Attention

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Contents

Introduction 4
Learning Outcomes 5
1 Auditory attention 6
1.1 Introduction 6
1.2 Disentangling sounds 6
1.3 Attending to sounds 10
1.4 Eavesdropping on the unattended message 11
1.5 Summary of Section 1 13
2 Visual attention 14
2.1 Introduction 14
2.2 Knowing about unseen information 15
2.3 Towards a theory of parallel processing 17
2.4 Rapid serial visual presentation 18
2.5 Masking and attention 23
2.6 Summary of Section 2 23
3 Integrating information in clearly-seen displays 24
3.1 Introduction 24
3.2 Serial and parallel search 24
3.3 Non-target effects 25
3.4 The ‘flanker’ effect 26
3.5 Summary of Section 3 28
4 Attention and distraction 29
4.1 Introduction 29
4.2 The effects of irrelevant speech 29
4.3 Attending across modalities 30
4.4 Summary of Section 4 31
5 The neurology of attention 31
5.1 Introduction 31
5.2 The effects of brain damage 31
5.3 Event-related potentials 34
5.4 Summary of Section 5 34
6 Concluding thoughts 35
Further reading 36
Conclusion 37
Keep on learning 37
References 38
Acknowledgements 40

Introduction

For many of us the concept of attention may have rather negative connotations. At school we were told to pay attention, making us all too aware that it was not possible to listen to the teacher while at the same time being lost in more interesting thoughts. Neither does it seem possible to listen effectively to two different things at the same time. How many parents with young children would love to be able to do that! One could be excused for feeling that evolution has let us down by failing to enable us to process more than one thing at a time. If that is how you feel, then this course might add insult to injury, because it will cite evidence that we do in fact process a good deal of the material to which we are not attending. Why, you might ask, do we go to the trouble of analysing incoming information, only to remain ignorant of the results? To attempt an answer it is necessary to consider a range of issues, stretching from registration of information by the sense organs, through the processes of perception, to the nature of awareness and consciousness. Attention is a broad and intriguing topic. That breadth makes it very difficult to offer a simple definition of the term, so I will not attempt to do so until the end of the course.

This OpenLearn course provides a sample of Level 3 study in Social Sciences.

Learning Outcomes

After studying this course, you should be able to:

- understand different cognitive psychological aproaches used to examine such forms of attention as attention to regions of space, attention to objects and attention for action
- summarise the different cognitive psychological approaches under a fairly abstract definition of the term
- understand how ideas about attention have changed and diversified over the last fifty years and how well they have stood up to examination.

1 Auditory attention

1.1 Introduction

To cover some of the concept of attention (we have only a course, and there are whole books on the subject) I shall follow an approximately historical sequence, showing how generations of psychologists have tackled the issues and gradually refined and developed their theories. You will discover that initially there seemed to them to be only one role for attention, but that gradually it has been implicated in an ever-widening range of mental processes. As we work through the subject, two basic issues will emerge. One is concerned with the mechanisms of attention, and raises questions such as:

- How much material can we take in at once?
- What happens to information to which we did not attend?
- In what circumstances does attention fail, allowing unwanted information to influence or distract us?

The other theme has a more philosophical flavour, and raises questions concerning why we experience the apparent limitations of attention:

- Are the limitations simply an inevitable characteristic of a finite brain?
- Have we evolved to exhibit attention – that is, does it confer advantages?

We shall begin to explore these issues by looking at the ways in which one of our senses (hearing) has developed to facilitate attention.

1.2 Disentangling sounds

If you are still feeling aggrieved about the shortcomings of evolution, then you might take heart from the remarkable way in which the auditory system has evolved so as to avoid a serious potential problem. Unlike our eyes, our ears cannot be directed so as to avoid registering material that we wish to ignore; whatever sounds are present in the environment, we must inevitably be exposed to them. In a busy setting such as a party we are swamped by simultaneous sounds – people in different parts of the room all talking at the same time. An analogous situation for the visual system would be if several people wrote superimposed messages on the same piece of paper, and we then attempted to pick out one of the messages and read it. Because that kind of visual superimposition does not normally occur, there have been no evolutionary pressures for the visual system to find a solution to the problem (though see below). The situation is different with hearing, but the possession of two ears has provided the basis for a solution.

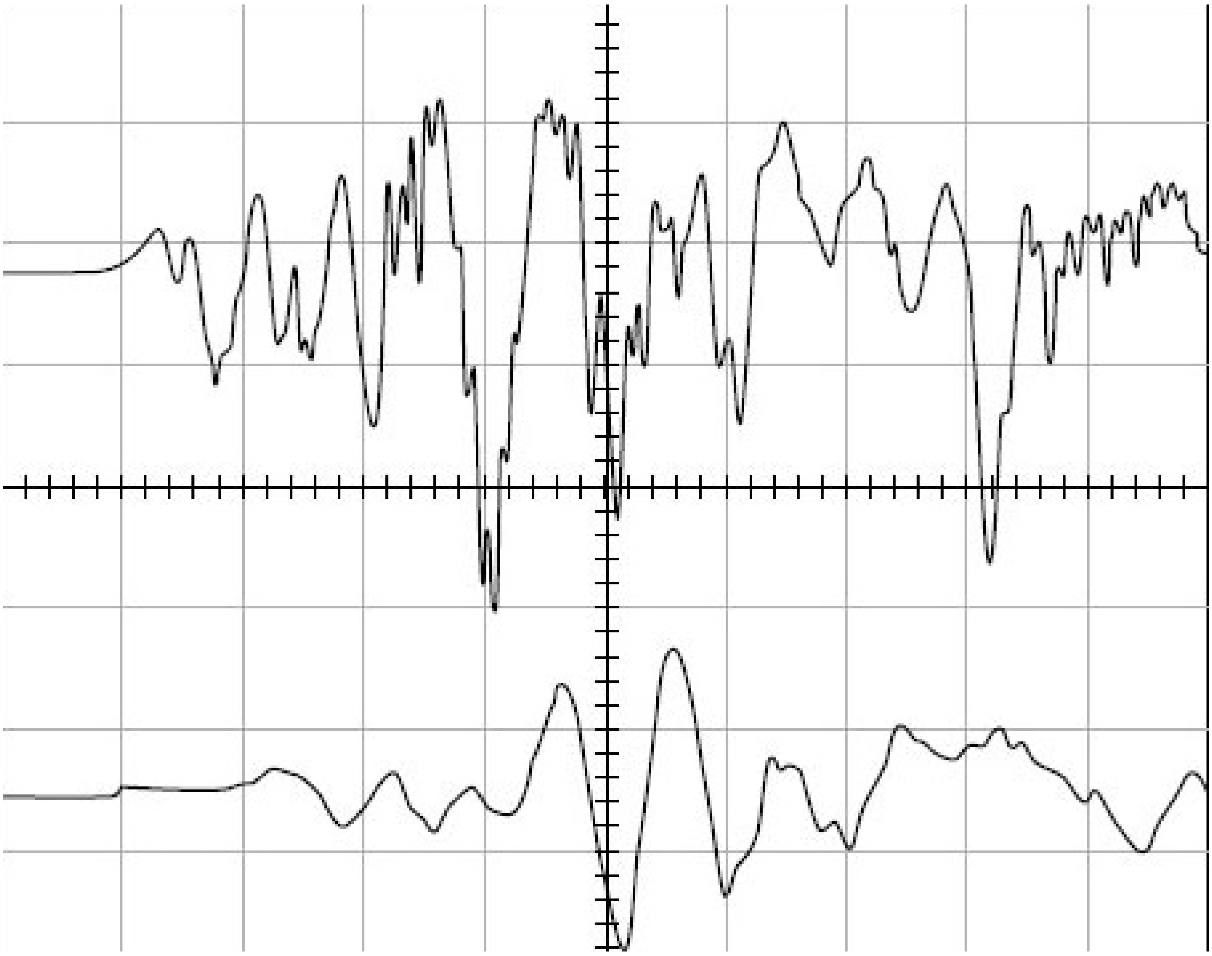


Figure 1 The waveform of a hand clap, recorded at the left (upper trace) and right (lower trace) ears. Horizontal squares represent durations of 500 microseconds (a microsecond is one-millionth of a second); vertical divisions are an arbitrary measure of sound intensity

Figure 1 shows a plot of sound waves recorded from inside a listener's ears. You can think of the up and down movements of the wavy lines as representing the in and out vibrations of the listener's ear drums. The sound was of a single hand clap, taking place to the front left of the listener. You will notice that the wave for the right ear (i.e. the one further from the sound) comes slightly later than the left (shown by the plot being shifted to the right). This right-ear plot also goes up and down far less, indicating that it was less intense, or in hearing terms that it sounded less loud at that ear. These differences, in timing and intensity, are important to the auditory system, as will be explained.

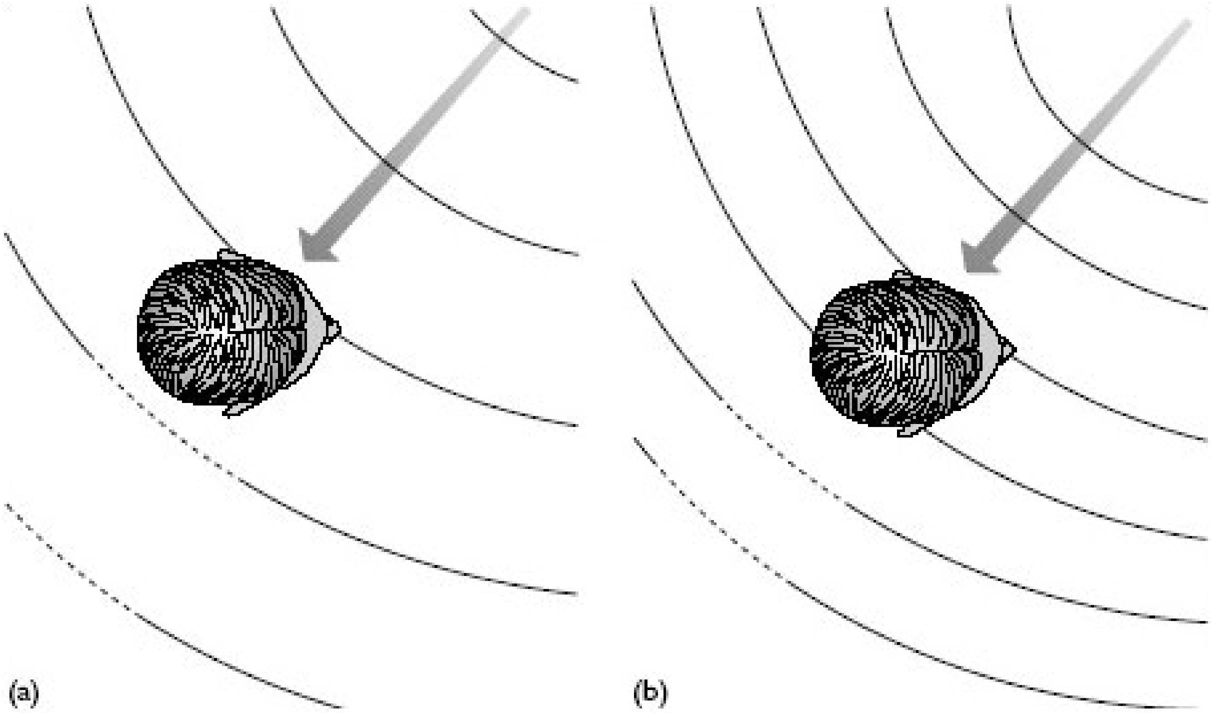


Figure 2 Curved lines represent wave crests of a sound approaching from a listener's front left. In (b) the sound has a shorter wavelength (higher pitched) than in (a), so waves are closer together, with a crest at each ear

Figure 2a represents sound waves spreading out from a source and passing a listener's head. Sound waves spread through the air in a very similar way to the waves (ripples) spreading across a pond when a stone is thrown in. For ease of drawing, the figure just indicates a ‘snapshot’ of the positions of the wave crests at a particular moment in time. Two effects are shown. First, the ear further from the sound is slightly shadowed by the head, so receives a somewhat quieter sound (as in Figure 1). The head is not a very large obstacle, so the intensity difference between the ears is not great; however, the difference is sufficient for the auditory system to register and use it. If the sound source were straight ahead there would be no difference, so the size of the disparity gives an indication of the sound direction. The figure also shows a second difference between the ears: a different wave part (crest) has reached the nearer left ear than the further right ear (which is positioned somewhere in a trough between two peaks). Once again, the inter-aural difference is eliminated for sounds coming from straight ahead, so the size of this difference also indicates direction.

Why should we make use of both intensity and wave-position differences? The reason is that neither alone is effective for all sounds. I mentioned that the head is not a very large obstacle; what really counts is how large it is compared with a **wavelength**. The wavelength is the distance from one wave crest to the next. Sounds which we perceive as low pitched have long wavelengths – longer in fact than the width of the head. As a result, the waves pass by almost as if the head was not there. This means that there is negligible intensity shadowing, so the intensity cue is not available for direction judgement with low-pitched sounds. In contrast, sounds which we experience as high pitched (e.g. the jingling of coins) have wavelengths that are shorter than head width. For these waves the head is a significant obstacle, and shadowing results. To summarise, intensity cues are available only for sounds of short wavelength.

In contrast to the shadowing effect, detecting that the two ears are at different positions on the wave works well for long wavelength sounds. However, it produces ambiguities for shorter waves. The reason is that if the wave crests were closer than the distance from ear to ear, the system would not be able to judge whether additional waves should be allowed for. Figure 2b shows an extreme example of the problem. The two ears are actually detecting identical parts of the wave, a situation which is normally interpreted as indicating sound coming from the front. As can be seen, this wave actually comes from the side. Our auditory system has evolved so that this inter-ear comparison is made only for waves that are longer than the head width, so the possibility of the above error occurring is eliminated. Consequently, this method of direction finding is effective only for sounds with long wavelengths, such as deeper speech sounds.

You will notice that the two locating processes complement each other perfectly, with the change from one to the other taking place where wavelengths match head width. Naturally occurring sounds usually contain a whole range of wavelengths, so both direction-sensing systems come into play and we are quite good at judging where a sound is coming from. However, if the only wavelengths present are about head size, then neither process is fully effective and we become poor at sensing the direction. Interestingly, animals have evolved to exploit this weakness. For example, pheasant chicks (that live on the ground and cannot fly to escape predators) emit chirps that are in the 'difficult' wavelength range for the auditory system of a fox. The chicks' mother, with her bird-sized head, does not have any problems at the chirp wavelength, so can find her offspring easily. For some strange reason, mobile telephone manufacturers seem to have followed the same principle. To my ears they have adopted ringtones with frequencies that make it impossible to know whether it is one's own or someone else's phone which is ringing!

Activity 1

1. Set up a sound source (the radio, say), then listen to it from across the room. Turn sideways-on, so that one ear faces the source. Now place a finger in that nearer ear, so that you can hear the sound only via the more distant ear. You should find that the sound seems more muffled and deeper, as if someone had turned down the treble on the tone control. This occurs because the shorter wavelength (higher pitched) sounds cannot get round your head to the uncovered ear. In fact you may still hear a little of those sounds, because they can reflect from the walls, and so reach your uncovered ear 'the long way round'. Most rooms have sufficient furnishings (carpets, curtains, etc.) to reduce these reflections, so you probably will not hear much of the higher sounds. However, if you are able to find a rather bare room (bathrooms often have hard, shiny surfaces) you can use it to experience the next effect.
2. Do the same as before, but this time you do not need to be sideways to the sound. If you compare your experiences with and without the finger in one ear you will probably notice that, when you have the obstruction, the sound is more 'boomy' and unclear. This lack of clarity results from the main sound, which comes directly from the source, being partly smothered by slightly later echoes, which take longer routes to your ear via many different paths involving reflections off the walls etc. These echoes are still there when both ears are uncovered, but with two ears your auditory system is able to detect that the echoes are coming from different directions from the main sound source, enabling you to ignore

them. People with hearing impairment are sometimes unable to use inter-aural differences, so find noisy or echoing surroundings difficult.

1.3 Attending to sounds

From the earlier sections, you will appreciate that the auditory system is able to separate different, superimposed sounds on the basis of their different source directions. This makes it possible to attend to any one sound without confusion, and we have the sensation of moving our ‘listening attention’ to focus on the desired sound. For example, as I write this I can listen to the quiet hum of the computer in front of me, or swing my attention to the bird song outside the window to my right. Making that change feels almost like swinging my eyes from the computer to the window and the term **spotlight of attention** has been used to describe the way in which we can bring our attention to bear on a desired part of the environment.

My account so far has explained the mechanisms that stop sounds becoming ‘jumbled’ and reminds us that, subjectively, we listen to just one of the disentangled sounds. It seems obvious that they would need disentangling to become intelligible, but why do we then attend to only one? That question leads us into the early history of attention research.

One of the first modern researchers formally to investigate the nature of auditory attention was Broadbent (1952, 1954), who used an experimental technique known as **dichotic listening**. This offers a way of presenting listeners with a simplified, more easily manipulated version of the real world of multiple sounds. Participants wear a pair of headphones, and receive a different sound in each ear; in many studies the sounds are recorded speech, each ear receiving a different message. Broadbent and others (e.g. Treisman, 1960) showed that, after attending to the message in one ear, a participant could remember virtually nothing of the unattended message that had been played to the other, often not even the language spoken.

Broadbent's experiments showed that two refinements should be made to the last statement. First, if the two messages were very short, say just three words in each ear, then the participant could report what had been heard by the unattended ear. The system behaved as if there were a short-lived store that could hold a small segment of the unattended material until analysis of the attended words was complete. Second, if the attended message lasted more than a few seconds, then the as yet unprocessed material in the other ear would be lost. The store's quality of hanging on to a sound for a short time, like a dying echo, led to it being termed the **echoic memory**.

It was also shown that people would often be aware of whether an unattended voice had been male or female, and they could use that distinction to follow a message. Two sequences of words were recorded, one set by a woman, the other by a man. Instead of playing one of these voice sequences to each headphone, the words were made to alternate. Thus, the man's voice jumped back and forth, left to right to left, while the woman's switched right to left to right. In this situation participants were able to abandon the normal ‘attending by ear’ procedure, and instead report what a particular speaker had said; instead of using location as a cue for attention, they were using the pitch of the voice.

The explanation for these findings seemed straightforward. Clearly the brain had to process the information in a sound in order to understand it as speech. In this respect, the brain was rather like a computer processing information (computers were beginning to appear at that time), and everyone knew that computers could only process one thing at a time – that is, **serially**. Obviously (theorists thought) the brain must be serial too, so, while processing the information of interest, it needed to be protected from all the rest: it needed to attend and select. However, the earliest stages of processing would have to take place in **parallel** (i.e. taking in everything simultaneously), ensuring that all information would potentially be available, but these initial processes would have to utilise very simple selection procedures; anything more complex would demand serial processing. The procedures were indeed simple: attention was directed either on the basis of the direction of a sound, or on whether it was higher or lower pitched. Broadbent's (1954) theory was that, after the first early stage of parallel information capture, a 'gate' was opened to one stream of information and closed to the rest.

Box 1 Research study: Application of research on auditory attention

Donald Broadbent's early career included research for the UK Ministry of Defence, and his findings often led to innovation. One problem he addressed was the difficulty pilots experienced, when trying to pick out a radio message from a number of interfering stations (radio was less sophisticated then). Pilots' headphones delivered the same signals to each ear, so it was not possible to use inter-aural differences to direct attention to the wanted message. Broadbent devised a stereo system, which played the desired signal through *both* headphones, while the interference went only to one or the other. This made the interference seem to come from the sides, while the signal sounded as if it was in the middle (identical waves at the two ears). In effect, this was dichotic listening, with a third (wanted) signal between the other two. The improvement in intelligibility was dramatic, but when Broadbent played a recording to officials they decided that it was so good that he must have 'doctored' the signal! The system was not adopted. Decades later, I demonstrated (Naish, 1990) that using stereo, and giving a directional quality to the headphone warning sounds used in aircraft cockpits, could result in significantly shorter response times. Thus, the warning indicating an approaching missile could be made to seem as if coming from the missile direction, so speeding the pilot's evasive measures. The next generation of fighter aircraft may at last incorporate '3-D' sound.

1.4 Eavesdropping on the unattended message

It was not long before researchers devised more complex ways of testing Broadbent's theory of attention, and it soon became clear that it could not be entirely correct. Even in the absence of formal experiments, common experiences might lead one to question the theory. An oft-cited example is the **cocktail party effect**. Imagine you are attending a noisy party, but your auditory location system is working wonderfully, enabling you to focus upon one particular conversation. Suddenly, from elsewhere in the room, you hear someone mention your name! If you were previously selecting the first conversation, on the basis of its direction and the speaker's voice, then how did your 'serial' brain manage to process another set of sounds in order to recognise your name?

Addressing this puzzle, Treisman (1960) suggested that, rather than the all-or-nothing selection process implied by Broadbent, the ability to pick out one's name could be explained by an **attenuation** process. The attenuation process would function as if there were a **filter**, ‘turning the volume down’ for all but the attended signal. Although that would leave most unattended material so attenuated as to be unnoticed, for a signal to which we were very sensitive, such as our own name, there would be sufficient residual information for it to be processed and hence attract our attention. Treisman devised a series of ingenious experiments which supported this idea. Many of her studies involved **shadowing**, a dichotic listening technique which requires the participant to repeat aloud everything that is heard in one ear, following like a shadow close behind the spoken message. (NB this is not to be confused with the very different ‘head shadowing’ referred to earlier.) This task demands concentration, and when the shadowed message ceases the participant appears to be completely ignorant of what was said in the other ear.

In one experiment Treisman actually made the storylines in the messages swap ears in the middle of what was being said. Thus, the left ear might hear:

*Little Red Riding Hood finally reached the cottage, but the wicked wolf was in * beds; one was large, one medium and one small*.

Meanwhile, the right ear would receive:

*When she had finished the porridge, Goldilocks went upstairs and found three * bed, dressed in the grandmother's clothes*.

The asterisks indicate where the storylines swap ears. The interesting finding is that when asked to shadow one ear participants tend to end by shadowing the other, because they follow the sense of the story. Broadbent's position could not explain that, since the listener could not know that the story continued in the other ear, if that ear had been completely ignored. Treisman, on the other hand, claimed that the story temporarily sensitised the listener to the next expected words, just as with the permanent sensitisation associated with our own name. Sensitisation of this temporary kind is known as **priming**, and many experimental techniques have demonstrated its existence. For example, in a **lexical decision task** (a task that requires participants to indicate as quickly as possible whether or not a string of letters spells a real word), people can respond much more quickly to a word if it is preceded by another related to it. For example, the ‘Yes’ is given to *doctor* (yes, because it is a word) more quickly when presented after the word *nurse* than when following the word *cook*.

Treisman's ideas stimulated a succession of experiments, some seeming to show that information could ‘get through’ from a wider range of stimuli than one's own name or a highly predictable word in a sentence. For example, Corteen and Wood (1972) carried out a two-part experiment. Initially they presented their participants with a series of words, and each time a word from a particular category (city name) appeared the participant was given a mild electric shock. In this way, an association was formed between the shock and the category. Although the shocks were not really painful, they inevitably resulted in something like mild apprehension when one of the critical words was presented. This response (which once learned did not require the shocks in order for it to continue) could be detected as a momentary change in skin electrical resistance. The sweat glands of a nervous person begin to secrete, and the salty fluid lowers the resistance to a small (non-shocking) electric current. The change is known as the **galvanic skin response (GSR)** and has been used in so-called lie detectors. Corteen and Wood connected their participants to GSR apparatus when they started the second part of the experiment: a dichotic listening task. As usual, participants could later remember nothing about the unattended message, but the GSR showed that each time the ignored ear received one of the ‘shocked’ words there was a response. Moreover, a GSR was detected even to words of the same category, but which had not been presented during the shock-association phase. This generalising of the response to un-presented words strengthens the claim that their meanings were established, even when not consciously perceived.

Not surprisingly, at this stage of research into auditory attention a number of psychologists began to question the idea that the brain could not process more than one signal at a time. Deutsch and Deutsch (1963) suggested that *all* messages received the same processing, whether they were attended or not; Norman (1968) proposed that unattended information must at least receive sufficient processing to activate relevant semantic memories (i.e. the memory system that stores the meanings of words. These suggestions certainly explained the intriguing dichotic listening results, showing people to be influenced by material of which they seemed to have no knowledge. However, the ideas, if true, would require the brain to be far more parallel in its function than had been supposed. At that time there was neither an analogue by which parallel processing could be conceptualised, nor sufficient neuroanatomical information to contribute to the debate. Today there is ample evidence of the parallel nature of much of the brain's processing and, additionally, computers have advanced to the stage where brain-like parallel processing can be emulated. Thus, modern researchers have no difficulty in conceptualising parallel processing and the nature of the attention debate has shifted somewhat. Nevertheless, recent studies have also revealed that early stages of analysis are modified by attention, effects that Broadbent would have immediately recognised as examples of filtering. We shall explore these issues in more depth, after first considering the nature of attention in visual processing.

1.5 Summary of Section 1

The auditory system is able to process sounds in such a way that, although several may be present simultaneously, it is possible to focus upon the message of interest. However, in experiments on auditory attention, there have been contradictory results concerning the fate of the unattended material:

- The auditory system processes mixed sounds in such a way that it is possible to focus upon a single wanted message.
- Unattended material appears not to be processed:
  - The listener is normally unable to report significant details concerning the unattended information.
  - Only the most recent unattended material is available, while still preserved in the echoic memory.
- These results suggest parallel acquisition of all available information, followed by serial processing to determine meaning for one attended message.
- Although there is little conscious awareness of unattended material, it may receive more processing than the above results imply:
  - Words presented to the unattended ear can produce priming and physiological effects.
  - Participants trying to ‘shadow’ one ear will follow the message to the other ear.
- These results imply that processing takes place in parallel, to the extent that meaning is extracted even from unattended material.

2 Visual attention

2.1 Introduction

I introduced Section 1 by suggesting that the auditory system had a special problem: unlike the visual system, it needed processes which would permit a listener to attend to a specific set of sounds without being confused by the overlap of other, irrelevant noises. The implication of that line of argument was that vision had no need of any such system. However, although we do not see simultaneously *everything* that surrounds us, we can certainly see more than one thing at a time. Earlier, I wrote of attending to the sound of the computer in front of me, or of the birds to one side. I can do much the same visually. While keeping my eyes directed to the computer screen, I can either attend to the text I am typing or, out of the corner of my eye, I can be aware of the window and detect a bird when it flies past. If our eyes can receive a wide range of information in parallel, does that give the brain an attentional problem analogous to that of disentangling sounds? If visual information is handled in much the same way as auditory information seems to be, then we might expect the various items in the field of view to activate representations in memory simultaneously. That should lead to effects equivalent to those found in listening experiments; in other words, it might be possible to show that we are influenced by items which we did not know we had seen. We shall examine evidence of this shortly, but I shall first draw your attention to another area of similarity between hearing and seeing.

I pointed out at the start of Section 1.2 that, whereas we often have to follow one speech stream while ignoring others, we do not normally have to disentangle overlapping handwriting. However, it is worth bearing in mind that visual objects do overlap and hide parts of each other, and the brain certainly has the problem of establishing which components of the image on the retina 'go together' to form an object.

As with hearing, a variety of cues is available to help in directing visual attention. Taking my window again as an example, I can either look at the glass and see a smear (I really must get round to washing the window!), or I can look through that, to the magpie sitting chattering in the apple tree. In this kind of situation we use distance to help separate objects, in much the same way as we use direction in hearing. However, we can deploy our attention in a more sophisticated way than simply on the basis of distance, as can be demonstrated by another aircraft-related example.

Military jets are often flown very fast and close to the ground (to avoid radar detection), requiring the pilot to attend intently to the outside view. At the same time, there are various pieces of information, traditionally displayed on instruments within the cockpit, which the pilot must check frequently. To avoid the pilot having to look down into the cockpit, the 'head-up display' (HUD) was developed. This comprises a piece of glass, just in front of the pilot, in which all the vital information is reflected. The pilot can read the reflection, or look through it to the outside world, just as one can look at reflections in a shop window, or look through to the goods on display. With a simple reflection, the pilot would still have to change focus, like me looking at the smear or the bird. However, modern HUDs use an optical system which makes the information reflected in the display appear to be as far away as the outside scene. This saves valuable re-focusing time. Nevertheless, although the numerals in the HUD now appear to be located at the same distance as, say, a runway, pilots still have the sensation of focusing on one or the other; if they are reading their altitude they are relatively unaware of the scene on which it is superimposed. This suggests (as we shall see in more detail later) that visual attention can be linked to specific objects rather than to general regions of space, very much as auditory attention can follow a particular speaker's voice, or the sense of a sentence.

2.2 Knowing about unseen information

An obvious difference between hearing and seeing is that the former is extended in time, while the latter extends over space. So, for example, we can listen to a spoken sentence coming from one place, but it takes some time to hear it all. In contrast, a written sentence is spread over an area (of paper, say) but, as long as it is reasonably short, it can be seen almost instantly. Nevertheless, seeing does require some finite time to capture and analyse the information. This process can be explored by presenting letters or words for a short, measured period of time; nowadays they are shown on a computer screen, but early research used a dedicated piece of apparatus, called a tachistoscope. Just how long was required to register a small amount of information was investigated by Sperling (1960), who showed participants grids of letters, arranged as three rows of four letters each. If such a display was presented for 50 ms (i.e. 50 milliseconds, which is one twentieth of a second), people were typically able to report three or four of the letters; the rest seemed to have remained unregistered in that brief period of time.

Sperling explored this further. He cued participants with a tone, indicating which of the three rows of letters they should try to report; a high note for the top row, lower for middle and deep for bottom. Crucially, the tones were not presented until just *after* the display had disappeared, meaning that participants were not able to shift their attention in preparation for the relevant row of letters when presented: it already had been presented. Strange as it seemed, people were still able to report three or four items from the cued row. Since they did not know until after the display had gone which row would be cued, this result implied that they must have registered most of the letters in *every row*; in other words, between nine and 12 letters in total. This apparent paradox, of seeming to know about a larger proportion of the items when asked only to report on some of them, is called the **partial report superiority effect**. The effect was also observed if letters were printed six in red and six in black ink, then two tones used to indicate which colour to report. Participants seemed to know as much about one half (the red, say) as they did about all 12, implying that, although they could not report all the letters, there was a brief moment when they did have access to the full set and could choose where to direct their attention. The ‘brief moment’ was equivalent to the echoic memory associated with dichotic listening experiments, so the visual counterpart was termed an **iconic memory** (an icon being an image). All the material seemed to be captured in parallel, and for a short time was held in iconic memory. Some was selected for further, serial processing, on the basis of position or colour; these being analogous to position and voice pitch in dichotic listening tasks. Unselected material (the remaining letters) could not be remembered.

With the close parallels between these auditory and visual experiments, you will not be surprised to learn that the simple selection and serial processing story was again soon challenged, and in very similar ways. Where the hearing research used shadowing to prevent conscious processing of material, the visual experiments used **backward masking**. Masking is a procedure in which one stimulus (the target) is rendered undetectable by the presentation of another (the mask); in backward masking the mask is presented after the target, usually appearing in the order of 10–50 ms after the target first appeared. The time between the onset of the target display and the onset of the mask is called the **stimulus onset asynchrony** (SOA). The target might be an array of letters or words; this disappears after a few tens of milliseconds, to be replaced by the mask, which is often a random pattern of lines. The SOA can be adjusted until participants report that they do not even know whether there has been a target, let alone what it was. In such circumstances the influence of the masked material seems sometimes still to be detected via priming effects. Thus, Evett and Humphreys (1981) used stimulus sequences containing two words, both of which were masked. The first was supposed to be impossible to see, while the second was very difficult. It was found that when the second word was related to the first (e.g. 'tiger' following 'lion') it was more likely to be reported accurately; the first, 'invisible' word apparently acted as a prime.

Claims such as these have not gone unchallenged. For example, Cheesman and Merikle (1984) pointed out that although participants say they cannot see masked words, they often do better than chance when forced to guess whether or not one had actually been presented. These researchers insisted that proper conclusions about extracting meaning from unseen material could be made only if the material was truly unseen; that is, when the participants could do no better than chance. Under these conditions they found no evidence for priming by masked words. However, more recently researchers have provided persuasive evidence that meaning *can* be extracted from material of which the participant is unaware. This is worth examining in more detail.

Pecher et al. (2002) used the Evett and Humphreys (1981) technique, but with modifications. As in the earlier study, they showed a potential prime (e.g. 'lion'), followed by a hard-to-see masked target (e.g. 'tiger'). However, there were two changes in this study. First, the priming word could be displayed either for a very short time, so that it was allegedly undetectable, or it was shown for a duration of 1 second, giving ample time for reading and guaranteeing a priming effect.

The second change was to use two sets of trials. In one, the following target was almost always (90 per cent of the time) related to the prime (e.g. 'lion' followed by 'tiger'). In the other set of trials only 10 per cent of trials used related words. For remaining trials the stimuli were unrelated, so that the first word was not strictly a prime (e.g. 'list' followed by 'tiger'). The results of this study are summarised in Table 1.

Table 1 The percentage of targets correctly reported under various priming conditions

	Short duration prime		1 second prime	
	10% related	**90% related**	**10% related**	**90% related**
Related words	56	52	70	91
Unrelated words	49	43	55	51
Priming advantage	7	9	15	40

Source: adapted from Pecher et al., 2002

The effects are best appreciated by looking first at the final two columns of figures, showing the results when the first word was displayed for 1 second. For the condition where only 10 per cent of targets were related to the preceding word, 70 per cent of those targets were correctly identified when there was a relationship. The hit rate fell to 55 per cent when the targets were not related, so the priming effect produced a 15 per cent advantage (70 − 55 = 15). The last column shows a massive 91 per cent hit rate for related words, when there was a 90 per cent chance that they would be related to the preceding prime. The priming advantage in this condition has risen to 40 per cent. Why does the benefit of a related prime jump from 15 per cent to 40 per cent when the targets are more likely to be related to the primes? The answer is that, when there is a high chance that they will be related, participants spot the connection and try to guess what the target must have been: they often guess correctly. Notice that they can do this only because the prime word was clearly visible. Look now at the corresponding figures, for when the prime was displayed very briefly. Here the priming advantages (7 per cent and 9 per cent) are far more modest (but statistically significant). However, the important result is that the change from 10 per cent to 90 per cent relatedness does not produce the large increase in the priming effect observed in the 1 second condition. The small increase from 7 per cent to 9 per cent was not statistically significant. It can be concluded that participants were unable to guess in the brief condition, so presumably had not been able to identify the prime words. Nevertheless, those words did produce a small priming effect, so they must have received sufficient analysis to activate their meaning.

2.3 Towards a theory of parallel processing

When people are asked to guess about masked material, they are commonly able to provide some information, but it often lacks detail. For example, if participants in a Sperling-type experiment have recalled three letters, but are pressed for more, then they can often provide one or two. However, they generally do not know information such as whereabouts in the display the letters occurred, or what colour they were. These, of course, are exactly the kinds of detail that can be used to select items for report, and were believed to be usable in that role because they were characteristics which could be processed quickly and in parallel. The guessing results seem to turn the logic on its head, because the presumed complex information, such as letter identities, is discovered, while the simple colour and position information is unavailable. Coltheart (1980) offered an elegant solution to this problem, built around the semantic/episodic distinction used when describing memory. In the context of letters, semantic information would be the basic knowledge of letter identity. Episodic detail links the general identity to a specific occurrence: detail such as the fact that ‘N’ is in large, upper-case type, and is printed in red and at the start of the sign ‘NO SMOKING’. Coltheart proposed that items do not normally reach conscious awareness unless both the semantic and episodic detail are detected. So, for example, one would not expect to be having an ‘N-feeling’ (semantic) in the absence of a letter with some specific characteristics (size, colour, etc.) in the field of view!

It has become clear from electrophysiological studies that visual item identification occurs in a different region of the cortex from the areas which respond to colour or location. These different kinds of information have to be united, and this process, Coltheart (1980) suggests, takes time and attention. According to this account, Sperling's 12 letters, or even Evett and Humphrey's *lion*, are indeed processed in parallel to cause semantic activation, but the viewer will not become aware of this, unless able to assign the corresponding episodic details. Nevertheless, if pressed, the participant may sometimes admit to ‘having a feeling’ that an item might have been presented, although not know what it looked like

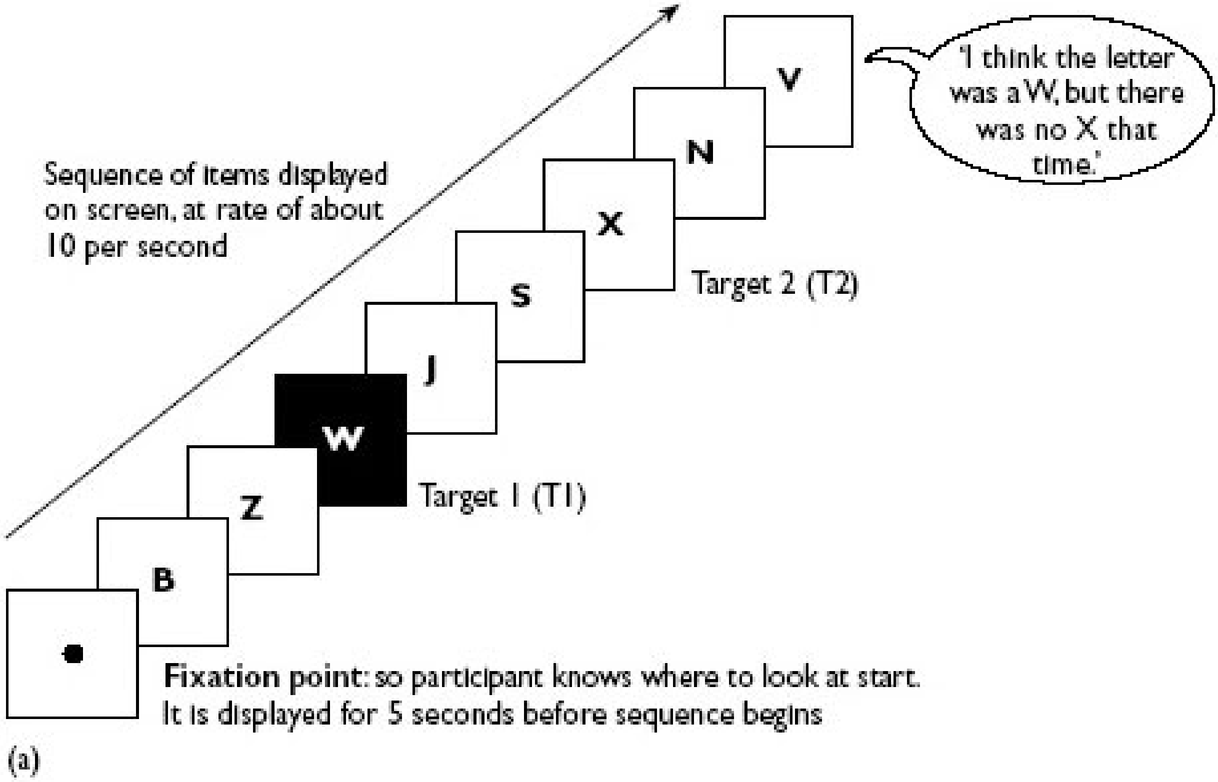
The important point to note in the above account is that attention is no longer being described as the process that selects material for complex serial processing (e.g. word identification). Instead, Coltheart suggests that attention is required to join the products of two parallel processes: the identification and the episodic characterisation. This idea that attention is concerned with uniting the components of a stimulus is not unlike a theory which Treisman has been developing (after her early auditory attention work, she now researches visual attentive processes). We shall consider Treisman's work (which does not involve backward masking), but first we should look a little further at what masking actually does to the processing of a stimulus.

2.4 Rapid serial visual presentation

It has been known for a long time that backward masking can act in one of two ways: **integration** and **interruption** (Turvey, 1973). When the SOA between target and mask is very short, integration occurs; that is, the two items are perceived as one, with the result that the target is difficult to report, just as when one word is written over another. Of more interest is masking by interruption, which is the type we have been considering in the previous section. It occurs at longer SOAs, and interruption masking will be experienced even if the target is presented to one eye and the mask to the other. This dichoptic (two-eyed) interaction must take place after information from the two eyes has been combined in the brain; it could not occur at earlier stages. In contrast, integration masking does not occur dichoptically when target and mask are presented to separate eyes, so presumably occurs quite early in analysis, perhaps even on the retina. On this basis, Turvey (1973) described integration as peripheral masking, and interruption as central masking, meaning that it occurred at a level where more complex information extraction was taking place.

Another early researcher in the field (Kolers, 1968) described the effect of a central (interruption) mask by analogy with the 'processing' of a customer in a shop. If the customer (equivalent to the target) comes into the shop alone, then s/he can be fully processed, even to the extent of discussing the weather and asking about family and holidays. However, if a second customer (i.e. a mask) follows the first, then the shopkeeper has to cease the pleasantries, and never learns about the personal information. The analogy was never taken further, and of course it is unwise to push an analogy too far. Nevertheless, one is tempted to point out that the second customer is still kept waiting for a while. Where does that thought take us? It became possible to investigate the fate of following stimuli, in fact whole queues of stimuli, with the development of a procedure popularised by Broadbent (Broadbent and Broadbent, 1987), who, like Treisman, had moved on from auditory research. The procedure was termed Rapid Serial Visual Presentation, in part, one suspects, because that provided the familiar abbreviation RSVP; participants were indeed asked to *repondez s'il vous plait* with reports of what they had seen.

Unlike the traditional two-stimulus, target/mask pairing, **Rapid Serial Visual Presentation (RSVP)** displayed a series of stimuli in rapid succession, so each served as a backward mask for the preceding item. SOAs were such that a few items could be reported, but with difficulty. Typical timings would display each item for 100 ms, with a 20 ms gap between them; the sequence might contain as many as 20 items. Under these conditions stimuli are difficult to identify, and participants are certainly unable to list all 20; they are usually asked to look out for just two. In one variation, every item except one is a single black letter. The odd item is a white letter, and this is the first target; the participant has to say at the end of the sequence what the white letter had been. One or more items later in the sequence (i.e. after the white target), one of the remaining black letters may be an 'X'. As well as naming the white letter, the participant has to say whether or not X was present in the list. These two targets (white letter and black X) are commonly designated as T1 and T2. Notice that the participant has two slightly different tasks: for T1 (which will certainly be shown) an unknown letter has to be identified, whereas for T2 the task is simply to say whether a previously designated letter was presented. These details, together with a graph of typical results, are shown in Figure 3.



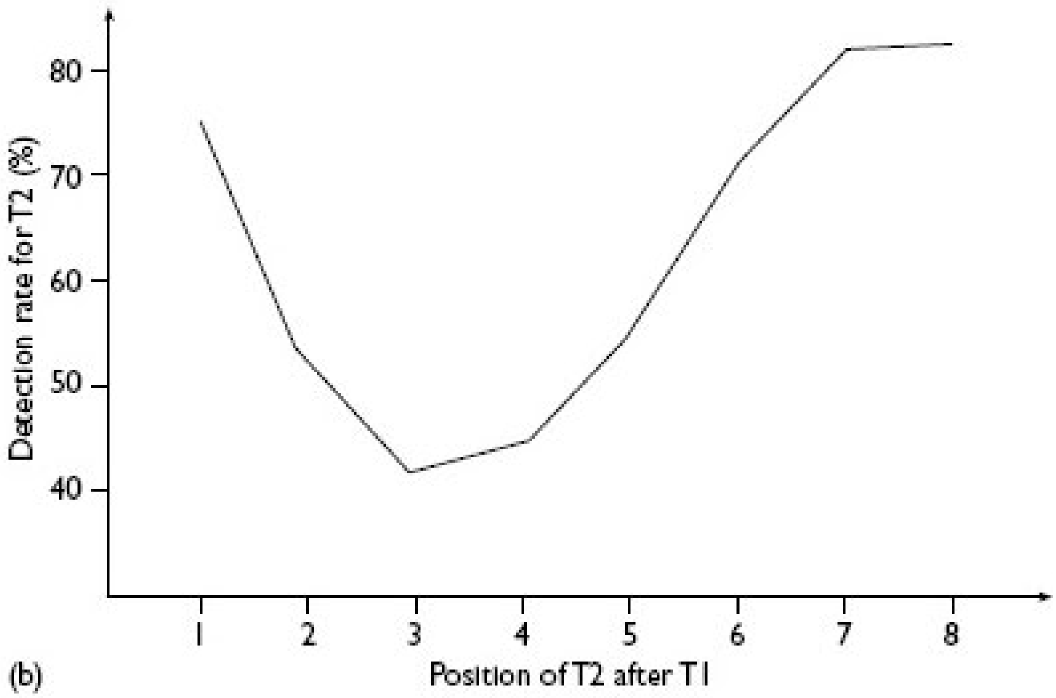


Figure 3 The RSVP technique: (a) The sequence of stimuli, shown in the same location on

a computer screen, in which the participant has to identify a white letter, then decide whether an X was also present; (b) Typical results, showing the likelihood of detecting the X, when presented in the first and subsequent positions following the white target

As can be seen from the graph in Figure 3b, T2 (the X) might be spotted if it is the item immediately following T1, but thereafter it is less likely that it will be detected unless five or six items separate the two. What happens when it is not detected? As you may be coming to expect, the fact that participants do not report T2 does not mean that they have not carried out any semantic analysis upon it. Vogel et al. (1998) conducted an RSVP experiment that used words, rather than single letters. Additionally, before a sequence of stimuli was presented, a clear ‘context’ word was displayed, for a comfortable 1 second. For example, the context word might be *shoe*, then the item at T2 could be *foot*. However, on some presentations T2 was not in context; for example, *rope*. While participants were attempting to report these items, they were also being monitored using EEG (electro-encephalography). The pattern of electrical activity measured via scalp electrodes is known to produce a characteristic ‘signature’, when what might be called a mismatch is encountered. For example, if a participant reads the sentence *He went to the café and asked for a cup of tin*, the signature appears when *tin* is reached. The Vogel et al. (1998) participants produced just such an effect with sequences such as *shoe* – *rope*, even when they were unable to report seeing *rope*. This sounds rather like some of the material discussed earlier, where backward masking prevented conscious awareness of material that had clearly been detected. However, the target in the RSVP situation appears to be affected by something that happened *earlier* (i.e. T1), rather than by a following mask. The difference needs exploring and explaining.

Presumably something is happening as a result of processing the first target (T1), which temporarily makes awareness of the second (T2) very difficult. Measurements show that for about 500 to 700 ms following T1, detection of T2 is lower than usual. It is as if the system requires time to become prepared to process something fresh, a gap that is sometimes known as a **refractory period**, but that in this context is more often called the **attentional blink**, abbreviated to AB. While the system is ‘blinking’ it is unable to attend to new information.

Time turns out not to be the only factor in observing an AB effect (‘AB effect’ will be used as a shorthand way of referring to the difficulty of reporting T2). Raymond et al. (1992) used a typical sequence of RSVP stimuli, but omitted the item immediately following the *first* target. In other words, there was a 100 ms gap, rather than another item following. Effectively, this meant that the degree of backward masking was reduced, and not surprisingly resulted in some improvement in the report rate for T1. Very surprisingly, it produced a considerable improvement in the reporting of T2; the AB effect had vanished (see Figure 4a). How did removing the mask for one target lead to an even larger improvement for another target that was yet to be presented? To return to our earlier analogy, if the shopkeeper is having some trouble in dealing with the first customer, then the second is kept waiting and suffers. That doesn't explain *how* the waiting queue suffers (if it were me I should probably chat to the person behind, and forget what I had come for), but that question was also addressed by removing items from the sequence.

Giesbrecht and Di Lollo (1998) removed the items following T2, so that it was the last in the list; again, the AB effect disappeared (see Figure 4b). So, no matter what was going on with T1, T2 could be seen, if it was not itself masked. To explain this result, together with the fact that making T1 easier to see also helps T2, Giesbrecht and Di Lollo developed a two-stage model of visual processing. At Stage 1, a range of information about target characteristics is captured in parallel: identity, size, colour, position and so on. In the second stage, they proposed, serial processes act upon the information, preparing it for awareness and report. While Stage 2 is engaged, later information cannot be processed, so has to remain at Stage 1. Any kind of disruption to T1, such as masking, makes it harder to process, so information from T2 is kept waiting longer. This has little detrimental impact upon T2 unless it too is masked by a following stimulus (I don't forget what I came to buy, if there is no-one else in the queue to chat with). When T2 is kept waiting it can be overwritten by the following stimulus. The overwriting process will be damaging principally to the episodic information; an item cannot be both white and black, for example. However, semantic information may be better able to survive; there is no reason why *shoe* and *rope* should not both become activated. Consequently, even when there is insufficient information for Stage 2 to yield a fully processed target, it may nevertheless reveal its presence through priming or EEG effects. There is an obvious similarity between this account and Coltheart's (1980) suggestion: both propose the need to join semantic and episodic detail.

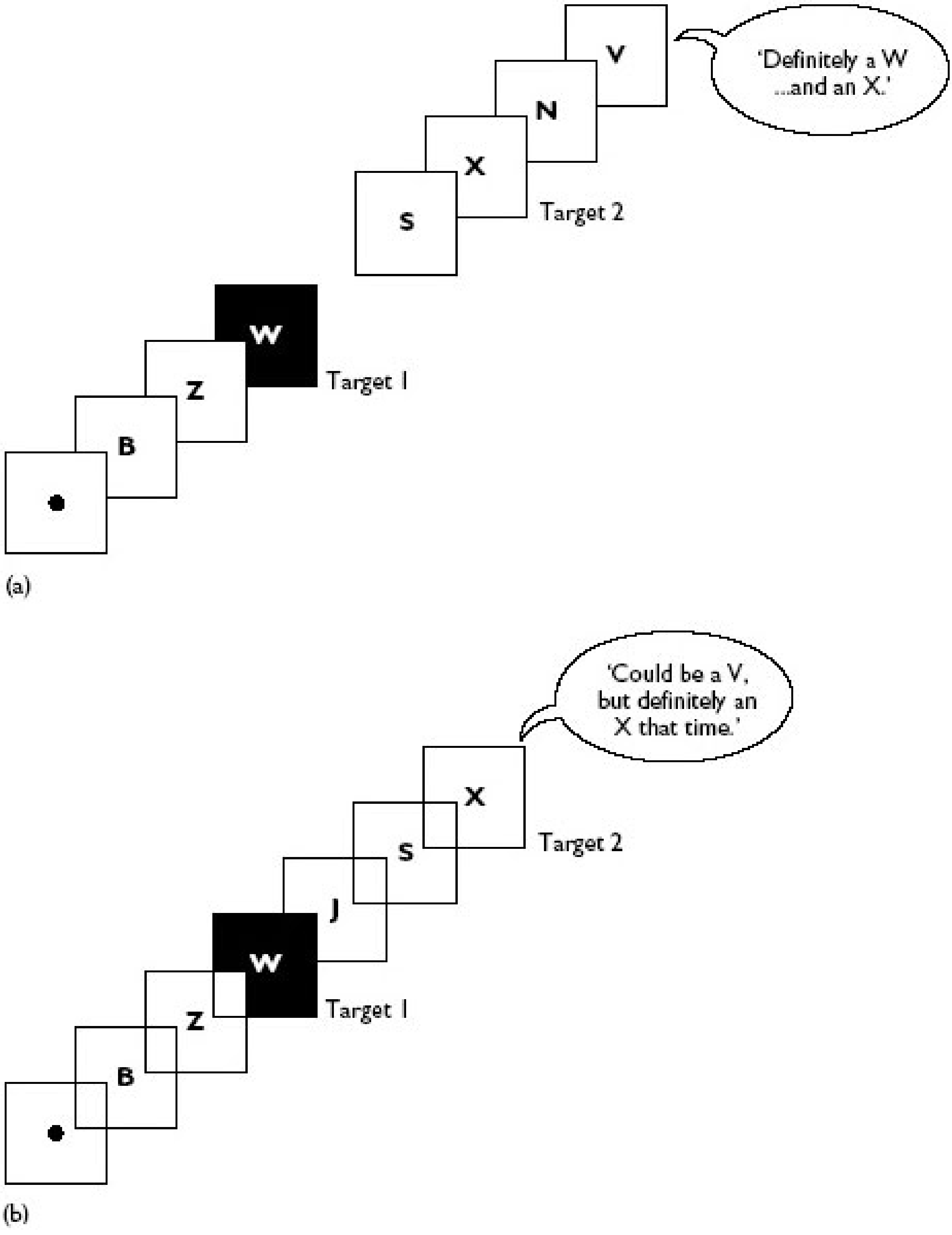


Figure 4 (a) Target 2 is seen more easily when Target 1 is made easier to see by removing the following item; (b) Target 2 is also seen easily when items following it are omitted

2.5 Masking and attention

Before I summarise the material in this section, and we move on to consider attentional processes with clearly-seen displays, it would be appropriate to consider the relevance of the masking studies to the issue of attention. We began the whole subject by enquiring about the fate of material which was, in principle, available for processing, but happened not to be at the focus of attention. Somehow we have moved into a different enquiry, concerning the fate of material that a participant was trying to attend to, but did not have time to process. This seemed a natural progression as the course unfolded, but are the two issues really related? Merikle and Joordens (1997) addressed this very question; they characterised it as a distinction between perception without awareness (such as in masking studies) and perception without attention (as with dichotic listening). They carried out a number of studies, in which processing was rendered difficult either by masking, or by giving the participants two tasks, so that they could not focus on the target. They concluded that the results were entirely comparable, and that the same underlying processes are at work in both kinds of study.

2.6 Summary of Section 2

The results of the visual attention experiments we have considered can be interpreted as follows.

- Attention can be directed selectively towards different areas of the visual field, without the need to re-focus.
- The inability to report much detail from brief, masked visual displays appears to be linked to the need to assemble the various information components.
- The visual information is captured in parallel, but assembly is a serial process.
- Episodic detail (e.g. colour, position) is vulnerable to the passage of time, or to ‘overwriting’ by a mask.
- Semantic information (i.e. identity/meaning) is relatively enduring, but does not reach conscious awareness unless bound to the episodic information.
- Attention, in this context, is the process of binding the information about an item's identity to its particular episodic characteristics.
- ‘Unbound’ semantic activation can be detected by priming and electrophysiological techniques.

3 Integrating information in clearly-seen displays

3.1 Introduction

The binding of features emerges as being a very significant process when displays are brief, because there is so little time in which to unite them. With normal viewing, such as when you examine the letters and words on this page, it is not obvious to introspection that binding is taking place. However, if, as explained above, it is a necessary precursor to conscious awareness, the process must also occur when we examine long-lived visual displays. Researchers have attempted to demonstrate that the binding process does indeed take place.

3.2 Serial and parallel search

Examine the three sections of Figure 5 and in each case try to get a feel for how long it takes you to find the 'odd one out'. The figure is a monochrome version of the usual form of these stimuli you can see a coloured example in colour Plate 3.

Click to view Plate 3: Typical stimuli used in Triesman's experiments.

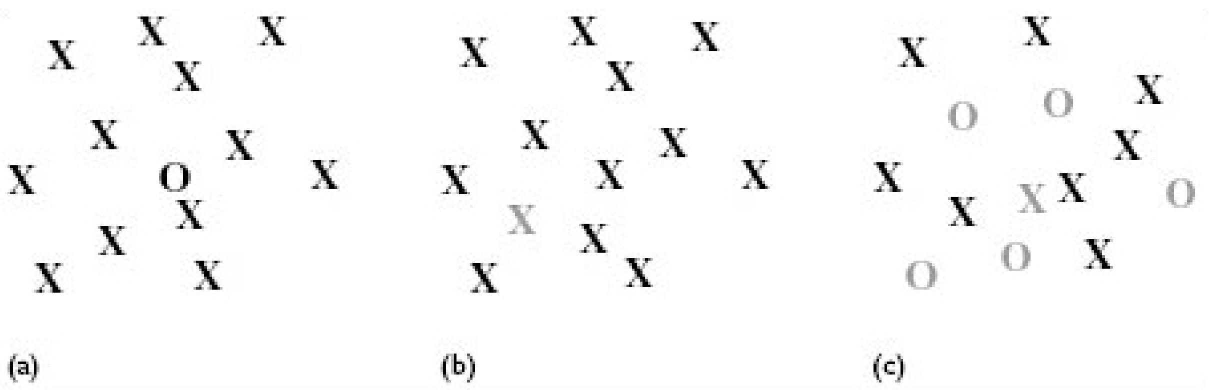


Figure 5 Find the odd item in each of the groups, (a), (b) and (c)

You probably felt that the odd items in Figures 5(a) and 5(b) simply 'popped out', and were immediately obvious, whereas the red X in Figure 5c took you slightly longer to find. These kinds of effect have been explored formally by Treisman (e.g. Treisman and Gelade, 1980). The odd item is referred to as the target and the others as the distractors. Treisman showed her participants a series of displays of this nature, and measured how long it took them to decide whether or not a display contained a target. She was particularly interested in the effect of varying the number of distractors surrounding the targets. It was found that for displays similar to Figures 5(a) and 5(b) it made no difference to decision times whether there were few or many distractors. In contrast, with the 5(c) type of display, participants took longer to decide when there were more distractor items; each additional distractor added approximately 60 ms to the decision time.

How is that pattern of results to be explained? Treisman pointed out that the first two displays have target items which differ from the rest on only one dimension; the target is either a round letter (O), among 'crossed-line' letters (X), or a red letter among black letters. The Figure 5(c) display type is different; to identify the target it is necessary to consider two dimensions. It has to be an X (but there are others, so on its own being an X does not define the target), and it has to be red (but again, there are other red letters). Only when X and red are combined does it become clear that this is an 'odd one out'. All these features (various colours and shapes) are quite simple and are derived in the early stages of visual processing, but importantly different types of analysis (e.g. of shape or colour) take place in different parts of the brain. To see whether there is just 'redness', or just 'roundness' in a display is easy, so easy in fact that the whole display seems to be taken in at a glance, no matter how many items there are. In other words, all the different items are processed at the same time, in parallel. The situation is very different when shape and colour have to be combined because they are determined in different brain areas; somehow the two types of information have to be brought together. You will recall from Section 2 that attention appears necessary to unite episodic and semantic information. Treisman proposed that it is also required to link simple features. Each item in the display has to receive attention just long enough for its two features (shape and colour) to be combined, and this has to be done one item at a time until the target is found. In other words, the processing is serial, so takes longer when there are more items to process. It has been known for some time that the parietal region of the brain (part of the cortex that sits like a saddle across the top of the brain) is one of the areas involved in attention. A fuller account of the problems that result from damage to this area will be given in Section 5.2; at this point it is relevant to mention that Treisman (1998) reports investigations with a patient who had suffered strokes in that region. He was shown simple displays, containing just two letters from a set of three (T, X and O); they were printed in different colours, from a choice of three (red, blue or yellow). He was asked to describe the first letter he noticed in the display. On a particular occasion he might be shown a blue T and a red O. Although he often made mistakes, he would rarely respond 'Yellow X' to that display; that is, he did not claim to see features that were not there at all, so he was not simply guessing. What he did say quite often would be something like 'Blue O'. He had correctly identified features that were present, but was unable to join them appropriately. The implication of this is that both the detection and the integration of features are necessary steps in normal perception, and that integration requires attention.

3.3 Non-target effects

Treisman's **feature integration theory** has been very influential, but it does not appear to explain all experimental observations, and there have been alternative accounts of the feature-binding process. Duncan and Humphreys (1989) reported effects which do not fit too well within the basic Treisman account. They required participants to search for the letter 'L' (the target) within a number of 'Ts' (the non-targets). You may get a feel for the relative difficulty of different versions of their task by examining Figure 6.

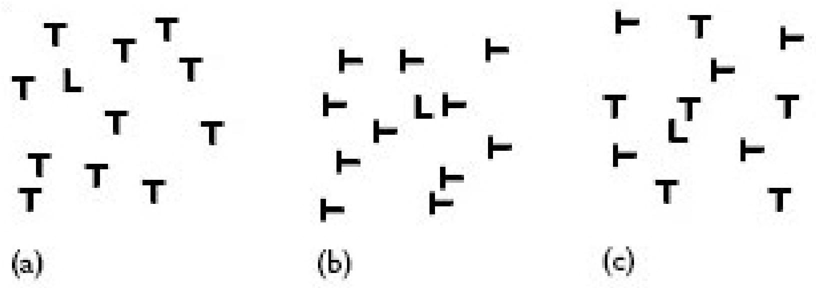


Figure 6 Examples of the kinds of stimuli used by Duncan and Humphreys (1989). Find the letter L in each of the groups, a, b and c

The task can be conceptualised as looking for two lines that meet at a corner (the L), rather than forming a T-junction. It should not make much difference whether the T-junctions are vertical or horizontal (as in Figure 6a and 2.6b), and, indeed, the search times for these two sorts of display are similar. However, when the Ts are mixed, as in Figure 6c, it takes longer to find the target. This finding would not have been predicted by a simple feature integration theory. Duncan and Humphreys (1989) argued that part of finding the target actually involves rejecting the non-targets and that this is a harder task when they come in a greater variety.

This explanation does not rule out the idea that features need to be integrated to achieve recognition, but it does suggest that non-targets, as well as targets, need to be recognised. The following section also describes evidence that non-targets are recognised, but in this case the recognition appears to take place in parallel.

3.4 The 'flanker' effect

A potential problem for the feature integration theory is the fact that the time taken to understand the meaning of a printed word can be influenced by other, nearby words. Of itself, this is not surprising, because it is well known that one word can prime (i.e. speed decisions to) another related word; the example *nurse – doctor* was given in Section 1.4. However, Shaffer and LaBerge (1979) found priming effects, even when they presented words in a way which might have been expected to eliminate priming. For their experiment a word was presented on a screen, and as quickly as possible a participant had to decide to what category it belonged; for example an animal or a vegetable. The participant was required to press one button for animal names, and another for vegetables. This sounds straightforward, but the target word was not presented in isolation; above and below it another word was also printed, making a column of three words. The target, about which a decision was to be made, was always in the centre. The words repeated above and below the target were termed the 'flankers'. Before the three words were displayed, markers in the field of view showed exactly where the target would appear. Figure 7 shows examples of possible displays.

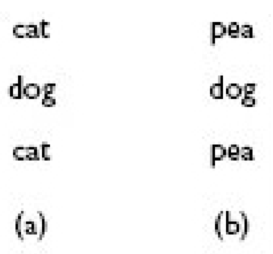


Figure 7 The flanker effect. It takes longer to decide ‘dog’ is an animal when surrounded by words of another category, as in b

You will probably not be surprised to learn that people make category judgements more quickly for examples such as that shown in Figure 7a than for the Figure 7b type of stimulus. Presumably, while the target information is being processed, details about the flankers are also being analysed, in parallel. When they turn out to be from the category associated with pressing the other button they slow the response. This slowing is very much like the impact of the conflicting colour names in the Stroop effect (see Box 2). However, recall that Treisman's theory suggests that focused, *serial* attention is required to join features together. A printed word has many features, and it would be thought that they require joining before the word can be recognised; it should not be possible to process the three words simultaneously. A participant focusing on the target could not (according to the theory) also be processing the flankers.

Box 2 Research study: The Stroop effect

Stroop (1935) reported a number of situations in which the processing of one source of information was interfered with by the presence of another. The best known example uses a list of colour names printed in non-matching coloured inks.

A variant is the ‘Emotional Stroop task’, which can be used in therapeutic diagnoses. For example, severe depression produces cognitive impairment and, in the elderly, it is difficult to distinguish this from the effects of the onset of dementia. Dudley et al. (2002) used colours to print a list of words, some of which were associated with negative emotions (e.g. the word *sadness*). Depressed people have an attentional bias towards such depression-related material. Patients were required to name the ink colours for each word, as quickly as possible. Both depressed patients and those in the early stages of Alzheimer's disease were slower than a control group, but only the patients with depression were extra slow in responding to negative words. The technique permits an appropriate diagnosis.

Click to view Plate 4: The Stroop effect.

Broadbent addressed this problem (Broadbent and Gathercole, 1990), and produced an explanation to ‘save’ the feature integration theory. He suggested that the central target word primed the flankers so effectively that they could be detected with the minimum of attention. Taking the items in Figure 7 as an example, if this explanation were true it would have to be argued that ‘dog’ primes ‘cat’, which, being another animal leads to faster decision times. ‘Dog’ cannot prime ‘pea’, as they are unrelated, so there is nothing to make the decision any quicker. In other words, it is not that ‘pea’ makes responses to ‘dog’ harder; rather, ‘cat’ makes them easier. Broadbent and Gathercole tested this explanation with an ingenious modification to the usual way of presenting targets and flankers. Instead of displaying all three words simultaneously, the target appeared first, to be joined by the flankers 40 ms later. The sequence is represented in Figure 9.

The reasoning behind this change was as follows. If Broadbent and Gathercole were correct that the flankers were analysed only because of priming from the target word, then giving the target a 'head start' should enable it to prime even more effectively; the flanker effect would be even stronger. On the other hand, if interference from the flankers were merely an example of processing not being as 'serial' as Treisman supposed, then making flankers arrive late, when target processing had already started, should *reduce* their impact. The results showed a strong flanker effect (i.e. faster responses with same-category flankers), suggesting that the priming idea was correct. However, there is another interpretation of the Broadbent and Gathercole results. It has been well established that an item suddenly appearing in the visual field will capture attention (e.g. Gellatly et al., 1999). By making the flankers appear later, Broadbent and Gathercole may have ensured that they would attract attention away from the target. This could explain why the flankers showed a particularly strong effect with this style of presentation. Although the Broadbent and Gathercole idea of staggering the display times of the stimuli was ingenious, a convincing demonstration of parallel processing requires all the different stimuli to be presented at the same time.

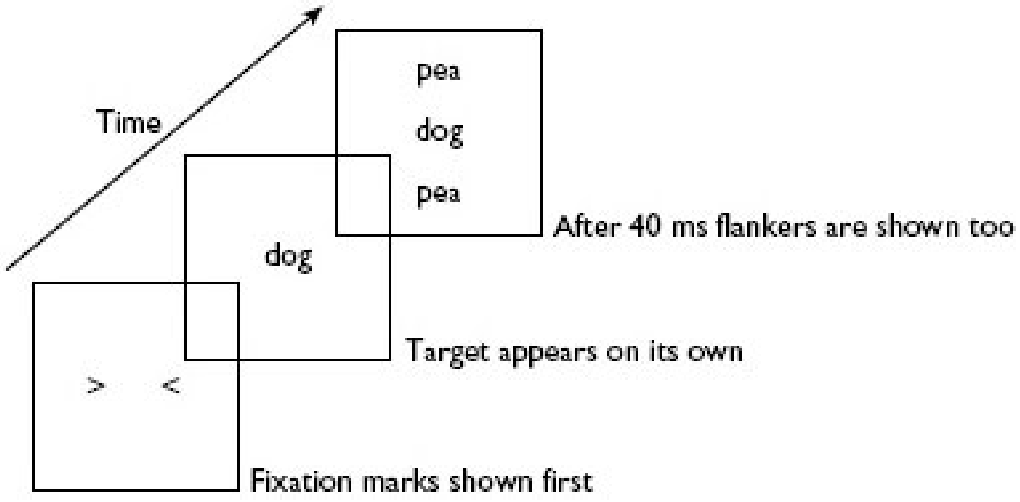


Figure 8 The Broadbent and Gathercole (1990) modification: the flankers are delayed for 40 ms

3.5 Summary of Section 3

When consciously perceiving complex material, such as when looking for a particular letter of a particular colour:

- Perception requires attention.
- The attention has to be focused upon one item at a time, thus …
- processing is serial.
- Some parallel processing may take place, but…
- it is detected indirectly, such as by the influence of one word upon another.

4 Attention and distraction

4.1 Introduction

The above account of having attention taken away from the intended target reminds us that, while it may be advantageous from a survival point of view to have attention captured by novel events, these events are actually distractions from the current object of attention. Those who have to work in open-plan offices, or try to study while others watch TV, will know how distracting extraneous material can be. Some try to escape by wearing headphones, hoping that music will be less distracting, but does that work? Are some distractors worse than others? These kinds of question have been addressed by research and the answers throw further light upon the nature of attention.

4.2 The effects of irrelevant speech

Imagine watching a computer screen, on which a series of digits is flashed, at a nice easy rate of one per second. After six items you have to report what the digits had been, in the order presented (this is called serial recall). Not a very difficult task, you might think, but what if someone were talking nearby? It turns out that, even when participants are instructed to ignore the speech completely, their recall performance drops by at least 30 per cent (Jones, 1999).

In the context of dichotic listening (Section 1.3), it was shown that ignored auditory material may nevertheless be processed, and hence its meaning influences perception of attended material. However, meaning appears to have no special impact, when speech interferes with memory for visually presented material. Thus, hearing numbers spoken, while trying to remember digits, is no more damaging than listening to other irrelevant speech items (Buchner et al., 1996). In fact, even a foreign language, or English played backwards are no less disruptive than other irrelevant speech items (Jones et al., 1990). On the other hand, simple white noise (a constant hissing like a mis-tuned radio) is almost as benign as silence. Interference presumably results from speech because, unlike white noise, it is not constant: it is broken into different sounds.

The importance of 'difference' in the speech can be shown by presenting lists of either rhyming or non-rhyming words. It turns out that a sequence such as 'cat, hat, sat, bat…' is less disruptive than a sequence such as 'cat, dog, hit, bus …' (Jones and Macken, 1995). Jones (1999) proposes that, whether listening to speech, music, or many other types of sound, the process requires the string of sounds to be organised into perceptual 'objects'. To recognise an auditory object, such as a word or melody, requires that the segments of the stream of sounds are identified, and it is also necessary to keep track of the order of the segments. This ordering process, which occurs automatically, interferes with attempts to remember the order of visually presented items. When the sounds contain simple repetitions (as with the rhyming 'at' sound) the ordering becomes simpler, so the memory task is less disrupted. This was demonstrated in a surprising but convincing way by Jones et al. (1999). Their participants attempted to remember visually presented lists, while listening through headphones to a repeating sequence of three syllables, such as the letter names 'k … l … m … k … l … m'. These were disruptive, since the three letters have quite different sounds. The experimenters then changed the way in which the speech was delivered. The ‘l’ was played through both headphones, so sounded in the middle (see Section 1.3, Box 1), but the ‘k’ was played only to the left ear and the ‘m’ was heard in the right. This manipulation results in the perception of three ‘streams’ of speech, one on the left, saying ‘kay, kay, kay …’, one in the middle, repeating ‘ell’, and the last on the right saying ‘em’. The significant point is that instead of hearing a continually changing sequence, the new way of playing *exactly the same sounds* results in them sounding like three separate sequences each of which never changes. Remarkably, the result is that they are no longer as disruptive to the visual recall task.

This section has taken the concept of attention into a new area. Previously we have seen it as a means of separating information, or of directing the assembly of different aspects of the attended item. In most of the earlier examples it has appeared that a great deal of processing can take place in parallel, although the results may not all reach conscious awareness. The impact of irrelevant speech shows that parallel processing is not always possible. It seems to break down in this case because demands are made on the same process – the process that places items in a sequence. Here it would seem that we have a situation where there really is a ‘bottleneck’, of the sort envisaged in early theories of attention (see Sections 1.3 and 1.4).

What of trying to study with music? Undoubtedly, ‘Silence is Golden’, but if music is to be played, then my suggestion is that it should perhaps be something that changes very slowly, such as the pieces produced by some of the minimalist composers.

4.3 Attending across modalities

The preceding section raised the issue of attention operating (and to some extent failing) across two sensory modalities. By focusing on distraction we ignored the fact that sight and sound (and other senses) often convey mutually supporting information. A classic example is lip-reading. Although few of us would claim any lip-reading skills, it turns out that, particularly in noisy surroundings, we supplement our hearing considerably by watching lip movements. If attention is concerned with uniting elements of stimuli from within one sense, then we might expect it to be involved in cross-modal (i.e. across senses) feature binding too. In this section we will look briefly at one such process.

A striking example of the impact of visual lip movements upon auditory perception is found in the **ventriloquism effect**. This is most commonly encountered at the cinema, where the loudspeakers are situated to the side of the screen. Nevertheless, the actor's voice appears to emanate from the face on the screen, rather than from off to the side. Driver (1996) demonstrated just how powerful this effect could be. He presented participants with an auditory task that was rather like shadowing in dichotic listening (Section 1.4) – only much harder! The two messages, one of which was to be shadowed, did not go one to each ear: they both came from the same loudspeaker, and were spoken in the same voice. To give a clue as to which was to be shadowed, a TV monitor was placed just above the loudspeaker, showing the face of the person reading the to-be-shadowed message. By lip-reading, participants could cope to some extent with this difficult task. Driver then moved the monitor to the side, away from the loudspeaker. This had the effect of making the appropriate message seem to be coming from the lips. Since the other message did not get ‘moved’ in this way, the two now *felt* spatially separate and, although in reality the sounds had not changed, the shadowing actually became easier!

These kinds of effects have further implications at a practical level. The use of mobile telephones while driving a car has been identified as dangerous, and the danger is not limited to the case where the driver tries to hold the phone in one hand and steer with the other. If a hands-free headset is used of the type which delivers sound via an earpiece to just one ear, the caller's voice sounds as if it is coming from one side. Attending to this signal has the effect of pulling visual attention towards the lateral message, reducing the driver's responsiveness to events ahead (Spence, 2002).

4.4 Summary of Section 4

We have seen that attentive processes will ‘work hard’ to unite information into a coherent whole.

- Even spatially separate visual and auditory stimuli can be joined if they appear to be synchronous (the ventriloquism effect).
- When stimuli are not synchronous the system attempts to order the segments of the stimuli independently, resulting in distraction and lost information.
- It is a ‘bottleneck’ in the ordering process that results in one stream of information interfering with the processing of another.

5 The neurology of attention

5.1 Introduction

Modern techniques for revealing where and when different parts of the brain become active have recently provided a window on the processes of attention. For example, one of these brain-scanning techniques, functional magnetic resonance imaging (fMRI), has been used to show the behaviour of an area of the brain that responds to speech. It turns out also to become activated in a person viewing lips making speech movements *in the absence of sound*. For this to happen there must be connections between relevant parts of the visual and auditory areas.

5.2 The effects of brain damage

Before the advent of ‘brain mapping’, such as by fMRI, it was nevertheless possible to discover something of the part played by different regions of the brain, by observing the problems resulting from brain damage (such as following a stroke). One such area was mentioned in Section 3.2 – the parietal lobe. Damage to a single lobe (there is one on either side) leads to what is called **sensory neglect**, or sometimes simply neglect. A patient is likely completely to ignore the doctor if s/he stands on the neglected side (the side opposite to the site of the damage). When eating, the patient will probably leave any food that is on the ‘wrong’ side of the plate, and if asked to draw a flower will put petals on only one side. The problem is not simply blindness to all that lies on the neglected side. A patient asked to draw a whole vase of flowers may draw only those hanging over the ‘preserved’ side, but with each individual flower itself only half complete. It appears sometimes to be half the *object* which is neglected, rather than half the field of view. Figure 10 shows a typical attempt, by a patient with visual neglect, to draw a clock face.

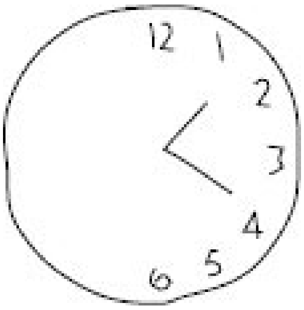


Figure 9 The typical appearance of a clockface, as drawn by a patient with visual neglect

That neglect may be associated with the object rather than the scene was demonstrated formally by Driver and Halligan (1991). They showed patients pairs of pictures that looked rather like silhouettes of chess pieces. Patients had to say whether the two pictures were the same or different. Where there *were* differences, they comprised an addition to one side, near the top of the figure (as if the chess queen had something attached to one ear!). When the addition was on the neglected side patients were unable to detect the difference. Suppose the 'problem' side was the left. The question is whether the patient has difficulty with processing information to the left of the page, or to the left of the object. Driver and Halligan tested this by tilting the pictures to the right (see Figure 10), so that the one-sided feature, although still on the left of the figure, was now in the right half of the page. Still the patients experienced difficulty: neglect was object-related.

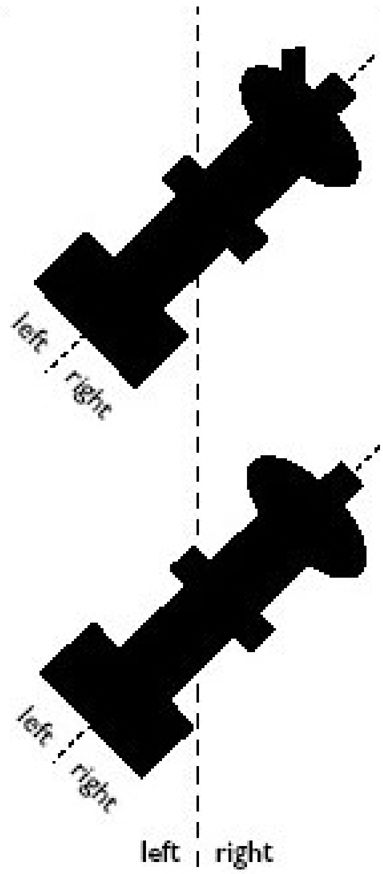


Figure 10 Same or different? The feature that distinguishes the two figures is to the left of the object, but on the right of the page

We have been describing attention as a mechanism for assembling the subcomponents of items in a scene, so it is not difficult to conceptualise a fault leading to some components being omitted. This account sees attention as an essential element of the perceptual process, helping to organise incoming information. However, neglect is not limited to objects that are physically present. Bisiach and Luzzatti (1978) asked their patient to imagine standing in the cathedral square of the Italian city where he grew up. He was to imagine looking towards the cathedral and to describe all that was in the square. He did this very well, except that he failed to mention any of the buildings down the left-hand side of the square (his brain injury was on the right). He was then asked to imagine standing on the cathedral steps, looking back towards his previous viewpoint. Again, he only reported details from the right. However, with the change of view, this meant that he was now describing previously ignored buildings! Clearly his memory was intact, but in some way not entirely accessible. Equally clearly, attentive processes are involved in the assembly of remembered material as well as of physically present stimuli.

An even more extreme form of neglect is encountered in a condition known as Balint's syndrome. It occurs when a patient is unfortunate enough to suffer damage to both parietal lobes, which results in it being extremely difficult to shift attention from one object to another. Thus, when trying to light a cigarette, the patient may find that his attention has been 'captured' by the flame, to the extent that he can no longer see the cigarette. One patient complained, 'When I see your spectacles I cannot see your face.' This is reminiscent of the experience of pilots using a head-up display (HUD) (see Section 2), where focusing on flight information displayed in the HUD makes the outside scene feel less 'visible'. Surprising as it may sound, it seems necessary to deduce from these effects that we *all* experience the world as a series of objects. However, unless our attentive process has been damaged, we can shift the attention so rapidly from one object to another that we perceive them all as being present simultaneously. Exactly what constitutes an object depends upon the situation; Balint patients are revealing here, because they see only one object at a time. Baylis et al. (1994) described a patient who could not report the letters making up an isolated word. Viewed in this way, each letter was a small object and it was not possible to switch attention from one to the next. However, the patient could read the whole word, since for this purpose it was a single object.

Early visual processing takes place in two major pathways in the brain, known as the ventral and dorsal streams; the parietal region is part of the dorsal pathway. Damage to the ventral stream results in different kinds of integration problems; patients are aware of all aspects of a scene, but to the patient they remain segmented into small elements. For example, an individual shown a photograph of a paint-brush described seeing a wooden stick and a black object (the bristles) which he could not recognise. Humphreys (2001) suggests that the varieties of different problems are evidence that the binding together of different features takes place in several different stages and brain locations.

5.3 Event-related potentials

When a sense organ (eye, ear, etc.) receives a stimulus, the event eventually causes neurons to ‘fire’ (i.e. produce electrical discharges) in the receiving area of the brain. The information is sent on from these first sites to other brain areas. With appropriate apparatus and techniques it is possible to record the electrical signals, using electrodes attached to the scalp. The electrical potentials recorded are called **event-related potentials (ERPs)**, since they dependably follow the triggering sensory event. In fact a whole series of electrical changes are detected, first from the receiving brain areas, then later from subsequent sites. The timing of the ERPs gives a clue as to where in this sequence they are being generated.

Woldorff et al. (1993) examined ERPs evoked by sounds. These included signals occurring as soon as 10 ms after the auditory event. To generate a response so quickly, these ERPs must have originated in the brain stem, in the first ‘relay’ between ear and auditory cortex. The earliest stages of registration at the auditory cortex were detected after about 20–50 ms. It was of particular interest that, whereas the 10 ms signal was not affected by attention, the magnitude of the electrical activity in the cortex was smaller when the sounds were played to an unattended ear. This shows that, at a very early stage of cortical analysis, attending away from a stimulus actually reduces the intensity of the signal in the brain. The result lends a good deal of support to the theory that attention is exercised by controlling a filter early in the processing sequence (see Section 1.3). Note, however, that the unattended signal is only attenuated, not eliminated.

5.4 Summary of Section 5

Many familiar themes have re-emerged in this section, together with the recognition that attention is involved in the assembly of remembered material as well as of current perceptions.

- Attention is associated with the generation of perceptual objects.

- In addition to being an essential part of external stimulus processing, attention influences remembered experiences.
- ERP data show that cortical signals derived from unattended external stimuli are attenuated.

6 Concluding thoughts

We seem to have come a long way and covered a great deal of ground since I approached this subject by explaining that a mechanism must exist to help us focus on one sound out of many. That clearly is one function of attention, but attention seems to have other functions too. The results of visual search experiments show that attention is a vital factor in joining together the features that make up an object, and the experiences of brain-damaged patients suggest that this feature-assembly role ensures that our conscious perceptions are generally of objects, rather than of their constituent parts. Cross-modal research has demonstrated that the gathering together of related information from different senses is also controlled by attention.

Attention has a role to play in dealing with competition. The early researchers believed that attention was vital, because the brain would be able to deal with only one signal at a time; a 'winning' signal had to be picked from among the competitors. Although we have shown that a good deal of analysis can actually take place in parallel, there are also results which suggest that more complex analysis is largely serial, thus requiring a mechanism to select from the competing stimuli. Often, the parallel processes have to be demonstrated rather obliquely, since their results do not become consciously available. Thus attention has to do with what reaches conscious awareness. Why should this be so? Why should we not be equally aware of several items simultaneously?

Allport (1987) offered an answer that suggests yet another role for attention: it is to direct actions. Although we might, in principle, be able to perceive many things at once, there are situations where it would be counterproductive to attempt to *do* more than one thing. Allport gave fruit-gathering as an example. When we look at a bush of berries we need to focus attention upon one at a time, since that is how they have to be picked. If animals had not evolved this ability to select, if all the food items remained equally salient, they would starve as they hovered over them all, unable to move toward any one! From this perspective, attention is the process that saves us from trying to carry out incompatible actions simultaneously. However, everyday experience reminds us that the issue of consciousness remains relevant. For example, novice drivers experience considerable difficulty in trying simultaneously to perform all the actions needed to control a vehicle; in Allport's view they are trying to 'attend-for-action' to more than one thing at a time. However, this could be restated as an attempt to be *conscious* of more than one thing at a time. Once the driver has become more skilful, the difficulty of combining actions disappears, but so too does the driver's conscious awareness of performing them: they have become automatic.

Box 3 Research study: Hypnosis, time and attention

Brain scanning has revealed that regions of the brain known to be involved in attention show unusual activity when hypnotised participants become tolerant of pain (Crawford et al., 1998), or experience hallucinations (Szechtman et al., 1998).

Many people are unable to achieve such extreme effects in hypnosis, but there is one phenomenon that almost everyone experiences: hypnosis sessions usually feel to have lasted for far less time than the actual duration. I have explained this observation (Naish 2001, 2002) by linking it to Gray's (1995) theory of consciousness, which involves some of the same brain regions. He proposed that we maintain the content of our conscious awareness by registering repeated ‘snapshots’ of our environment. Our sense of time may be linked to the rate at which the environment is sampled.

To become hypnotised usually involves an induction in which one is asked to relax and focus attention on internal feelings, such as the heaviness of limbs or the rate of one's breathing. Subsequently, one is invited to imagine and attend to a pleasant, relaxing scene. Neither of these activities produces fast-changing streams of stimuli; the bodily feelings change only slowly and the relaxing scene is self-generated, so changes only when one wants it to change. I propose that in these circumstances there is no need to take such frequent snapshots, since little will change from one to the next. Consequently, we are less aware of the passage of time. In support of this claim, it turns out that participants who rate themselves as more successful at attending to their self-generated experiences and ignoring the real world are those who make larger underestimates of the session duration (Naish, 2003).

One might well ask how the term ‘attention’ has come to be applied to so many roles and processes; it might have been better to use different labels to distinguish between them. To use one word with so many aspects certainly makes a unitary definition very difficult to formulate. I suspect that the single term has stuck because ultimately all these facets of attention do lead to one result: conscious awareness. Even in so-called altered states of consciousness, such as hypnosis, attention appears to be a vital component (see Box 3). To conclude with a personal view, I will offer the following definition:

> Attention is the process which gives rise to conscious awareness.

I promised at the start of this course that attention was a broad and intriguing topic. I am sure you will agree that it was broad – and we haven't covered half of it – but I hope you are now intrigued too. It is generally accepted that readers cannot continue to devote attention to text that goes on too long, so I trust that I have stimulated, rather than sated, your attention!

Further reading

Styles, E.A. (1997) *The Psychology of Attention*, Hove, Psychology Press. A very readable textbook, which covers and extends the topics introduced in this course.

Pashler, H. (ed.) (1998) *Attention*, Hove, Psychology Press. An edited book, with contributors from North America and the UK. Topics are dealt with in rather more depth than in the Styles book.

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