow.) Mistakes often made, but would rarely respond 'Yellow X' to a Blue T and Red O - instead, 'Blue O' / 'Red T' mistakes made. Implies features identified correctly, but the integration of the features has failed as attention is required to do this.

Non-target effects

Triesman's **feature integration theory** has been challenged. **Duncan and Humphreys** found searching for a single 'L' within a field of 'T's (with some 'T's on their side) took longer than searching just within a field of 'T's or 'T's on their side - would not be predicted by this theory. Argued the result shoed that part of finding the target involves rejecting non-targets as well - harder if non-targets are more varied.

Note that this result does not rule out that integration needs to occur - just that non-targets also need to be recognised during search.

Flanker effect

Known that one word can prime another. **Shaffer and LaBerge** found evidence of priming effects even when words were presented in a way to eliminate priming.

Found that using column of three words where the middle word is the target and the top and bottom words are flankers that category recognition of the middle word was faster if the top and bottom words are of the same category. Implies that some parallel processing of flankers occurs while the target word is processed. Similar to the Stroop effect for non-similar flankers.

[Emotional Stroop Test – **Dudley et al** – depressed people are extra slow in responding to depression related words (like sadness) in a Stroop test – moreso than say people with early stages of Alzheimer's. Can therefore be used as a diagnostic tool]

Result of **Shaffer and LaBerge** creates problem for **Triesman**'s theory – as this argues a person focusing on the target could not be processing the flankers at the same time.

Broadbent and Gathercole suggested the explanation was that the target word primed the flankers so they could be detected with an absolute minimum of attention – *i.e. it's not unrelated flankers that make the task harder, but related flankers making the task easier.* (*) Modification of the **Shaffer and LaBerge** procedure used so that the target appears 40ms before the flankers. If this proposition is true, related flankers should prime even more effectively as the target has been given a 'head start'. Results showed this to be the case.

Other explanation possible – **Gellatly et al** suggests by making the flankers appear late, it ensures attention is taken away from the target. So a convincing demonstration of parallel processing would require all different stimuli to be presented simultaneously.

Attention and distraction

The ability to have attention taken away from a target may have been advantageous from a survival perspective, but is problematic in open plan offices or attempting to study with other distractions taking place. Some distractions are worse than others …

The effects of irrelevant speech

Six item serial recall task – participants perform 30% worse if someone is talking nearby, even if they've been told to ignore them (**Jones, 1999**.)

Dichotic listening tasks show ignored auditory material may be processed – its meaning affects the perception of attended material. However, the content of spoken material seems to interfere with memory of visual material even if it is not related – e.g. hearing numbers spoken when trying to remember presented digits is no more damaging than hearing anything else (**Buchner et al**). However, white noise is almost as benign as silence. The interference comes from the 'difference' in the speech sounds.

Rhyming words are less disruptive than non-rhyming words (**Jones and Macken**). **Jones**' explanation is that speech consists of strings of sounds that have to be organised into auditory objects to be recognised. Occurs automatically. When simple repetitions are present, it becomes simpler, interfering less.

'k,l,m' experiment – **Jones et al** – demonstrates this. Disruptive, as they have different sounds, but if played in such a way that k is in one ear, m in the other and l sounds as if it is between the two, then repeated, it is no longer as disruptive as playing the three sounds as a continually changing sequence.

Impact of irrelevant speech shows parallel processing not always possible. There is a 'bottleneck' – as envisaged in very early theories of attention.

Attending across modalities

In noisy surroundings, we supplement our hearing by lip reading. An example of this is the **ventriloquism effect** – seen in cinema sound and vision systems – actor's voice appears to come from the screen, but the loudspeakers are positioned to the side of it.

Driver – two messages from a loudspeaker below a monitor. One message to be shadowed. Lip reading helps a little with this task. Play the same messages but position the speaker to one side gives the illusion of spatially separate messages and the task becomes simpler.

Has a practical impact – e.g. use of mobile phones. A single ear earpiece has the effect of sounding as if the voice comes from one side – distracting the driver's attention away from the road ahead and hence their responsiveness – **Spence, 2002**.

The neurology of attention

fMRI is used to show how areas of the brain behave when responding to speech. These areas are also activated when a person moves their lips but makes no sound. Implies connections between visual and auditory processing areas.

The effects of brain damage

Damage to one of the two parietal lobes leads to **(sensory) neglect**. Patients are likely to ignore someone standing on the neglected side (opposite to the damage) or draw a flower or clock face with only the parts that are present on the unaffected side. i.e. it is sometimes half the *object* that is neglected, not half the field of view.

This has been demonstrated formally by **Driver and Halligan**. Pairs of pictures that look like chess piece silhouettes. When an 'addition' was on a neglected side the participant could not see it. But by tilting the object on its side so that the addition came into the side that did not suffer from neglect, the participant was still unable to detect the difference, showing the effects of neglect to be object-related.

Bisiach and Luzzatti demonstrated that neglect is not only related to objects that are physically present. A patient was asked to describe a scene they new well from two different viewpoints - only buildings in the side that did not suffer from neglect were described each time.

This finding demonstrates memory being intact, but not completely accessible.

Balint's syndrome – a more extreme form of neglect. Patients find it difficult to shift their attention from one object to another – e.g. they only see the flame when trying to light a cigarette, only see a person's spectacles and not their face.

Implies we all see the world as a series of objects. Unless our attentive process has been damaged we are able to shift our attention rapidly from one object to another.

Damage to the ventral stream (*See Ch 6*)results in different integration problems – individuals aware of all aspects of a scene but they are perceived as small elements - e.g. a paint brush is a wooden stick with a black object (bristles).

Humphreys - the presence of these different types of problems are evidence that binding together of different features takes place in different stages and in different brain locations.

Event-related potentials

Sensing something eventually causes neurons to 'fire'. These ERPs can be detected by monitoring equipment. Information as to the sequence of brain activities can therefore be determined.

Woldorff et al – studied ERPs evoked by sounds, including signals occurring as quickly as 10ms after the event. This speed of response implies the ERPs must have originated in the brain stem – the first 'relay' between ear and auditory cortex. Registration at the cortex was 20-50ms after the event. While 10ms signal not affected by attention, magnitude of signal at cortex is smaller for unattended sounds. This result supports the theory attention is due to an (attenuating, not eliminating) filter that is very early in the processing sequence.

Conclusions

Attention:

- Acts to help us focus on one sound out of many
- Has a role in joining together features that make up an object
- Studies of brain damage suggests the feature assembly role ensures we perceive objects rather than their parts
- Gathering together related information from different senses is controlled by attention
- Plays a role in dealing with competition between the senses

Allport – attention is to direct actions. In many situations although we can perceive many things at once it is not sensible to attempt to do more than one thing at a time. E.g. if there are lots of food items available, we need to pick one to eat – otherwise we would starve! (**)

Research study - Hypnosis, time and attention

When hypnotised, the areas of the brain concerned with attention show unusual activity when a patient becomes able to tolerate pain (**Crawford et al**) or hallucinates (**Szechtman et al**). Not common, but nearly all people who are hypnotised think it lasts for less time than is actually the case.

Naish explains by linking it to **Gray**'s theory of consciousness. This suggests we take 'snapshots' of our environment – which are the contents of our conscious awareness. Because in hypnosis we are not asked to focus on fast changing stimuli (in fact, the opposite), we need to take fewer snapshots, making us less aware of time passing.

Issue of consciousness is still relevant -e.g. the difference between new and experienced drivers – effortful control becomes automatic, eventually.

Attention is applied to many different roles and processes – but even so, eventually lead to one result – conscious awareness. Therefore, **Naish** concludes 'Attention is the process which gives rise to conscious awareness'

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Link to emotion and cognition: MacLeod et al – 'dot probe' task – if a participant is faster to find the dot where a threatening item was (e.g. cancer), then reasonable to assume that the person's attention was directed there rather than to a neutral item (e.g. mother). Non-anxious participants slightly faster for neutral stimuli; anxious participants the other way around. Results consistent with emotional Stroop tests – an attentional bias.

(*) More recent research provides support and challenges to the flanker effect reported by **Broadbent and Gathercole**. **Finkbeiner and Forster (2007)**: Only attended material can have a flanking effect; but **Gronau, Cohen and Ben Shakhar (2009)** unattended material can be processes and flank - if it is relevant to the task at the focus of attention.

(**) **Humphreys et al (2010)** Found **perception being strongly influenced by potential for action** - like **Allport** – // processing of the brain has to be directed by attention to **act** on one thing at once. These may be groups of related items, as well as single items.