5

HUMAN INFORMATION PROCESSING AND THE AUDIOVISUAL APPROACH TO EDUCATIONAL

Figure 5-1. The Relative Effectiveness of the Primary Senses

WE LEARN:

1.0% THROUGH TASTE
1.5% THROUGH TOUCH
3.5% THROUGH SMELL
11.0% THROUGH HEARING
83.0% THROUGH SIGHT

PEOPLE GENERALLY REMEMBER:

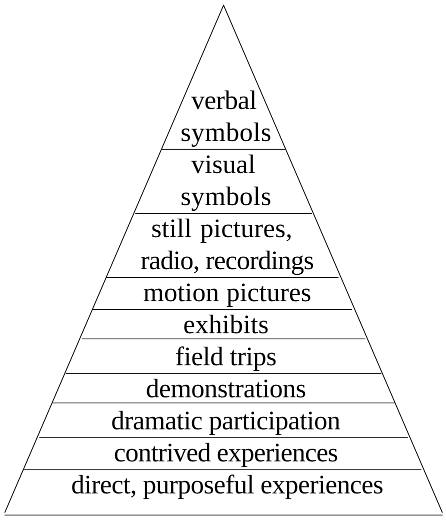
10% OF WHAT THEY READ
20% OF WHAT THEY HEAR
30% OF WHAT THEY SEE
50% OF WHAT THEY SEE AND HEAR
70% OF WHAT THEY SAY AS THEY TALK
90% OF WHAT THEY SAY AS THEY DO A THING!

We receive information from a vast array of sources, some experienced directly and physically as we come into contact with our immediate environment, others experienced vicariously through media such as films and television, or through symbolic modes such as words or figures. Some of these are perceived through all our senses, while others are perceived through a more limited number of senses. Treichler (1967) presents a number of interesting conclusions, which may accord with many commonly held beliefs concerning the relationship between our senses and how we learn and remember (Figure 5-1), although they should be treated with caution because he gives no indication of their basis.

Treichler's views have been reinforced by the theoretical orientations of a number of influential writers concerned with the audio-visual movement. For example, Dale (1954) listed the following proven contributions of such materials:

1. They supply a concrete basis for conceptual thinking and hence reduce meaningless word-responses of students.
2. They have a high degree of interest for students.
3. They make learning more permanent.
4. They offer a reality of experience which stimulates self-activity on the part of pupils.
5. They develop a continuity of thought; this is especially true of motion pictures.

Figure 5-2. Dale's "Cone of Experience"



6. They contribute to growth of meaning and hence to vocabulary development.
7. They provide experiences not easily obtained through other materials and contribute to the efficiency, depth, and variety of learning.

He concluded by asserting that these points do not constitute private beliefs or opinions, but are the 'distillation of a vast amount of research by many investigators.' Dale's 'Cone of Experience' (Figure 5-2) illustrates the narrowing of sensory experience from the concrete, purposeful experiences of direct, contingent experience to the higher reaches of abstract verbal and visual symbols. It reflects his original theoretical position that the predominant modes of instruction, found towards the pinnacle of the cone, provide restricted experiences for the pupil, who would greatly benefit from a more comprehensive range of educational experiences, encompassing those modes towards the base of the cone. Early support for Dale's approach came from Carpenter (1953) in the form of the 'sign similarity hypothesis' which stated that:

> ...films whose signals, signs, and symbols have high degrees of similarity ('iconicity') to the objects and situation which they represent will be more effective for most instructional purposes than films whose signals, signs, and symbols have low degrees of 'iconicity'. (Carpenter, 1953, p. 41)

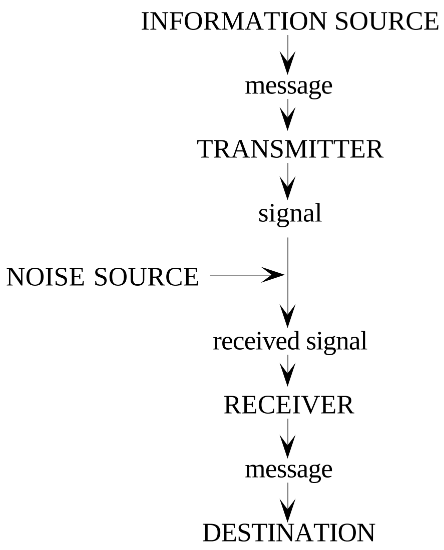
The term 'iconicity' was borrowed from Morris (1946), who suggested that signs vary in 'iconicity' to the degree to which they are similar to things or situations which they represent or signify. For example, a motion picture of a specific event may be described as highly iconic, whereas a pencil sketch may be described as being of low iconicity.

Such theories and other similar orientations (Knowlton, 1966; Gibson, 1954) have been given the collective term 'realism' theories by Dwyer (1978). In essence they suggest that the additional information flowing through several different sensory channels (ie. haptic, visual, auditory, etc.) will provide a multiplicity of stimuli which in turn will assist learners in organizing and structuring their perceptions, thereby ensuring more complete learning.

This approach has been preoccupied with the effects of the new media which were seen as being implicitly good because they were innovative devices that could supplant the verbal functions traditionally fulfilled by the teacher and text. Jonassen (1985) suggests that this materialistic conception of learning dominated the field in the early part of the century, yielding to the emergence of behaviourism towards the middle part of the century. In fact, it did not entirely give way and remained a powerful influence for several decades. Indeed, recent researches from cognitive psychology suggest that some, though by no means all, of the early claims may still be valid.

The major challenge to this physical science approach to educational technology came from the emerging cognitive psychology of the 1950's and 1960's. This was epitomized by Travers (1964) who felt that the work of psychologists and researchers was at variance with the

Figure 5-3. Shannon and Weaver's Linear Model of Communication (Shannon and Weaver, 1949)



claims made by the proponents of the audio-visual movement. Travers concluded that:

> ...there does not seem to be a single contemporary scientist who takes the position that the human can receive more information if exposed to information transmitted through two sense modalities rather than one. The position of the research scientists and the designers of audio-visual materials are at such opposite poles that it hardly seems possible that both can be correct. (Travers, 1964, p.375)

Travers supported the idea that the human information processing system is best represented as a single channel of limited capacity and that increasing the available information to the human receiver, either by using several sensory modalities or using very realistic displays, will merely produce information overload, which in extreme cases will actually cause decreases in learning. His theoretical base was rooted in the work of many psychologists interested in the problems associated with human perception and communication, most notably that of Broadbent (1958).

This issue is a complex one. It has profound implications for education. On the one hand there are those who hold to the belief that direct, contingent experience, with multi-sensory inputs, is essential for intellectual development; and, set against these beliefs, are those which suggest that only a fraction of the total sensory information available at a given time is capable of being processed by the central nervous system and, therefore, that educators should aim to compress reality into a form most compatible with the central processing systems.

PSYCHOLOGICAL APPLICATIONS OF INFORMATION THEORY

Information theory was developed initially for communication systems such as the telephone or radio, the best known of the early models being that of Shannon and Weaver (1949), shown in Figure 5-3. According to Attneave (1959):

> The idea that information is measurable in precise terms was not widely appreciated until 1948, when Norbert Weiner's book "Cybernetics" appeared and Claude Shannon published a pair of articles titled "The Mathematical Theory of Communication"....The quick spread of Shannon's ideas beyond the field of engineering may be attributed largely to a skillful and imaginative introductory article by Warren Weaver which appeared in the July 1949 issue of Scientific American. (Forward to "Applications of Information Theory to Psychology").

In this system the message from the information source is converted into a signal by the transmitter, for example, a sentence spoken into a microphone which is broadcast by a radio transmitter. At some point this signal is contaminated by 'noise' (an electrical engineering term, denoting some form of interference), before being decoded by the receiver, eg. a radio receiver, and reconstituted as the message. As more 'noise' enters the system, so the intelligibility and integrity of the original message changes, leading to new signals and information.

Shannon and Weaver viewed communication in a very broad sense to include all the procedures by which one mind may affect another: written and oral speech; music; pictorial arts; theatre; ballet; indeed, all human behaviour. Shannon's mathematical theory applied in the first instance only to the technical problem of accuracy of transference of various types of signals from sender to receiver. However, Weaver claimed that the theory was 'exceedingly general in its scope, fundamental in the problems it treats, and of classic simplicity and power in the results it reaches.'

The technical meaning of information is not radically different from every day usage, it is essentially 'choice', the narrowing down of alternatives, and the unit most often used for measurement is the 'bit', or binary digit. The word 'information' in communication theory relates not so much to what you do say, as to what you could say. The amount of information is defined in such a way that the nature of the information is irrelevant, just as weight is defined in such a way that the nature of the object is irrelevant: and the definition uses binary choice as its basis. In effect, the definition states that the information contained in a given situation, where a number of equally likely events could take place, is equal to the number of binary choices required to identify a specific event.

For example, imagine two boxes side by side, one of which contains an object (any object), with each box as likely to contain the object as the other. This situation represents one bit of information because it requires one binary choice to identify the box containing the object. No matter which box you choose to open you will know where the object is, and all uncertainty is removed. If you open the box and it is empty, you know unequivocally where the object is - in the other box! Of course, you also know where it is if you make the other choice. The point is, you only have to choose once to remove all uncertainty.

Thus, information is essentially choice, the narrowing down of alternatives. The mathematical theory of communication was developed in order to deal quantitatively with the transmission of messages over 'channels', to measure the amount of information transmitted, but Weaver indicated that the theory should not be restricted to engineering situations. It was to be seen as general in its scope.

The theory opened up a whole new avenue in psychology and some of Shannon's general concepts were rapidly introduced into the psychological literature by Miller and Frick in 1949. This led to a mushrooming of interest in information theory and its implications for the study of perception and communication. It was realized that, once received by the sensory apparatus, signals are then passed through the nervous system, whose channels are just as susceptible to capacity limits, equivocation and the degrading effects of 'noise', as are those of the telephone and radio.

Information Capacities of the Eye, Ear and Central Nervous System

The initial application of information theory to radio-communications dealt with measures of information transmission rates and the capacities of channels of communication, and this was reflected in the field of physiological psychology. Jacobsen (1950, 1951) compared the relative capacities of the eye and ear, and concluded that there was a factor of about 30 in favour of the eye on the basis of nerve fibres leading from the organs. However, when consideration was given to the efficiency with which an individual nerve fibre transmits information, Jacobsen found that the 900,000 optic nerve fibres each produced 5 bits per second, compared with a maximum of 0.33 bits per second for each of the 30,000 auditory fibres, giving a factor of nearly 500 in favour of the eye.

These results indicated a far higher rate of information transmission for the eye when compared with the ear, at least as far as the optic and auditory nerves are concerned. However, further research indicated that there was a restriction on the amount of information that could be transmitted through the central nervous system, and that central information processing would be subjected to an upper limit. The existence of such a limit implies that any information beyond the limit is lost; in information theory this loss is called equivocation.

The earliest experiments indicated that this capacity of the central nervous system was rather low. Hake and Garner (1951) required subjects to make judgements concerning the position of a pointer between two markers and found that the channel capacity for judgements of visual position was approximately 3.25 bits. In other words, they could accurately and consistently assign up to about 9 alternative positions on the scale , but as the number of positions they were required to estimate increased beyond 9 the subjects became less efficient. Similar results were obtained by Pollack (1952, 1953) for absolute judgements of auditory pitch. Subjects were asked to listen to a tone and assign a numeral to it. When only two or three tones were used the listeners never confused them, with four tones confusions were quite rare, but with five or more tones confusions were frequent. The upper limit was estimated to be 2.5 bits (6 alternatives).

It was soon realized that for one-dimensional judgements we rarely confuse 7 or so alternatives, and this seems to be a general limit on our capacity for such judgements. With multi-dimensional judgements, with a number of independently variable attributes, the capacity would be expected to increase. The position of a dot inside a square is clearly a two dimensional proposition. If we have a capacity of 3.25 bits for estimating intervals, as the Hake and Garner experiment indicated, and if we do this for two dimensions we should get 6.5 bits as our capacity for locating points in a square. In fact, the limit appears to be 4.6 bits or 25 alternative positions (Klemmer and Frick, 1953), rather than the 90 predicted from the uni-dimensional judgements. Pollack (1953) antici-

Figure 5-4. Dichotic listening experiment (Broadbent, 1954)

5	3	1	RIGHT EAR
6	4	2	LEFT EAR

Anticipated recall: 1,2,3,4,5,6 or 2,1,4,3,6,5

Actual recall : 1,3,5,2,4,6 or 2,4,6,1,3,5

pated that for listeners asked to judge both the loudness (2.3 bits) and pitch (2.5 bits) there would be an augmenting effect so that the multi-dimensional judgement would raise the capacity to 4.8 bits. The limit is raised, but only to 3.1 bits (9 alternatives rather than the 28 anticipated). In fact, the largest channel capacity in these early studies was found to be 7.2 bits (150 alternatives) when Pollack and Ficks (1954) used 6 different acoustic variables in their multi-dimensional display. These results led Travers (1967) to state that:

> ....as more dimensions are added there is a decreasing increment in the channel capacity of the multi-dimen sional system. People are less accurate in any one dimension if they must judge more than one attribute at a time.

The data suggest that the amount of information which can be taken in on a single presentation of a display is probably quite limited - perhaps of the order of 10 bits.

Further, the general conclusion was that the channel capacity is ordinarily less than that estimated by Jacobsen (1951), perhaps as little as a tenth of the figures given, and that the information used is probably less than one tenth of one percent of the channel capacity of the sensory input.

Human Information Processing: The Single-channel Model

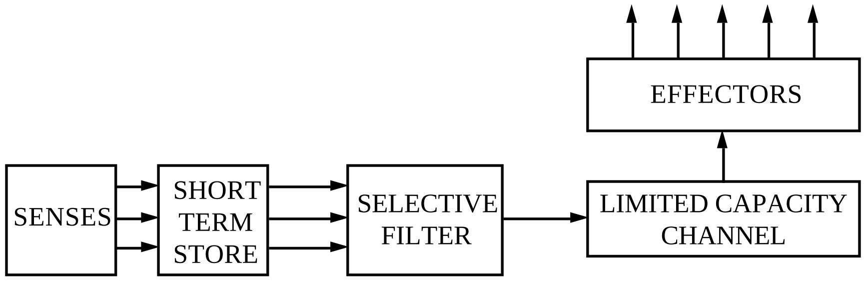
At this time there was good evidence to suppose that the information available from the senses far exceeds the limits of the central processing system. In addition, evidence was emerging from a series of experiments which indicated that sensory information fed into a central system for processing information, which was effectively a single channel system, in which information could be processed sequentially from only one source at a time.

The question was, as there clearly is a limit to the capacity of the central system, how does the system select which information to pay attention to and which to ignore? The formulation of the first complete theory of human information processing and selective attention by Broadbent (1958) attempted to provide an answer to this. The theory had obvious implications for anyone involved in producing teaching materials, particularly if those materials use a combination of senses, as is the case with many audio-visual aids. Broadbent's model was later developed by Travers (1964) who placed the research scientists and audio-visual designers at such opposite poles in their ideas concerning human information processing capacities.

Broadbent's original theory evolved from a series of experiments and techniques developed in the early 1950's. As with information theory, the main impetus for interest in this area was the tremendous rate of development of communication systems during the second world war. Colin Cherry's work in this field demonstrates the international and inter-disciplinary nature of this branch of psychology. Although he was an Englishman his major contribution was published as a result of research conducted at the Massachusetts Institute of Technology, and it appeared in the 'Journal of the Acoustical Society of America.' It was called 'Some experiments on recognition of speech with one and two ears' (1953) and used the technique known as 'shadowing'. Shadowing consists of playing a message into a set of headphones and asking the subject to repeat the words of the message, keeping pace with the presentation as far as possible. It is, in fact, a lot easier than it may seem, though the spoken words are slightly delayed behind those to which the subject is attending, and the voice tends to have a pronounced monotony. If the material being shadowed is of a complex nature the subject will invariably have very little idea of what it is about, even though every word has been recognized and repeated.

Cherry was concerned with what he chose to call the 'cocktail party effect', which also has the more scientific title: selective attention. He wanted to know how we were able to select that one voice to which we are attending from the general babble of the party. He was also interested in the retention of information from conversations to which we do not pay attention. In the experiments one continuous spoken message was fed into a headphone on the subject's left ear and a different message was applied to the right ear. The subject was then asked to repeat one of the messages concurrently while listening, and to make no mistakes. The really fascinating thing about the experiment concerns the nature of the subject's perception of the unattended message at the unshadowed ear. The subject could say

Figure 5-5. Simplified version of Broadbent's Model of Information Flow (1958).



little about it, apart from acknowledging that sounds occurred. In further experiments Cherry attempted to find out just what attributes of the rejected message were recognized.

In one experiment, for example, both messages started in English, and when the subject was comfortably shadowing the attended message, the unattended message was changed from English to German. When questioned later the subject was unaware of the change. In another experiment the unattended message was composed of one of the following: normal English spoken by a male; English spoken by a female; English played in reverse; and, finally, a 400 cycle per second tone. With all the conditions of human speech, including the reversed speech, all subjects reported it as such, but could not identify specific words or even the language as English. Physical characteristics, such as a change to female voice or the introduction of the tone, were always noticed.

Cherry concluded from these experiments that detailed aspects such as language, individual words or semantic content are not noticed in the unattended channel. In effect, he felt that the utilization of information by the higher centres of the nervous system can be represented best by a single channel system. Broadbent extended this idea that the perceptual system generally functions as a single channel with information from only one source gaining access to it at a given time. But he cautioned against saying simply that 'a man cannot listen to two things at once'. On the contrary, he receives some information even from the unattended ear: but there is a limit to that amount of information. Broadbent (1954) had found that subjects could actually recall details of information presented to the unattended ear, under the specific conditions known as 'dichotic presentation'. Subjects were presented with three pairs of simultaneous digits, one of each pair to each ear (Figure 5-4), and were asked to recall as many digits as they could. Under normal circumstances subjects would have had little difficulty in remembering 7 or even 10 digits, but under dichotic presentation they could recall only 4, 5 or 6.

The most interesting observation was that subjects preferred to report the digits by ear rather than in the order in which they were heard. In Figure 5-4, digits 1 and 2 are presented simultaneously, both being presented before the second set, digits 3 and 4. If subjects reported digits in temporal order both 1 and 2 would be recalled before either 3 or 4, giving two alternative temporal report patterns (anticipated). However, subjects chose to report the digits first by one ear and then by the other. When six pairs of digits were given, so that subjects had to recall 6 digits from one ear, before switching to the other, subjects were unable to recall the second set. Broadbent concluded that there must be a short-term memory store for information lying between the two stages of recognition of auditory messages. The experiment was repeated with half the digits presented to the ears and half to the eyes and the same result was obtained, showing that the buffer storage system was a general feature of human perception (Broadbent, 1956). This short-term memory store holds items which have not yet received attention and it may be thought of as keeping a record of raw sensory data. These results, and those of many other psychologists, physiologists and communications engineers, led Broadbent to the tentative formulation of his model of information flow in the human organism (Figure 5-5).

According to the Broadbent model, information passes from the senses and is held for a few seconds in the short term memory store where it will rapidly fade unless the selective filter mechanism permits access to the single limited channel, thence to the higher centres concerned with long term memory and control of behaviour.

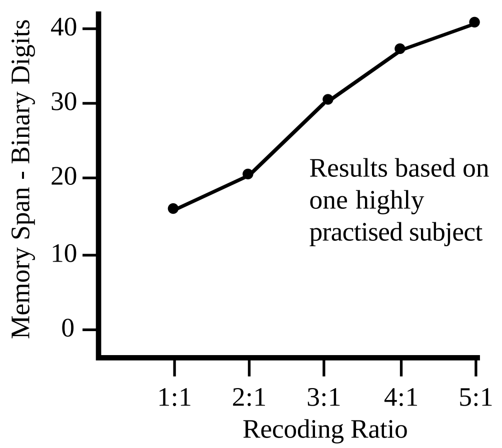
The short-term store which feeds information into the processing channel, via the filter mechanism, was demonstrated to have certain limitations, in that only a relatively small number of items could be held in the memory at a given time, and that attention to new inputs causes old activations to fade away. Even short lists will completely fade in as little as 18 seconds if the subject is prevented from repeating the list to himself (a process known as 'rehearsal').

Table 5-1. Ways of Recoding Sequences of Binary Digits.

Bits:	1	0	1	0	0	0	1	0	0	1	1	1	0	0	1	1	1	0

2:1	10	10	00	10	01	11	00	11	10
	2	2	0	2	1	3	0	3	2
3:1	101	000	100	111	001	110			
	5	0	4	7	1	6			
4:1	1010	0010	0111	0011	10				
	10	2	7	3	2				
5:1	10100	01001	11001	110					
	20	9	25	6					

Figure 5-6. Effects of Recoding Binary Digits on Short-Term Memory Performance.



Beating the Channel Capacity: "Chunking" Information

The limit of the storage system is 6-10 units of information, and these units were called 'chunks' by Miller (1956) to differentiate them from 'bits', because the amount of information retained is not fixed. If the storage of items was like absolute judgement, then there should be a fixed amount of information that can be retained. We should remember less items when they contain a lot of information and remember more when they contain little information. As Miller pointed out:

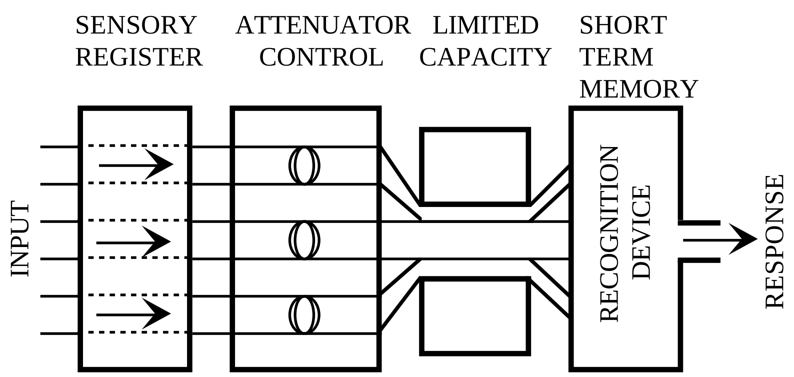
> For example, decimal digits are worth 3.3 bits apiece. We can recall about 7 of them, for a total of 23 bits of information. Isolated English words are worth about 10 bits apiece. If the total amount of information is to remain constant at 23 bits, then we should be able to remember only 2 or 3 words chosen at random. (Miller, 1956, p.91)

Clearly, this is not the case, we can recall substantially the same number of items for a range of materials: digits, letters, words. In fact, by a process of coding and recoding information into larger chunks to increase the total amount of information, Miller demonstrated that the informational bottleneck, caused by the severe limitations placed on the amount of information that we are able to receive, process and remember, could be stretched. Strings of binary digits were recoded by experimental subjects who were trained to code the strings into increasingly more complex chunks (Table 5-1). This meant that a string of 20 binary digits could be reduced to just four chunks of information using re-coding techniques. This, in turn, permitted the amount of information held in short-term storage to be increased dramatically (Figure 5-6). Miller concluded from this data that 'The kind of linguistic recoding that people do seems to me to be

Figure 5-7. Channel Switching.

Attended Ear :	sitting at the mahogany	/	three
Unattended Ear:	let us look at these	/	table

Figure 5-8. Treisman and Geffen's Attenuator Model of Attention.



the very lifeblood of the thought processes.' In other words, given the inherent limitations of our information processing system, we extend our capacities by recoding information in a more economical form, from which we can reconstitute the original message when required, much as we do with dried vegetables when shelf storage space is limited.

Human Information Processing: Alternative Models

Miller had demonstrated one way in which the basic limitations of the single-channel information processing system could be overcome and within a short time further research began to challenge a central concept of the Broadbent model, that unattended information could only be analyzed at the level of gross physical characteristics. For example, Moray (1959) found that although his subjects could not recall nor recognize irrelevant messages presented as many as 35 times to the unattended ear, they frequently heard their own name when presented in this channel.

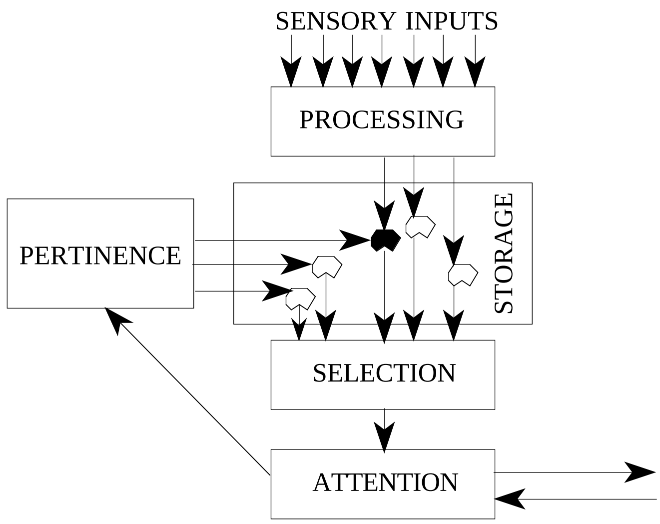
Further, Treisman (1960) demonstrated in an elegant fashion that subjects would follow the sense of a passage rather than the channel being shadowed, which indicated that processing was to some extent semantic. Figure 5-7 demonstrates how two sentences are switched in the shadowing experiment. Treisman found that subjects frequently shifted attention to the unattended ear to complete the sense of the sentence, so that it read 'sitting at the mahogany table', rather than 'sitting at the mahogany three'.

The conclusion from these experiments was that some, but not all, of the information from all the channels is processed and this led to the development of Treisman and Geffen's (1967) 'attenuator' model of attention. Figure 5-8 shows how the model permits various sources to use the channel simultaneously. However, since there is a limited capacity, inputs from some channels must be attenuated.

This model has one primary channel that is being attended to, while all other channels are passing information in reduced amounts, but in such a way that whenever important information enters one of these attenuated channels it can be responded to. Treisman and Geffen (1967) obtained results strongly favouring this 'attenuation' view. Their subjects shadowed one of two dichotically presented prose passages, while simultaneously they had to monitor both channels for the occurrence of a target word, tapping each time it was detected. The results showed that whereas 90% of target words were identified in the primary channel, only about 9% were responded to in the unattended channel.

Norman (1968) extended this model of selection and attention to include a 'pertinence' factor (Figure 5-9). Pertinence, in the Norman model, is based on the expectations of future inputs and the properties of the currently attended channel of information. Certain classes of inputs, such as the sound of one's name, can be expected to have a permanently high level of pertinence, others will have levels which fluctuate with the expectations and analyses of ongoing events. The items in storage were termed 'logogens' by Morton (1969) in his complementary theoretical position. The logogens are seen as having thresholds, with the output for further processing depending on the level of activation from both sensory input processing and pertinence. Norman's model incor-

Figure 5-9. Norman's Model of Selection and Attention.



porates suggestions that for proper assessment all input information must have access to storage (Deutsch and Deutsch, 1963), and that an adjustable threshold pre-sensitizes the organism to sensory information of high relevance (Treisman and Geffen, 1967).

The item selected for further processing by the attention mechanism in the Norman model corresponds to the stored representation which received the greatest combination of pertinence and sensory activation. This was developed in a further paper by Norman and Bobrow (1975) who suggested that varying allocations of attention can be made up to the capacity limit of the processing system. An important distinction was made between resource limitations and data limitations. Resource limitations depend on the available internal resources of the human processor; data limitations relate to the sources of data forming the incoming signals. The suggestion was that some tasks require less than maximum processing resources and that if two tasks together required less than the maximum available they could both be performed simultaneously without any decrement in performance. However, if more than the maximum processing resources are required effort will be directed in favour of one or the other, resulting in a deterioration in the performance. The concept of data limitation introduces the constraints imposed by the external stimulus upon the processing system. With some tasks, applying more resources to processing may not result in an increase in performance. The result is that the task has reached the point of pure data limitation. In such a case performance can only be improved by adjusting the stimulus data.

The Norman-Bobrow account resolved some anomalies in the data concerning information available in unattended channels and it is now generally accepted that information in these channels receives a level of processing higher than the crude physical characteristics suggested by the early Broadbent model. The processing is probably as high as semantic processing, and allows for channel switching as important information is registered in the attenuated channel. Cherry and Taylor (1954) demonstrated that this switching time was in the region of one sixth of a second or about 160-170 msecs, and Broadbent (1956) obtained a similar figure of 200 msecs in a later experiment.

The overall picture which emerges from these and similar studies of attention and information processing is one in which the major sense organs show great differences in their capacities for transmitting information, the eye being endowed with a greater number of nerve fibres, each of which is capable of transmitting more information than the corresponding auditory fibres. However, the transmitted information from the senses enters the central processing system which has a limited capacity. This limited capacity for information processing causes attention to be directed mainly towards one of several competing channels, the remaining channels being attenuated or receiving less than optimal processing but still receiving some high-level processing. Attention can be switched rapidly as important information is registered in the attenuated channels.

Depth of Processing and Mental Effort

Implicit in most of the early models of information processing was the division of memory into two parts: short-term memory (STM) and long-term memory (LTM), each with different characteristics but with both being essentially verbal storage systems. The distinction between STM and LTM has more recently given way to the view that memory should be viewed as an integral part of the whole information processing system, and that STM and LTM are merely artifacts of different

Figure 5-10. Availability of two coding systems as a function of stimulus concreteness; degree of availability is indicated by the number of plus (+) signs.

STIMULUS	**CODING SYSTEM**	
	Imagery	Verbal
Picture	+++	++
Concrete word	+	+++
Abstract word	-	+++

'depths of processing' (Craik and Lockhart, 1972). The different levels of processing range from shallow or physical analysis of a stimulus, to deep or semantic analysis. The depth of processing is defined in terms of the meaningfulness extracted from the stimulus rather than the number of analyses performed upon it. Information which is processed at a greater depth, which will be more meaningful than shallow processed information, will also be more memorable.

A typical experiment designed to demonstrate such an effect consists of having subjects perform different orienting tasks with a list of words before being given a recall test. Some tasks, such as detecting the occurrence of specific letters in the words or deciding the part of speech appropriate to each word, do not involve deep processing, whereas others, such as judging the pleasantness or frequency of usage, involve semantic processing at a deep level. Recall scores have generally tended to be higher for the deep processing list, although there is some circularity in the argument as to what constitutes a deep processing activity (Eysenck, 1984).

A recent adjunct to depth of processing is the elaboration of processing, with deep encodings being more elaborate or extensive and, therefore, providing more stored information than shallow processes. Retrieval, being affected by the amount of stored information, will be better for deep, elaborated encodings. Craik and Tulving (1975) ask 'Is spread of encoding a more satisfactory metaphor than depth?' and conclude that elaboration depends on the breadth of analysis carried out in each domain, and that a minimal semantic (deep) analysis will be more beneficial for memory than an elaborated structural (shallow) analysis.

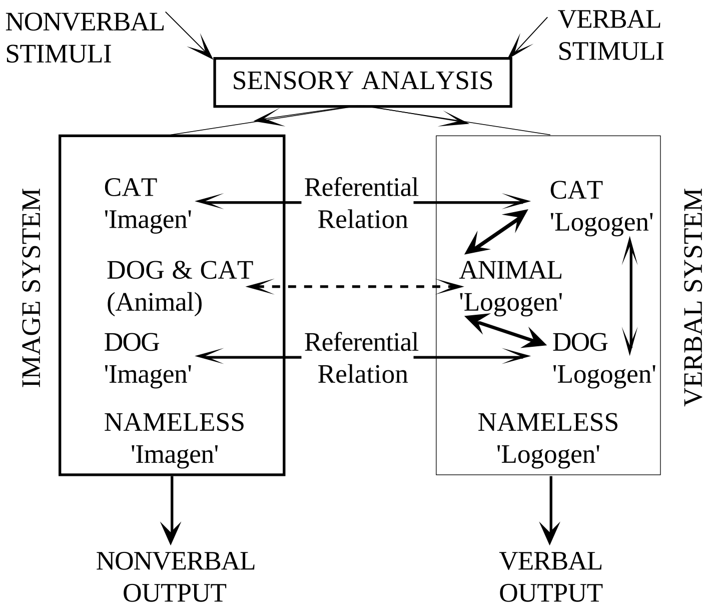
Eysenck (1984) has suggested that a more complete theory than the original levels of processing proposed by Craik and Lockhart (1972) should take account of the fact that learning and memory depend upon at least four major factors: (1) the nature of the task (2) the nature of the stimulus materials (3) the characteristics of the subjects and (4) the nature of the retention test used.

Salomon (1984) has attempted to incorporate some of these factors into his application of the levels of processing theory in media research. He observed that while many U.S. experts claimed that television somehow inhibits 'deeper' processing of material and thus cannot serve well as an instructional medium, his cross-cultural study of Israeli and American children demonstrated that Israeli children retain more information and are more strongly affected by its formal features than their American peers. The Israeli children seemed to take the medium more seriously, processing the material with greater depth. He reasoned that above and beyond the cognitive activities a source of information activates or inhibits in learners (see Chapter 7), the depth with which its information is processed may depend on the way in which it is perceived. Pre-existing perceptions, particularly if socially reinforced, may preclude deep processing of available information.

In his experimental study he found that children thought of themselves as being more able to learn from tv than from books. When presented with similar material to learn from tv or print, the tv group reported investment of significantly less mental effort than the book group. This self-reported amount of invested mental effort (AIME) was reasoned to be related to 'non-automatic, effortful mental elaborations' which are at the base of both depth of processing and Langer's (1984) idea of mindfulness.

With more tv group members reporting the tv programme to be 'easy stuff' and more book children reporting the text to be 'difficult', it should follow that the tv group should perform better than the text group on the test measuring inference making and factual recognition. This was not the case. It was the text group that achieved significantly higher scores. Salomon found that for the book group those who felt more 'efficacious' tended to invest more mental effort in reading the text, and those who invested more mental effort learned more. A different pattern emerged for the tv group. Those who felt more efficacious tended to invest less mental effort in the programme and thus learned less from it. Measures of the perceived realism of the different media showed tv to be rated higher and this correlated with the perception that the message was easier and therefore demanded less effort, a worrying result for advocates of realism theories! These results clearly indicate the complexity of the inter-relationships between those factors suggested by Eysenck (1984) as impinging on applications of depth of processing and elaboration paradigms.

Figure 5-11. Schematization of Paivio's Dual-coding Model (Bleasdale, 1983).



The Dual-coding Hypothesis.

Although the depth of processing approach has attempted to resolve the STM/LTM division, a new division has emerged based on two different but complementary systems of storage: a semantic/verbal logogen system and an image-based 'imagen' system. This division is necessary because of increasing evidence in support of a separate image-based system of information storage.

Many researchers have found that pictures are superior to words in a variety of tasks. In fact, people have an extraordinary recognition memory for pictures, and one of the most dramatic demonstrations was reported by Shepard (1967). Subjects viewed 600 pictures and were tested for recognition by pairing one of these pictures together with a new picture, not previously seen by the subject, who was required to identify the picture from the original set. Words were also presented in a similar manner: one set made up from fairly common words (100 times or more per million according to Thorndike and Lorge, 1944); the other from 'rare' words (less than once per million). Finally, a third group had sentences presented in the same way. The medians of the percentage correct were 98.5, 90.0 and 88.2 for pictures, words and sentences. The results also indicated that subjects were better able to recognize words which were rare (92.5 percent correct) than when they were frequent (84.4 percent correct). Similar results have been found by Gorman (1961) and Olver (1965). Further results showing the extent of visual recognition memory were obtained by Standing, Conezio and Haber (1970), who presented 2,560 photographs for 10 seconds each over a period of 2 to 4 days, with recognition being maintained at 90.5 percent for as long as 3 days. When recognition time was reduced to one second per picture and the orientation of the picture in the test was altered, performance remained largely unimpaired. It has been suggested that the superiority of pictures in recognition tests may be due to differential verbal responses rather than 'picturability'. However, much of the evidence indicates a higher recognition memory for pictures of familiar objects than their concrete-noun labels (Paivio, 1971, p.183), indeed, recognition memory appears to be a direct function of stimulus concreteness: recognition increases from abstract words, to concrete words, to pictures.

Paivio (1971) has concluded that these results suggest both verbal and non-verbal symbolic processes. The superiority of concrete over abstract words suggests that referent images, associatively evoked by the concrete nouns, also facilitate recognition memory. Paivio also found that, within the limitations imposed by task characteristics, there is evidence that non-verbal processes can also play a crucial mediational role in free recall. 'Picturability' has been shown to be consistently positive since the earliest experiments (Kirkpatrick, 1894; Calkins, 1898) when average recall was highest for objects and pictures when compared with words. Substantially the same results have been obtained in more recent time (Paivio, Rogers and Smythe, 1968; Sampson, 1970).

These results are of great interest because the required response in recall tasks is verbal in both cases (for both pictures and their verbal labels) and it may be anticipated that the to-be-remembered name should be more readily available when the stimulus is a word rather than a picture. Since it is not, verbal processes alone cannot account for the finding. On the basis of such experimental results Paivio has suggested the dual-coding model for pictures and words (Figure 5-10), where

Table 5-1: Channel Effectiveness (Hsia,H.J., 1968a).

VISUAL CHANNEL	AUDITORY CHANNEL
Spatial in nature, excepting tv and motion pictures	Temporal in nature
Both sequential and simultaneous presentation	Sequential presentation
Good referability: information can be stored in the display.	Poor referability
Numerous dimensions in information coding	Fewer dimensions in information coding
Restricted flexibility and advanced coding	Greater flexibility; variation in connotations, nuances and inflection
Much faster rate of transmission	Rate of transmission limited to speaking rate
Greater versatility	Less versatility
Less attention demanding	More attention demanding
Less resistant to fatigue	More resistant to fatigue

the availability of an item is indicated by its total representation in the dual (imagery/verbal) coding system.

These results certainly indicate the presence of both a non-verbal (imagen) and a verbal (logogen) storage system. Indeed, Bleasdale (1983) claims that it would seem logical from a phylogenetic and ontogenetic perspective to assume that linguistic ability is preceded by the acquisition of perceptually-based information. Piaget (1953) suggested that knowledge structures (schemata) start to be formed almost from birth, and are basically formed from the co-ordinated remnants of sensory and motor signals that have been generated as the child has interacted with the world. This view has been incorporated by Paivio (1971), who also assumes that linguistic competence and performance are based on a substrate of imagery, although verbal behaviour and understanding ultimately becomes free of dependence not only upon a concrete situational context but to some extent from the imagery as well.

This concept of independent verbal and imaginal representational systems is at the heart of Paivio's dual-coding model (Figure 5-11). According to this model, words and pictures receive an initial, relatively peripheral, sensory analysis and are usually recognized by one of the stored representations (imagen/logogen), permitting access to further referential processing, during which time certain words may be imaged (especially concrete nouns) and pictures (or line drawings or objects) may be named. Finally, associative relations may be formed intraverbally among logogens and intra-imaginally among imagens.

Other models with similar dual-representational systems (Seymor, 1973; Morton, 1980), have also been developed to account for the accumulating evidence, coming from a wide variety of sources, for a separate image-related system.

WORDS, PICTURES AND INSTRUCTIONAL MEDIA

The pedagogical interest in the major channels of communication, their relative capacities, the limits placed on the processing of information, and the types of storage systems for processed information stems from a realization that the effectiveness of media generally, and instructional media in particular, will depend on the different properties of the channels used. Hsia (1968a) summarized these differences for the eye and ear and concluded that unless the fundamental information processing properties of the modalities are known then comparisons between different media using one or both senses will be meaningless (Table 5-1) and Travers (1967) agreed with this, clearly identifying those instructional tasks for which one or the other of the main channels is an obvious choice:

> One cannot reasonably ask the general question whether the eye or the ear is more efficient for the transmission of information, for clearly some information is more efficiently transmitted by one sensory channel than by another. If a person needed to know about the appearance or physical characteristics of an unfamiliar animal he would do much better to examine the animal visually than to have a description related by another observer. Such visual observation would be best until he asked about the vocal noises emitted by the animal, in which case he would do better to hear the actual sound of the animal than to obtain visual information about the vocal mechanism. Where direct information is needed about the world, the sensory modality should be used which

> can best transmit directly the particular physical information involved. (Travers, 1967, p.88)

Words: Print and Speech

However, under certain circumstances it is quite legitimate to compare the efficiency of the two main sensory modalities because both may seem appropriate. For example, identical material may be presented to both eye and ear in the form of print or speech. Based on the knowledge gained from cognitive psychology it can be postulated that the eye with its superior capacity will be more effective, although the limiting factor in the form of the central processing capacity may diminish the eye's overall superiority. Also, auditory information may have a greater tendency to become data limited because of the lower transmission rate of the peripheral nervous pathways. This would suggest that for certain types of information the application of additional processing resources would not effect improvements in performance, which could only be brought about by changes in the stimulus data. Further, it could be argued that print will gain access to both verbal and image systems, enhancing memory performance.

Day and Beach (1950) conducted one of the earliest and most thorough surveys of the research literature comparing visual and auditory presentation of information, and reached the following conclusions:

1. Meaningful, familiar material is more efficiently presented aurally, whereas meaningless and unfamiliar material is more efficiently presented visually.
2. The greater the reading ability of the receiver, the relatively more effective is a visual presentation.
3. The relative efficiency of a visual presentation increases with age from a definite inferiority at the age of six to a possible superiority at the age of sixteen.
4. Unusually difficult material is more effectively received with a visual presentation, whereas part icularly easy material is better understood with an auditory presentation. The relative effectiveness of the visual presentation increases with increasing difficulty of the material.
5. The relative efficiency of a visual presentation diminishes as the interval of delayed recall in creases.

There is a tendency here to support the predictions made on the basis of the new understanding of human information processing. Performance was found to be dependent on age, reading skill and the difficulty of the material and this was confirmed for studies using nonsense syllables or digits, meaningful words in serial order, and meaningful prose reviewed by Hartman (1961a). He found that:

> Relative channel effectiveness depends on the difficulty or complexity of the material for a given group of subjects provided the subjects can read. With material such as nonsense syllables and digits, adults find print an advantage. The reading skills of younger children, however, are so limited that the audio channel is probably the most effective for them regardless of task. (Hartman, 1961a, p.237)

In other words, the print channel becomes more effective relative to the audio channel as the difficulty of material increases, provided a fair degree of literacy is present. The meaningful prose materials consisted of educational talks, passages selected from fiction, essays and advertisements. Print was found to be superior in nine studies; audio was favoured in eleven; and three found no difference. With few exceptions, those studies favouring print dealt with adult subjects and complex stimulus materials and the studies supporting the relative effectiveness of the audio channel used young children as subjects, or adults and older children with simpler information.

Gulo and Baron (1965) presented prose material via print, lecture, television lecture and radio to college students and found reading to be superior to the other three presentations on a multiple-choice retention test. Thalberg (1964) found that for moderately difficult and very difficult material, reading was superior to listening for college students. These results were confirmed by Levie and Dickie (1973) in their later review.

One explanation for the superiority of reading relates to the greater referability of print, first recognized by Day and Beach (1950), combined with the fact that during equated time periods in which listening subjects were receiving only one exposure, reading subjects (who were receiving information at a faster rate, because reading is faster than speaking) could obtain more than one learning opportunity by re-reading. The results are also consonant with estimates of the higher rate of information transmission within the visual system and the probable lower data limitation threshold of the auditory system.

Words: Comparisons of Multi-channel with Single-channel Presentations

Results of studies comparing information presented to one sense modality with that presented to more than one modality are of particular importance when considering the Broadbent (1958) model of information processing as elaborated by Travers (1967) for information transmission by means of audio-visual materials. In this model incoming information is compressed (redundancy is reduced) by the sense organs and peripheral nervous system so that some bits of information are 'chunked' together into fewer bits of information. This compressed information enters a central processing system which can handle sequential but not simultaneous information. If the central processing system is overloaded, some information may be stored briefly before it fades. The model predicts that if a presentation of the same information (spoken words and the same printed words), delivered simultaneously to both channels, is compared with either separately, no difference will be observed in the performance (recognition or recall) since all information must ultimately pass through a sequential processing system.

Later models, particularly those of Paivio (1971) and Morton (1980), support an alternative view of the results of such comparisons. A combination of spoken word and written word would activate both imagen and logogen systems, contributing to an increase in performance when compared with single presentations. Print alone would also have access to both systems, via the referential relation links, but not in such a direct manner.

The results of Day and Beach (1950) clearly support the later view. Another of their conclusions states unequivocally that a combined visual and auditory presentation leads to more efficient comprehension than either alone. Similarly, Hartman (1961a) reviewed nine studies comparing audio-print with print alone and found seven of them to favour the simultaneous presentation. Hartman (1961b) also found the audio-print presentation to be the most consistently effective of seven possible combinations of three channels tested. He concluded that a simultaneous audio-print presentation is more effective than either audio alone or print alone, when the simultaneously presented information is redundant (ie. when the same information is presented to both channels).

Van Mondfrans and Travers (1964), however, found evidence to support the Broadbent/Travers model. When recall of common words presented simultaneously by vision and audition was compared with words presented by vision alone and by audition alone no differences were found. Hsia (1968b) later found an audio-visual presentation of prose passages to be affected less than either audition or vision alone when 'noise' was introduced into the display (25% white noise in the audio channel; random black dots scattered over 25% of the visual display). Severin (1967) found that when recognition testing was provided in the channel or channels in which the information was presented, words presented simultaneously in audio and print were not significantly different from the print only condition, but were superior to the audio only presentation. Interestingly, the most effective condition was audio plus related pictures, which was superior to the print condition, a result consonant with the dual-coding model.

Joy and John Menne (1972) confirmed Hartman's conclusion. They tested their subjects under aural, visual and audio-visual presentations. Three simple four-line verses, each containing 22 words were presented via television. The subjects each received an audio presentation, a visual presentation and a combined presentation of words, spoken and written. After each they were required to recite the verse. The results demonstrated that an audio-visual presentation was superior to either presentation alone.

The weight of evidence is clearly in favour of the later models of human information processing, with their emphasis on resource allocation, data limitation and dual coding of information in separate but related image and verbal systems. These studies do represent a rather special case, with the same material (words) being presented to the two channels.

There are some limited pedagogical applications that may be derived from this work, for example, in the teaching of languages, but comparisons of pictures and words are of much greater educational interest. After all, the principle aim of the early educational media theorists was to set education free from the constraints imposed by 'excessive verbalism'.

Words and Pictures: Comparisons of Single-channel Presentations

There is a complication in this area because it opens up intra-channel comparisons, as well as inter-channel comparisons. Thus, we can consider differences between words and their pictorial representations within one channel (print and pictorial: visual channel) and between channels (spoken words and pictures: auditory and visual channels). Much of the research has concentrated on the intra-channel comparison.

Hartman (1961a), in his review, concluded that the weight of studies comparing a pictorial presentation with an audio presentation (eg. pictures of objects compared with spoken words of the objects), favoured the pictorial mode, although he was cautious in his commitment to the generalization because of the small number of studies, and because one of the studies compared the effectiveness of the visuals in films with their sound tracks, a procedure which compares two elements which may have substantially different functions within the display. The results do, however, confirm those obtained for spoken and printed words, which demonstrated superiority for the visual channel.

Comparisons between pictorial representations and written words have received much wider concern - the attraction of tighter experimental control is obviously one factor. Hartman (1961a) reported five such studies, all favouring the pictorial channel. Later studies (Gorman, 1961; Olver,1965; Rohwer, Lynch, Levin and Suzuki, 1967; Jenkins, Neale and Deno, 1967; Shepard, 1967) confirmed this in a variety of situations. Recall and recognition have been shown to increase from abstract words, to concrete words, to pictures, leading to Paivio's proposal for the dual-coding approach to perception and cognition.

Paivio (1971) describes one experiment in which subjects were shown words or pictures for a fraction of a second and were then asked to recall them. One group was tested after a delay of one week. Half of the subjects were not informed of the recall test until after the presentation ('incidental' group) . The stimulus items were composed of pictures, concrete words (ie. the words associated with the pictures) and abstract words. The immediate recall results demonstrated a clear advantage for pictures, with concrete words superior to abstract words, for both 'incidental' and 'intentional' groups. The delayed responses maintained this order, with the incidental group showing a higher delayed recall of pictures than was previously obtained for concrete words on immediate testing. Needless to say, this and many other studies led eventually to the development of the later models of human information processing.

Words and Pictures: Comparisons of Multi-channel with Single-channel Presentations

This strikes at the very heart of audio-visual theory. What evidence is there to support the idea that a combination of audio and visual will bring about more complete learning than either channel alone?

In most of the early studies information presented to the two channels was related (eg. a pictorial representation of an object and a verbal description of it) although other possibilities do exist: the information may be unrelated or even contradictory. Hartman's (1961a) review found the available thirteen studies to be inadequate for the formulation of generalizations, but did conclude that comparisons of pictorial-verbal presentations with single-channel presentations strongly indicated an advantage for the combination of channels.

Early researches dealing with motion film variables (Hoban and Van Ormer, 1950) supported the advantage for sound plus picture combinations, and this was confirmed by Ketcham and Heath (1962) who demonstrated that sound plus relevant pictures was superior to sound alone, with sound plus irrelevant pictures proving to be least effective. When comparing the effectiveness of relevant pictures in multiple-channel communication Severin (1967) found audio plus related pictures to be the most successful of six combinations, including print alone and audio alone, with unrelated-picture/audio combinations least effective. More recently, Nugent (1982) demonstrated that when content is the same in visual, audio and print channels, younger students learn equally well from all modes, but combining pictures with print or audio generally maximized learning. This research suggests that by conveying information through both linguistic and iconic symbols students were provided with complementary processing systems, and they could alternate between the two to obtain information. This study offers support for the theoretical position that learners process pictorial and linguistic information through functionally independent, though interconnected, cognitive systems.

The most thorough exploration of multiple-channel communication has been undertaken by Dwyer (1978). In a series of experiments starting in 1967 Dwyer systematically studied the effects of different conditions of presentation of the same material. This consisted of a study unit 'The Human Heart', which was presented either as an oral/verbal presentation, with the recorded script being accompanied by keys words in the visual display, or as an illustrated presentation, with pictures accompanying the recorded script. Several different series of pictures were prepared, ranging from simple line drawings to full colour photographs. In addition to different types of illustration, there were four different types of test: a drawing test, in which the subject drew a labelled representative diagram of the heart; an identification test, in which subjects had to identify certain numbered parts of a heart; a terminology test which evaluated knowledge of specific terms; and a comprehension test which evaluated understanding and an ability to use information to explain phenomena. The individual scores were pooled to give a 'total criterial score', showing the subject's total knowledge and understanding.The results of the first experiment led Dwyer to conclude that:

> The results of this study indicate that when students viewed their respective instructional presentations for equal amounts of time, the simple line drawing presentation was significantly more effective in facilitating achievement than was the oral presentation without visuals on the drawing, identification and total criterial tests. The oral presentation without visuals of the heart was found to be as effective as each of the visually complemented treatments on both the terminology and comprehension tests. (Dwyer, 1972, p.22)

The results have not always been quite so clear-cut. With different populations of subjects the results have sometimes shown visuals to be beneficial for the terminology and comprehension tests. Visuals produce consistently higher levels of achievement for the drawing, terminology and total criterial test, when compared with the oral presentation, although such benefits are not sustained over a two week delayed-testing period. However, Dwyer's research consistently demonstrates the benefits associated with pictorial accompaniments to spoken commentaries, and provides additional support to the audio-visual theorists.

Texts and Illustrations

The effects of illustrations on the understanding of text is obviously of pedagogic interest. It is assumed that illustrations must add to recall, comprehension and understanding. Otherwise, why should publishers of school texts take so much trouble to prepare them? However, despite this assumption, much of the early research on text illustrations reported a slight advantage for text alone (Miller, 1938; Vernon, 1953, 1954) and this led Samuels in 1970 to conclude that pictures do not facilitate comprehension of text. He was particularly concerned that the assumed benefits of illustrations produced to supplement texts should be subjected to scrutiny, claiming that:

> If fish were to become scientists, the last thing they might discover would be water. Similarly, researchers have too often failed to investigate important aspects of their environment because being immersed in it, they fail to notice certain components of it; or, having noticed a component, they simply assume it must be that way. One such example from reading is the ubiquitous use of illustrations.... (Samuels, 1970, p.397)

Samuels suggested that pictures are used in instructional materials under the assumption that they facilitate learning by appealing directly to the student's five senses. This was tested for by Bourisseau, Davis and Yamamoto (1965) but, as with other studies reviewed by Samuels, the results were negative and the authors concluded that although many people believed that one picture is worth a thousand words, so far as sensory response is concerned, the assumption is unwarranted.

In conclusion Samuels suggested that the answer to the question 'Should pictures be used as adjuncts to printed texts?' depended on the objectives.

> If the objective is to promote acquisition of a sight vocabulary, the answer would seem to be 'no.' If the objective is to facilitate comprehension, the answer is less definite.... Although the research, in general, does not show that pictures aid comprehension, neither does it show that they hinder comprehension (Samuels, 1970, p.405)

Much subsequent research disagrees with this view, but the out-of-date reviews may still be sighted authoritatively as sources of wisdom concerning this topic, according to Levie and Lentz (1982). Having 'discovered water' later researchers began to analyze the constituent parts and determine how they interacted.

Levie and Lentz (1982) reviewed the later research, starting by looking at the effect of visual illustrations on the learning of verbal information presented in the text. This excluded oral or audio-visual presentations; word lists, single sentences, or deliberately ambiguous passages; charts, diagrams and graphs. Essentially they were looking at studies comparing learning from illustrated texts versus learning from text alone. They took what they termed an 'information-analysis approach' to the research, based on the possible relationships between the information in a text passage and in the illustrations. Information presented only in the text passage (ie. without illustration) they termed 'non-illustrated text information'; other information provided only in the pictures was termed 'picture-only information'; and when text material was accompanied by relevant illustrations it was called 'illustrated text information.'

The researcher's test of learning is a critical factor in evaluating results in this area. For example, does the test measure the learning of illustrated text information only, non-illustrated text information only, or some combination? Levie and Lentz (1982) claimed that when researchers control these relationships, greater clarity about the effects of text illustrations is possible. They identified a total of 46 comparisons of learning illustrated text information from illustrated text versus text alone. A majority of the results were statistically significant and in favour of the illustrated text, giving an average effect size of 0.55, with the illustrated text group score averaging 36% more than the text alone. This led Levie and Lentz to conclude that:

> With a few exceptions, the results showed that illustrations had a significant positive effect on learning illustrated text information and no effect on learning non-illustrated text information. (Levie and Lentz, 1982, p.198)

Vernon (1953) suggested that illustrations laid undue emphasis on certain points and therefore distracted attention from other aspects of the text, thus hindering overall performance. A more popular view is that illustrations have a generalized motivating effect and will improve learning of information which is not illustrated. Levie and Lentz (1982) lend support to the middle view, that illustrations simply have no effect on learning non-illustrated text information.

When learning a combination of illustrated and non-illustrated text information it can be predicted from the above results that the effect of including illustrations will depend on the proportion of supported text in the test employed. This is confirmed by Levie and Lentz, who indicate that 'the addition of pictures should not be expected to hinder learning; nor should pictures always be expected to facilitate learning.' However, they conclude that learning is better with pictures in most cases.

Dwyer's researches include many studies in which the materials are presented in the form of a text, and the results of these were also analyzed by Levie and Lentz. Similar differential effects were observed for the different types of test as were found in the studies using an audio-visual presentation, with the largest effect size in favour of illustrations being observed for the drawing test (0.58), lesser effects for the identification test (0.38) and terminology test (0.28), and a trivial effect for the comprehension test (0.09). These results were interpreted as showing that the degree to which an educational objective is aided by pictures depends on the emphasis given to knowledge about spatial information in the test of learning, demonstrating a consistency between Dwyer's work and other research in this area.

Levie and Lentz's results have been confirmed in a further meta-analysis conducted by Levin, Anglin and Carney (1987). Levin (1981) had previously speculated that illustrations could be categorized as having five different functions: decoration, representation, organization, interpretation and transformational. He suggested that each of these functions would produce different

Figure 5-12. Dwyer's realism continuum for black and white and coloured illustrations.

1. Simple line representations (black and white)
2. Simple line representations (colour)
3. Drawings - detailed and shaded (black and white)
4. Drawings - detailed and shaded (colour)
5. Photographs of a model (black and white)
6. Photographs of a model (colour)
7. Photographs of a real heart (black and white)
8. Photographs of a real heart (colour)

degrees of prose learning facilitation, ranging from no effect for the decorative function to substantial for transformational pictures designed specifically with a mnemonic objective in mind. Moderate to substantial facilitation was anticipated for representation, organization and interpretation functions. The meta-analysis confirmed these expectations with a near zero effect size for decorative illustrations and an average 0.71 across other text-relevant studies. For children the average effect size ranged from 0.5 for representational pictures to 1.43 for transformational illustrations; for older subjects the range was from 0.7 to 1.04. These results further confirm the power of illustrations to enhance prose learning, particularly when pictorial information is further encoded as in the transformational mode.

Pictorial Complexity

Levie and Lentz (1982) comment that even within the limits imposed on studies considered in their review there is still considerable diversity, particularly in the types of illustration used, which varied from simple line drawings to colour photographs. Dwyer's work demonstrated advantages for including illustrations compared with no illustrations for specific types of test, offering support to the audio-visual approach, but as yet the differential effects of the various types of illustrations included in his researches have not been discussed. Four different types of illustration were used in most of Dwyer's experiments. They varied in the amount of detail and general pictorial complexity, and were produced in a black and white version and a colour version, giving a total of eight different types which could be arranged, according to Dwyer, along a 'realism continuum' (Figure 5-12).

Dwyer (1978) suggested that the two competing theories of human information processing, represented by the single-channel and multiple-channel perspectives, predicted different results for experiments varying the degree of realism in illustrations. The multiple-channel theorists, which Dwyer identified as stemming from the writings of Dale (1946) and Carpenter (1953), predicted an increase in the efficiency in facilitating learning as the realism increased from the simple line representations to the photographs of a real heart. The single-channel theorists, based on the work of Broadbent (1958) and Travers (1964), predicted no effect from the increase in pictorial complexity, indeed when information in picture and text was redundant they predicted no effect from the addition of illustrations to the text. The results of the initial experiment (Dwyer, 1967) was equivocal. Illustrations did facilitate achievement for a majority of the test measures. However, increasing the degree of realism in the illustrations did not increase the performance on any of the tests. In other words, the addition of a simple line drawing enhanced performance on three of the five tests, but there was no difference in the effects of any of the different types of illustrations.

Further experiments reported by Dwyer (1972) tended to support the initial findings with a majority of the studies demonstrating superiority for the presentations illustrated with simple line drawings when assessed on the total criterial test and the drawing test. For the terminology and comprehension tests illustrations were generally not an advantage; and the identification test indicated an intermediate position, with many studies indicating benefits from the addition of simple line illustrations, and similar numbers indicating no such advantage. In only a minority of cases (16%) were illustrations which were more complex than the simple line drawings more effective, and there was no discernible pattern to this minor effect.

These results are not surprising when considered against the background of several decades of research in this area. Vandermeer (1954) had investigated the comparative effects of colour and black and white motion films, on the assumption that colour would add realism to the visual display, which would increase the efficiency of the films as teaching aids. This was not the case, and he concluded that:

> The use of colour in instructional films which may seem to 'call for colour' does not appear to be justified in terms of the greater learning on the part of those who view the films. If colour is to be used effectively in films there must be careful pre-production consideration of the probable psychological impact of specific uses

of colour upon the learner. (Vandermeer, 1954, p.134)

These results were confirmed by later researchers (eg. Kanner and Rosenstein, 1960) and reviews (Kanner, 1968; Cox, 1976).

A fascinating report from the Yale film research programme (May and Lumsdaine, 1958) showed the lack of effects from increased pictorial complexity when they compared a crude black and white film version of a film, based on the story-board sketches, with the finished full colour motion picture. The results were totally unexpected: there was no difference in the achievement of the objectives between the two versions, although there was a large difference in cost. Twyford (1954) had obtained similar results when comparing a full colour motion picture with a version consisting of a series of still pictures in black and white. There were slight differences in favour of the expensive colour version, but the differences obtained were not of educational significance, and Twyford cautioned against the indiscriminate use of realistic presentations when they could not be justified in terms of instructional benefits.

Human Information Processing: Conclusions

There has been a healthy rivalry between theorists advocating either a single-channel of limited capacity or a multi-channel approach to human information processing. The present position calls for a resolution of the different positions. In part, both positions are correct.

The single-channel theory proposed by Broadbent (1958) and elaborated by Travers (1967) is no longer wholly tenable, and it is reasonable to assume that varying allocations of attention can be made to incoming information, with apparently unattended information receiving high levels of processing, as suggested by Norman and Bobrow (1975). Incoming information may receive variable amounts of processing, and the depth of processing may depend upon such factors as the 'realism' of the display, the receiver's perceived self-efficacy and the perceived demand characteristics of the particular medium.

There is good evidence to support two complementary representation systems, along the lines suggested by Paivio (1971), with extensive interconnections between verbal and image systems. This is clearly acceptable to the multi-channel advocates, and supports the early claims of the 'audio-visual' approach to educational technology.

However, there are limits to the audio-visual approach. Although multi-sensory presentations do seem to facilitate learning on specific tests, they do so only in circumstances where audio and visual components are mutually supportive. Visuals increase learning when they are relevant to the text or commentary, they do not produce a generalized effect on unrelated textual or verbal information. Visual information also appears to be compressed by the processing system, as suggested by Travers (1964). This is necessary because of the limited capacity of the system and precludes any facilitating effects anticipated by increasing pictorial complexity or realism. It suggests that for the more common activities associated with visual testing (eg. drawing, identifying) students may benefit from visuals which are pre-compressed and simplified by the instructor.

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