Changing Attention

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Acknowledgments

All my love and respect to my family and the McCarthy clan back in Leigh. I'm sorry I've been away for so long, but you know what they say: "A man's gotta do what a man's gotta do". I just hope it was worth it.

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The focus of the thesis is to question how attention or selection bias might initially develop and change over time. In addressing this question it is argued that a linear information processing framework fails to account for the source or origins of selection bias. This issue has been ignored in the many selection paradigms because the source of bias is usually the experimenter. In other words, subjects are provided with a description of the target to select prior to the presentation of stimuli. Therefore, in this case, the question asked is how bias has its effect on subsequent processes rather than on the cause of bias in the first place. To break down this problem Posners' (1980) distinction between Endogenous and Exogenous factors is drawn on. Endogenous factors govern attention to internal goals whereas Exogenous factors govern attention to external circumstance. To account for these two sources of bias, a cyclic framework with two processing loops is proposed. By contrasting the proposed functions of the loops, it is inferred that a behavioural comparison needs to be made between biases towards familiar and novel objects. To investigate such selections empirically, a paradigm developed by Johnston et al. (1990) is adopted. Within this paradigm subjects are briefly presented with an array of four objects that must be identified and localised. If all the array objects are familiar then localisation performance is superior to when they are all novel. However, if a lone novel object is introduced into a familiar array then this pattern is reversed, showing superior localisation of novel, relative to familiar objects. This effect, known as Novel Popout, is examined in a series of six studies. The findings from the popout paradigm are used to develop a theoretical network model of the cyclic processing framework.
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Chapter 1

Frameworks for Changing Attention

"Since the succession of two acts is usually regarded as an indication of their causal relationship, (post hoc ergo propter hoc), thought is generally accepted as the cause of action. When the external influence, i.e. the sensory stimulus, remains unnoticed, which occurs very often, thought is even accepted as the initial cause of actions. Add to this the strongly subjective nature of thought, and you will realize how firmly man must believe in the voice of self-consciousness when it tells him how such things occur. But actually this is the greatest of falsehoods: the initial cause of any action always lies in the external sensory stimulation, because without this thought is inconceivable."

I.M. Sechenov (1863)
1.1 Attentional Frameworks

Within this chapter, three frameworks for interpreting attentional phenomenon are reviewed; the linear framework, the cyclic framework and the attentional network framework developed by Posner and Rothbart (1990). Following Allport (1993), it is argued that the dominant cognitive framework assumes a linear unidirectional processing sequence. Although this has been useful in delineating sequential symbolic stages, one drawback of the assumption is that it fails to account for the development or origins of selective behaviour. To address this issue, a cyclic processing framework is examined as a potential alternative. One feature made explicit by a cyclic framework is that selection at one point in time is determined by selections at previous points in time. To examine this, paradigms employing a single repetition methodology are reviewed to assess the effects of a previous selection on subsequent selection performance. The dominant methodology of this type is the so-called "cue-target" paradigm, from which Posner and Rothbart (1990) have developed a neuro-anatomical framework of attentional function. An important feature of their framework is the distinction between Endogenous (Internally Driven) and Exogenous (Externally Driven) factors governing attention. Put simply, Endogenous factors govern attention to internal goals whereas Exogenous factors govern attention to external circumstance. These two functions are associated with separable anatomical areas. Endogenous shifts are identified with a set of areas termed the Anterior network. By comparison, Exogenous shifts are associated with a set of areas called the Vigilance network. A priori there is no reason to suppose that the development of attention will have equivalent consequences in these two functional areas. In light of this, a general framework of attention is proposed which represents Endogenous and Exogenous functions as separable processing cycles. This framework will be developed throughout the thesis in an attempt to disentangle the changes in attention that occur with experience.
1.2 Attention and the Linear Framework

Selective attention is conceptualised by contemporary theories as a process that highlights a particular information source for potential action (Allport, 1980; Colby 1991). Selection operates by differentially processing a subset of information from the total informational set. As described by Neill et al. (1995), current conceptions of attention assume that information is processed automatically up to a point where attention intervenes to select or gate certain information for further processing. The information that isn't selected is assumed to receive no further processing. The selection process itself has been characterised in two distinct ways. One view suggests that attended information is selected through direct facilitation (See Fig. 1.1a). A logical alternative to the facilitation hypothesis is that selection is achieved by inhibiting information to be ignored. This allows the attended information to proceed unhindered (See Fig. 1.1b).

![Diagram of Neill's (1995) conception of alternative selection processes.](image)

**Figure 1.1:** Neill's (1995) conception of alternative selection processes.
As noted by Allport (1993) the above conceptions of attention are underpinned by a set of assumptions about cognitive and perceptual-motor architecture. Of relevance to the present argument are: (1) that information follows a linear unidirectional sequence from sensory input to response; and (2) that there is a single locus of selection at some point in the sequence, such that only a subset of the information available is processed further. These assumptions form the foundations of an information processing framework with a long history and a large influence. A unidirectional processing sequence can be seen in frameworks dating from Broadbents' (1958) conception through to contemporary versions some thirty years later (Cowan, 1988). Similarly, the single locus assumption has generated a huge body of research targeting whether selection occurs early or late in the process sequence. Again, this assumption has driven research for over thirty years, from the formation of opposing camps in the early sixties (eg. Treisman, 1964; Deutsch & Deutsch, 1963) through to new age compromises of the nineties advocating a flexible locus of selection (eg. Yantis & Johnston, 1990).

One influential model of this type is Feature Integration (FI) theory (Treisman, 1988). As illustrated in Fig. 1.2, FI theory assumes an early stage of visual processing in which the different dimensions of stimuli are initially conjoined. This "master map of locations" shows where object boundaries are located but does not indicate the featural makeup of objects. To "retrieve" the features of an object it must be attended. This is achieved by activating a set of locations in the master map to route the information on to specialised processing modules. The specialised modules are tuned to particular visual features such as colour and orientation. Attention to a particular region of the master map allows these modules to recover (or process) the perceptual features within the region. Once recovered, the features are ultimately recombined into a temporary object representation at the final processing stage. Thus, the basic processing sequence is a unidirectional progression from stimulation to representation. Within this sequence attention operates at the earliest stage to govern which representation is recovered.

A distinguishing feature of this type of framework is the emphasis it places on where in the sequence attention has its effect, rather than on the original cause of attention being directed in the first instance. For example, in FI theory the presence of a selective process
operating on the map of locations is simply assumed as given. Yet in the model it is not clear from where the signal for this process originates. Another way to describe this issue is to distinguish between the site of selective effects and the source of signals which initiate those effects (Posner & Peterson, 1990). Thus, although FI theory focuses on the site of selective effects, it has nothing to say about the source of the signal that produces these effects. This is perhaps not surprising, as the ultimate source of selective signals is usually the experimental instruction. However, in most everyday behaviour we not select things in response to instructions. Instead, selective behaviour develops over time through learning about the relevant and irrelevant aspects of an environment. Thus, in order to develop an account of source signals for selection, we must describe how these signals can develop through repeated experience. Within the linear framework, this involves an account of how input relates to source signals as well as how the source signals relate to the selection site.
1.3 Attention and the Cyclic Framework

An alternative framework to accommodate the issue of source signals is Neisser's (1976) perceptual cycle. According to Neisser, perception is a constructive process of testing anticipations. These anticipations are embodied in preexisting associative structures called schemata. To test anticipations there is exploration of the environment through eye, head and body movements that make certain information available in the optic array. An outcome of these explorations is that new information is picked up, which in turn modifies the original schema. Once modified a new schema is then available to direct further exploration. This cycle of processes is illustrated in Fig. 1.3. Within this framework, selection is a process that determines a particular associative structure to test. For example, if we look at a necker cube, then there are two alternative anticipations we can make about the structure of the figure. The selection of one over the other involves the establishment of a perceptual cycle for that particular anticipation. One advantage of this framework is that no assumptions are made

![Diagram](https://example.com/diagram.png)

**Figure 1.3:** The perceptual cycle (adapted from Neisser, 1976).
about the direction of processing or the locus of selection. At any given moment many concurrent anticipations may be active, any of which could direct further exploration. Some of these might be activated by the concurrent stimulation, yet others might be activated indirectly by some previous event. Furthermore, the framework also allows for different perceptual cycles to be concurrently tested, such as listening to a friend while driving, or watching television while knitting.

There are two notable features in this framework. First, it should be evident that the process of exploration or movement is fundamental to the sampling process. In other words, the ability to test simultaneous anticipations is restricted by the compatibilities in action they involve. For example, in vision, high quality of sampling is restricted to foveated stimuli. So if a subject is presented simultaneously with two novel objects, a selection must be made between directing sampling towards one object or the other. With this view, attention is essentially a process of response selection, as it is the nature of the response that governs how stimuli are subsequently sampled. The second feature to note is that attention is fundamentally a dynamic concept (Boring, 1970). In other words, what is selected at any given moment will be affected by the preceding actions. Therefore, to investigate changes in attention, we must address how selection at one point in time can affect selection at a later point.

1.4 Repetition Effects

Perhaps the simplest way to study such attentional change is to address what happens under conditions of repetition. Over short temporal intervals, responses to a second event can provide information about the time course of processes engaged to the first event. Thus, by looking at responses to repeated events it is possible to unravel the dynamics of the processes engaged when a stimulus is selected.

In the sections below, a variety of repetition based experiments are reviewed. As a broad generalisation they illustrate that responses to a repeated stimulus may either be facilitated or inhibited. For example, when an event is repeated, an enhanced response to the
second stimuli is attributed to the orienting of attention towards that event. In contrast, a diminished response is attributed to the withdrawal of attention from the event. The negative effect on performance tends to suggest that representations are actively inhibited after selection has occurred.

1.4.1 Word Repetition Effects

The contrasting effects of stimuli repetitions have been observed with word stimuli. One of the most robust effects of word repetition is an increased efficiency in word recognition. This has been observed with in lexical decision, naming and word completion tasks (Scarborough et al., 1977; Scarborough et al., 1979; Tulving et al. 1982). Although these benefits are relatively small they are also very persistent and can be observed with long repetition intervals of an hour, day or year (Morton, 1979; Jacoby and Dallas, 1981; Salasoo et al., 1985). One interpretation of these effects is that they reflect the coincidence of the second word presentation with an episodic memory trace of the first presentation. The benefit observed will thus be a function of the similarity of a word to the trace of its previous presentation (Jacoby, 1983).

In addition to the above long term effects, there are also short term effects of repetition. Short term benefits can be induced by masking the first, or PRIME, presentation of a word, so that it cannot be reported (Forster and Davis, 1984). In other words, naming of the second presentation of a word can be speeded if subjects have just been exposed to an unreportable masked presentation of that word. By comparison, naming of the second presentation can be slowed if subjects are given a relatively long prime exposure (300ms) followed by a masked second presentation (Humphreys et al., 1988). In other words, when subjects are allowed to identify the first presentation of a word they are slower at recognising a second masked presentation of the same word. This negative effect of repetition is similar to the phenomena of repetition blindness whereby subjects can fail to notice repetition of common words such as the the word. The failure to subjectively experience the second occurrence of a word may occur even if its omission violates normal grammatical structure. For example, a sentence such as "When she spilled the ink there was ink all over" tended to
be reported as "When she spilled the ink there was all over" (Kanwisher, 1987; Kanwisher and Potter, 1989, 1990). The effect can also occur when the second item is a homograph (eg. "He wound the cloth around the wound on his hand") or a homonym of the first (eg. "She rose from the chair to take the red rose from the bouquet"). One interpretation of these contrasting effects is that they reflect changes in event perception. Thus, if attention has recently been withdrawn from an event then a subsequent occurrence of that event will fail to engage attention.

1.4.2 Covert Orienting

In terms of stimulus sampling, body, head and eye movements are the most massive instruments of perceptual selection (Hochberg, 1970). At a finer scale, the structure of the retina itself has intrinsic selectivity with the concentration of receptor cells in the fovea. For perhaps this reason attention and gaze direction normally coincide. However, while the relationship between attention and eye movements is normally close, recent studies show that attention may be moved independently of eye movements (Posner et al., 1980). This has been called Covert Orienting. Within these paradigms attentional movement is inferred from the pattern of costs and benefits observed in the reaction time to the second of two events. The contribution of eye movements is factored out by repeating events at intervals too short for eye movements to occur, or by requiring subjects to maintain a neutral fixation point throughout. Recent work on covert orienting has revealed two components of processing, those of facilitation and inhibition (Posner, 1980; Maylor and Hockey, 1985). The facilitatory component is indexed by a speeded detection response to targets occurring within 100ms and in the same location as a previously presented cue. This facilitation is attributed to the orienting of attention to the cued location which enhances processing of the subsequent target. The inhibitory component is evident through slower responses to targets when they occur 300-1300ms after the cue and in the same location. This effect has become known as Inhibition Of Return or IOR (Posner and Cohen, 1984).
One explanation of IOR is in terms of response inhibition. In a cue-target paradigm, the subject must avoid responding to the cue but make a speeded response to the target. Thus, although there is repetition in the spatial sequence of events, there is no repetition in the task requirements to the two events. Because of this Harvey (1980) has argued that the inhibition observed to the second event may be due to a response inhibition to the previous cue. However, further work by Maylor and Hockey (1984) discounts this explanation by showing the same IOR effect in a strictly repeating target-target paradigm. Therefore, the inhibition to a repeated spatial event is observed irrespective of the task demands to the initial event. In light of this finding Maylor and Hockey (1985) attribute IOR to an externally or stimulus driven bias against responding to a recently stimulated location. One possible function of this process is to induce efficient responding to novelty in the visual environment.

Another observation from the cue-target paradigm is that selection may be governed by both **Endogenous** and **Exogenous** factors (Posner, 1980). Endogenous factors are associated with internally driven shifts in spatial attention such as searching for a particular person in a room or looking for food. In contrast, Exogenous factors are associated with the stimulus driven shifts in spatial attention that occur in response to an external event, such as a sudden flash, a movement in the periphery, or an unexpected change in the environment (Muller & Rabbit, 1989; Yantis & Jonides, 1984). Within the cue-target paradigm, Endogenous control is observed by using a centrally presented symbolic cue, (eg. an arrow), that shows where a target is likely to appear. When the cue is valid, there are performance enhancements in both reaction time and accuracy (Remington & Pearce, 1984; Eriksen & Yeh, 1985). By contrast, when the cue is invalid, there is generally an impairment in performance. This pattern of benefits and costs is consistent with the hypothesis that attention is spatially allocated in response to the central cue. The allocation is considered Endogenous, or internally driven, as no costs or benefits are observed when the central cue has no relevance (Jonides, 1981). By comparison, Exogenous, or externally driven, allocation has been shown through observations of performance costs when an invalid cue is always irrelevant (Remington et al., 1992). Thus, even when subjects know that a spatial cue is invalid, they appear unable to ignore it.
1.5 **Posners' Framework**

In recent years the cue-target manipulation discussed above has been established as a standard paradigm for investigating attentional orienting. In combination with pharmacology, neurophysiology and neuropsychology this relatively simple manipulation has proved very productive in mapping the attentional functions of a variety of brain areas (See Colby, 1991). The most influential framework to emerge from this venture is the attentional network scheme proposed by Posner and colleagues. Drawing on a range of evidence, Posner and Rothbart (1990) suggest the operation of at least three attentional networks, the Posterior Network, the Anterior Network and the Vigilance Network. Of these, the Posterior Network is attributed the function of orienting or moving attention in space. The following section presents a brief description the three networks and their underlying anatomy and function.

1.5.1 **The Posterior Network**

The Posterior Network is associated with "moving" or orienting attention to different spatial events. Such orienting may be initiated by both Endogenous (goal state) and Exogenous (input state) signals. Anatomically, the network involves thalamic areas of the pulvinar nucleus, portions of the parietal lobe and midbrain areas of the superior colliculus. In an attempt to unravel the functions of these three areas Posner et al. (1984) distinguished three aspects of attentional orienting: 1) the ability to ENGAGE attention to a location (Pulvinar); 2) the ability to DISENGAGE attention from a location (Parietal Areas); and 3) the ability to MOVE attention from one location to another (Superior Colliculus). Through coordination of these three functions the network effectively "explores" feature space through sampling at different locations.

1.5.2 **The Anterior Network**

Anatomically, the Anterior Network involves areas of the midprefrontal cortex including the anterior cingulate gyrus. Functionally, it is a candidate source of Endogenous signals to the Posterior Network, as it appears to be involved in the detection of target or goal
states. For example, when Corbetta et al. (1991) compared passive with active viewing conditions, they observed additional activity in the anterior cingulate, basal ganglia sites and right lateral frontal cortex when stimuli were actively selected. Furthermore, Posner et al. (1988) observed that activation of the system during detection tasks was related to the number of targets presented rather than the actual number of events. The system is active for a large variety of target types, whether they involve colour, form, motion or word semantics (Corbetta et al., 1990; Peterson et al., 1990), and has recently been proposed as a general source of Endogenous orienting signals to the posterior network.

1.5.3 The Vigilance Network

This third attentional network suggested by Posner and Peterson (1990) is involved in maintaining an alert state. Anatomically it involves areas of the right frontal lobe and modulation of norepinephrine input to the cortex via a midbrain structure known as locus coeruleus. The lateralisation of the network to the right has been interpreted as a reflection of its involvement in heart rate regulation (Rothbart, Posner & Boylan, 1990). Activation in these areas has been observed in vigilance tasks with visual, auditory and somatosensory stimuli, and lesioning of the right frontal lobe produces deficits in developing and maintaining an alert state (Cohen et al. 1988; Posner & Peterson, 1990). In its interactions with the other networks, Cohen et al. (1988) observed that increased right prefrontal activation is accompanied by decreased anterior cingulate (Anterior) activation. This has been interpreted by Posner as reflecting the suspension of "target" detection as vigilance is maintained. However, this interpretation is a little unclear as vigilance studies are target detection tasks. One would therefore expect some anatomical overlap with the Anterior Network such as the right frontal activation observed by Corbetta et al. (1991). In its interaction with the Posterior Network, the Vigilance Network is thought to "tune" the orienting system by increasing the speed of interaction with object recognition systems (Posner, 1978). Primary input from locus coeruleus (LC) is observed to all the Posterior Network areas (ie. pulvinar, superior colliculus and parietal). Furthermore, the simultaneous activity of the locus coeruleus cells can alter the receptive field size of cells in these areas (Morrison and Foote, 1986).
1.5.4 Summary

At present, Posner's scheme offers a loose framework to interpret psychological empiricism from a neuro-anatomical perspective. With the advent of scanning techniques such as PET and MRI this type of approach is becoming increasingly important. Furthermore, as psychologists, we should recognise that our existing frameworks, or grammars, require a degree of translation into the language of neuroanatomy.

Using the cue-target paradigm as the basic methodology, Posner's framework has been most useful in the investigation of areas associated with Posterior Network. More specifically, it has offered an insight into the short term dynamics of attentional engagement, disengagement and motion. However, the framework also offers the possibility dealing with learning and long term attentional change in neuro-anatomical terms. With this in mind, the following section presents a more general framework which attempts to integrate the psychological and neuro-anatomical perspectives on attentional phenomena.

1.6 A General Attentional Framework

Each of the three frameworks considered so far (ie. Linear, Cyclic and Posner's) has its own strengths and weaknesses. In view of this, it seems reasonable to attempt a synthesis with a view to maximizing the explanatory power. The advantage of the linear framework is the emphasis on information structures in the processing sequence. However, its disadvantage lies in the neglect of learning effects and an account of the source of these structures and corresponding behaviour. In other words, there is no account of how information structures might initially develop or change over time. By contrast, the cyclic framework outlined by Neisser (1976), is specifically designed to address these dynamic aspects of behaviour. Its obvious disadvantage however, lies in the considerable lack of detail at the structural level (ie. schemata). Finally, the approach pursued by Posner offers a functional/anatomical framework of the potential sources of attentional modulation. But while the cue-target paradigm offers an insight into short term dynamics, there is again a neglect of
Figure 1.4: Synthesized framework of attentional processes.

learning and development.

An integrated framework of these three approaches is presented in Fig.1.4. The basic structure is modelled on a cyclic processing sequence. However, in contrast to Neissers' (1976) scheme the framework is completely internalised. In the original perceptual cycle, the domains of object information and exploration were conceived as external variables. The available information was equated with the optic array (Gibson, 1966) and exploration was equated with observable movement. Yet, in theory, the cyclic approach is applicable to changing the point of view relative to any information source, whether external or internal. To accommodate this idea an early internal information source is assumed, analogous to Treismans' master map (See Section 1.2). The exploration of this source is mediated by the Posterior network. This controls exploration of the map by engaging, disengaging and moving attention to different information sites. Finally, the two classes of schema directing this exploration are equated with the Anterior and Vigilance networks outlined by Posner. The Anterior network is associated with Endogenous or internally driven source signals for
attention. By contrast the Vigilance network is associated with Exogenous signals, driven
directly by the input. Thus, through the combined action of these two systems sampling
behaviour is balanced between achieving current goals and maintaining vigilance to the state
of the environment. Furthermore, because the framework is essentially dynamic, it offers the
possibility of addressing how attention changes over time. This issue is tackled in the next
chapter by considering the effects of multiple repetition on selection processes.
Chapter 2

Experience and Changing Attention

"Repetition, ah, there's the rub,"

Leonard Bernstein (1976)
2.1 The Effects of Experience

The single repetition methodology reviewed in the previous chapter is useful in revealing the dynamics of attention when a particular event is attended. However, it is also of interest how such dynamics might change with further repetition or experience of events. As we become more familiar with an object our sampling can become "tuned" to informative or relevant aspects of that object. For example, with a familiar face or object, a few lines on a page may be sufficient to recreate a familiar impression of that object. Conversely, we may experience as novel a feature which in reality we have been exposed to many times. To examine this issue the present chapter reviews experiments where subjects are given extended experience with stimuli. In brief, these studies suggest that multiple repetition of stimuli induces two opposing changes in behaviour. These can be summarized as an enhancement in the encoding of stimuli and a decline in the alertness to stimuli. From a sampling perspective, enhanced encoding can be understood as a tuning of sampling processes to informative or relevant aspects of a selected object. By contrast, the decline in alertness may be understood as a reduced tendency to sample repeated objects further. In the final section of the chapter these two changes will be equated with the functionality of the two processing loops outlined in the general framework.

2.2 Two Procedures for Studying Experience Effects

Within cognitive psychology the most common approach to studying experience effects is to provide subjects with an Endogenous or goal driven selection bias and then observe the changes in that bias with practice. With this type of design the bias is introduced by the experimenter, who associates subsets of stimuli with particular responses (ie. Select/Ignore). In reviewing a number of studies of this type, Schneider and Shiffrin (1977) distinguish between controlled and automatic processing. Controlled processing is observed without practice and appears to be based on a serial comparison procedure. This is inferred from the linear relationship between search times and the selection set size.
In contrast, automatic processing is observed with extended practice, and is less dependant on the selection set size. As practice proceeds, subjects appear to "automatically" detect the presence of targets without the need to search. An important variable modulating the development of automatic processing is the consistent-mapping of stimuli to particular responses from trial to trial. In other words, for automaticity to develop, one set of items (e.g. the letters A to N) must always be associated with a selection response and another set of items (e.g. the letters O to Z) must always be associated with an ignore response. Under varied-mapping conditions, where the associations change across trials, only a small improvement with practice is observed (Shiffrin & Schneider, 1977). Furthermore, a reversal of mapping after extended consistent-mapping training can produce a dramatic decline in selection performance. For example, Schneider et al. (1984) showed that under these conditions detection accuracy drops to well below that observed in unpractised subjects, and requires over 1000 further trials to regain a naïve performance level. This suggests that automatic selection occurs despite the intention of subjects (Posner & Snyder, 1975).

A second approach to studying experience effects is to again provide subjects with an initial Endogenous or goal driven selection bias but then introduce an additional association which subjects must discover. For example, in a study by Lambert and Hockey (1986), subjects were asked to judge whether a presented stimulus was horizontally or vertically oriented. Because the orientation of targets was varied from trial to trial, subjects never knew which response was required. However, on one side of the display diamond shaped stimuli were more likely to appear, and on the other side elliptical stimuli were more likely. Therefore, although subjects could not predict stimulus orientation, they could generate an expectancy of its shape when an event was detected. Consequently, the results show that RT is faster for diamonds than ellipses when the stimulus appears where diamonds are likely, and RT is faster for ellipses than diamonds when the stimulus appears where ellipses are likely. The expectancy of shape therefore speeds the selection of stimuli's orientation. Analogous results have been shown with expectancy of position (Posner et al., 1980), colour (Humphreys, 1981), class (Neely, 1977), modality (Klien, 1977) and onset time (Klemmer, 1956).


2.3 Multiple Repetition Paradigms

A third and simpler approach is to repeat stimuli without any initial selection bias. In the sections below, a number of studies of this type are reviewed. Broadly speaking they illustrate two contrasting effects of experience. One is an enhancement in the encoding of events (or Perceptual Learning). Within the general framework, this is interpreted as an elaboration of target representations in the Anterior network that enhances subsequent selection efficiency. However, this change is balanced by the second consequence of repetition, namely a decline in further sampling (or Habituation). In the general framework this is attributed to the development of a temporary representation of events in the Vigilance network that inhibits the selection of repeated events.

2.3.1 The Orienting Response

One of the earliest measures of Exogenous attention is the Orienting Reflex/Response (OR), first described by Pavlov (1927). As a behaviour, the OR is somewhat complex. Although initially it was described as an interruption of ongoing activity, (or external inhibition of conditioned reflexes), further studies have revealed an array of behavioural and physiological components. The most frequently used as measures of orienting are changes in heart rate, skin conductance, alpha-rhythm depression and an orienting of sense receptors to the source of stimulation. Within the animal literature, this focusing towards the information source has been described as the targeting response (Konorski, 1948).

An important feature of the Orienting Response (OR) is its habituation with repetition of a stimulus. To account for this change, Sokolov (1963) suggested that the magnitude of the OR is proportional to how well current events match a neural model of previous events. Because an organism will develop a more accurate neural model with repetition, the magnitude of the OR will decline. The model itself is assumed to be formed in synaptic connections between cortical feature detectors and hippocampal "novelty" neurons (Sokolov, 1975). These connections are modulated by inhibitory interneurons whose activity is potentiated with repetition. Thus, when a repeated stimulus is applied, the responses of the
novelty neurons become gradually weaker until they are finally extinguished. However, when a different or changed stimulus is applied, the novelty neurons may be reactivated through synaptic connections that are still "open" (Naatanen, 1992). The other connections in the orienting reflex arc are illustrated in Fig.2.1.

![Diagram of orienting reflex arc](image)

**Figure 2.1:** Structure of the orienting reflex arc (adapted from Sokolov, 1975).

When a novel stimulus is presented, activation from the hippocampal neurons is thought to switch on an "activating" system and inhibit a "synchronising" system. Anatomically, the activating system involves the locus coeruleus, which is a central component of Posner's Vigilance network. This in turn is connected to the superior colliculus, which within Posner's framework mediates the moving of attention\(^1\). The synchronising system is thought to involve interactions between the thalamus and cortical feature detectors and appears to correspond to the "engage" function of Posner's Posterior network. When a mismatch signal is received from the hippocampus there is a desynchronisation of the engage function that temporarily interrupts ongoing activity (Danilova, 1975). Simultaneously, output from the activating system enhances the excitability of cortical neurons and alters the

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\(^1\) Sokolov (1975) suggests instead that the superior colliculus is involved in specialised visual reflexes. One of such reflex may mediate the detection of abrupt visual onsets (Yantis and Jonides, 1990).
response characteristics of the superior colliculus (Dubrovinskaya, 1975). However, when a stimulus is repeatedly presented, the influence of the activating system will gradually disappear as output from the hippocampus becomes blocked. Simultaneously there is an enhancement of activity in the synchronizing system that leads to the generation of slow waves in the cortex. These two changes “create a favourable background for the realisation of stereotyped reflexes” (Sokolov, 1975).

To summarize, Sokolovs’ model outlines the mechanism for two systems of reactions. When novelty is introduced an activation-desynchronisation reaction occurs which facilitates processing of the new information. But as events become familiar this is replaced by a synchronisation-inactivation reaction that tends to impede external signal detection. Of particular interest however, are the anatomical and functional overlap between the attentional mechanisms described by Sokolov (1975) and Posner and Rothbart (1990). In Posners’ framework the orienting response is mediated through an interaction of the Vigilance and Posterior attentional networks. However, an important addition from Sokolov’s model is the hippocampus, which maintains a temporary record of repeated and non-reinforced events.

### 2.3.2 The Stimulus Repetition Effect

The effects of stimulus repetition have been studied in the context of other paradigms. Cantor (1969) reviews a range of experiments that suggest children (4-6 yrs) respond more slowly to a stimulus if they have been previously exposed to a series of brief presentations (20-40) of that stimulus. This effect is observed (i) with simple lights or buzzer stimuli (Cantor and Cantor, 1964), (ii) in simple and choice RT tasks (Cantor and Cantor, 1965) and with either passive or contingent responding during familiarization (Bogartz and Witte, 1966). In addition, increasing the duration of each preexposure trial increases the decrement in RT (Witte, 1967).

Kraut (1976) extended these findings with children, and identified two consequences of stimulus repetition. In showing that a familiar stimulus is less effective as a warning signal in a choice RT task he proposed that the alertness elicited by a stimulus decreases with
repetition. However, if the repeated stimulus is the target and a warning signal is presented, then RT is faster to a repeated stimulus. Kraut (1976) suggests this is due to the facilitation in encoding as a consequence of repetition. In a later study, Kraut and Smothergill (1978) replicated these findings in adults. They further showed that although responses were slower for repeated stimuli, (in an un-signalled RT task), the pattern can be reversed if testing occurs 15 or 30 mins after preexposure. Therefore, the alertness decrement was relatively transient in comparison to encoding facilitation. A follow-up study by Kraut et al. (1981) produced similar conclusions with repeated word stimuli.

These results show that repetition may have two empirical effects that work in opposition. One is to decrease the alertness to stimuli and the other increases their encoding. The observed response to repeated stimuli will therefore depend on whether the task demands rapid orienting or rapid encoding. If subjects' attention is pre-focused by a warning signal and instructions to respond, then a reaction time advantage is observed to familiarised stimuli. However, in circumstances where no instructions are given it might be expected that selection of familiar stimuli would be less likely due to the alertness decrement.

2.3.3 Opposing Mental Biases

A recent model by Johnston and Hawley (1994) accounts for opposing effects of repetition by distinguishing between conceptual and perceptual coding and suggesting that repetition may simultaneously enhance conceptual processes and inhibit perceptual processes. As supporting evidence they review a range of phenomena (some of which have been covered above). For example, Besner et al. (1990) observed positive effects on lexical decision following a prime presentation of a related word, yet a negative effect was observed on RT to decide whether the prime and test word had letters in common. Also, in the realm of memory, semantic priming may enhance performance on explicit memory tests yet inhibit performance on implicit tests of memory (Jacoby, 1983). Johnston and Hawley (1994) conclude that these effects show repetition may enhance performance on measures reflecting conceptual processing yet may decrement performance on measures reflecting perceptual processing.
As another example of inhibited perceptual processing following repetition, Johnston and Hawley contrast word superiority and inferiority effects. Since Cattel (1886), it has been known that a single word can be identified more accurately than a single letter. More recent investigations have further shown that identification of a letter, such as T, is quicker when presented in a word (e.g. METER), than when presented in a non-word (e.g. RETEM), or alone (Reicher, 1969). One interpretation of this effect is the interactive activation model (McClelland & Rumelhart, 1981), which suggests processing at the word level may facilitate processing at the letter level. However, other findings suggest that letter detection may also be impaired by familiarity and conceptual processing. Healy (1976) showed that detection of a letter, such as T, in a passage of text is often lower when it embedded in a very familiar word such as THE, than in a less familiar word such as TAR (See also, Healy and Drewnowski, 1983). This effect can be disrupted by several changes in procedure such as (i) presenting words in a list, (ii) requiring right-left scanning of words, (iii) presenting a long space before or after the words, or (iv) presenting words in isolation. According to Johnston and Hawley (1994) these findings indicate conceptual processing of words has an inhibitory effect on perceptual processing for very familiar words. A more general interpretation suggests that patterns of stimulus sampling will vary with different tasks and with repetition of those tasks. For example, in normal reading, O' Regan (1979) suggests that word THE may be identified parafoveally and skipped over by foveal fixations. This will obviously affect the amount of information uptake from the word.

Limits on information uptake are also observed in subjects' perceptual knowledge of very familiar objects. For example, Nickerson and Adams (1979) demonstrated that subjects have little detailed knowledge of objects they have experienced many times. A clue to changes in information uptake is supplied by studies of expert knowledge. Myles-Worsley et al. (1988) showed that recognition memory for normal chest X-rays first increased and then decreased with increasing expertise. A similar pattern was observed by Schmidt and Boshuizen (1993) in the relationship between medical knowledge and memory for clinical case reports. An interesting aspect of this study was the effect of study time on the relationship. When subjects were prevented from fully reading the reports, memory was directly related to expertise. This may reflect the ability of experts to reconstruct an image of the report based on previous experience. As another effect of time, it was shown that although memory increased with
study time with novices it was unaffected by study time in experts. This suggests that stimulus sampling performed by experts may be (i) very fast and efficient and (ii) rigidly governed by structures (or chunks) formed through previous experience. Such conclusions are also supported by studies of chess expertise. For example, Chase and Simon (1973) showed that better players where quicker in their encoding of positions. This was indicated by shorter glances. In addition, they suggested that the number of pieces encoded in a chunk varied with expertise, estimating that the strongest players encoded about 2.5 pieces/chunk compared to only 1.9 pieces/chunk for the weakest players. Given such changes in stimulus sampling it may be possible to observe negative effects on perceptual processing.

An experiment by Hippel et al. (1993) may be a case in point. Subjects were required to first read the "washing clothes" passage of Brandsford and Johnson (1973). Half the subjects were given the disambiguating title to encourage conceptual processing whereas the other half were not. On later tests of perceptual identification, stem completion and word fragment completion they show that perceptual memory for words is much lower for subjects who read the passage conceptually than for naive readers. They conclude "that although schemata facilitate organised conceptual processing, and hence recall, they simultaneously inhibit perceptual encoding. This inhibitory effect should emerge because schemata allow perceivers to rely on prior knowledge in place of incoming information".

Again it seems that repetition may have opposing effects. Performance may be enhanced or impaired depending on the measure used. However, a few words of warning should be made about this last section. First, the studies differ significantly from those in previous sections as repetition is not explicitly manipulated but is inferred as a necessary condition of experience. The second point, which follows from this, is that it is unclear exactly what has been repeated through experience. Thirdly, at the theoretical level it is unclear whether an empirical finding of impaired performance should be translated directly into an inhibitory process. This point applies to all the previous sections. As an example, suppose a subject is trained to look towards a food tray every time a red light appears. With practice, this action sequence may be initiated relatively automatically at the onset of the light. If the subject is now tested for encoding of a green light that appears shortly after the red light the performance would be very poor. However, this is due to a failure of sampling rather than
active inhibition of a representation of the green light. Put quite simply, the green light is not encoded because the subject is not looking at it. Therefore, actions initiated by prior stimuli may affect how subsequent stimuli are sampled. A similar point was made in the study by O'Regan (1979) which suggested that frequent words may be identified parafoveally. Here, the increased detection efficiency, induced through prior sampling, makes it unnecessary to foveate common words. Therefore, it might be more meaningful to discuss the decrement in letter detection as due to a shift in strategy or response rather than inhibition per se².

2.3.4 Learning Effects

Within animal learning, the phenomena of Latent Inhibition and Perceptual Learning are further testimony to the contrasting effects of repetition. Latent Inhibition or LI was first observed by Lubow and Moore (1959). The basic observation is that non-contingent preexposure of a stimulus results in a slowing of later conditioning to that stimulus. It has been observed in a variety of animal paradigms and more recently has been demonstrated in children and adults (Ginton et al. 1975; Kaniel and Lubow, 1986). In contrast, if two stimuli are preexposed, then there may be an enhancement of subsequent discrimination learning using those two stimuli. This is known as Perceptual Learning (Gibson and Gibson, 1955; Gibson and Walk, 1956).

According to the Pearce-Hall (1980) theory, the associability of a stimulus declines because the subject pays less attention to it. By using the Orienting Response, OR, as an index of attention, Kaye and Pearce (1984) showed that OR's (i) habituate during repeated, unreinforced presentations, (ii) gradually recover when the stimulus is paired with a reinforcer and then (iii) habituate again as conditioning proceeds and the reinforcer becomes well predicted. A similar sequence is observed under normal conditioning procedures. The OR's

² Of course this begs the question as to how a shift in strategy or response is achieved. As most bodily control processes seem to rely on inhibition it seems unlikely that it does not play a role. The point however is to caution against oversimplification. Care should be taken not to translate changes in performance measures directly into excitatory and inhibitory processes without reference to the computational problems.
habituate over a series of conditioning trials, rapidly recover when the reinforcer is omitted and then subsequently habituate again as the non-reinforced presentations continue. Therefore if the OR is taken as a measure of attention or alertness then the evidence suggests attention declines as events are repeated and alertness recovers as events are changed.

The encoding effects of repetition are described by McLaren, Kaye and Mackintosh (1989). They suggest that any two objects, A and B, can be conceived as represented by two discrete sets of elements or features. Two subsets \( a \) and \( b \) will be unique elements to the two objects and there will also be an intersection \( x \) of common elements (See Fig. 2.2). Sampling of these elements is assumed to have three different consequences. First, repetitive sampling reduces associability or attention. Secondly, elements sampled simultaneously will become positively associated. As it is assumed that sampling occurs to objects, this will results in the formation of \( a-x \) and \( b-x \) associations. This process increases generalisation between the stimuli as the previously unique elements \( a \) and \( b \) are now associated through common elements \( x \). To account for Perceptual Learning they suggest a third process that counteracts

![Figure 2.2: Associative formation within and between objects.](image)

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such generalisation. This is the formation of inhibitory connections between elements that are negatively correlated. As sampling is directed to objects, the activation of the unique elements a and b would be negatively correlated through time. Therefore, inhibitory associations would be formed between a and b elements. These inhibitory associations will reduce the generalisation between the objects by increasing their discriminability. They represent a control structure that groups elements unique to particular objects or samples.

2.4 Summary

In the above sections, literature on the orienting response, stimulus repetition and latent inhibition illustrates that simple passive preexposure leads to a decline in subsequent sampling of stimuli. This is indexed by habituation of the OR, slowed responses to unsignalled familiar events and retarded classical conditioning to familiar events. To date, the most comprehensive account of this change is Sokolov's (1975) orienting reflex arc, which assigns a central role to the hippocampus in forming representations of repeated events. Furthermore, in other respects the model shares much of the underlying anatomy of Posner's Posterior and Vigilance networks. Considering this similarity, it seems reasonable to interpret the sampling decline as mediated by the Vigilance-Posterior loop in the general framework.

The second consequence of repetition, is an elaboration on the encoding of an event. This is indexed by the speeded response to a signalled familiar event, shifts in sampling strategy and enhanced discrimination learning of familiar events. Within the general framework there are two potential loci for these changes. They could either occur early in the processing loop as associations developed within the visual cortex. Alternatively they could develop later in the loop within the Anterior network as representations of targets for subsequent action. Of these possibilities the Anterior-Posterior loop is preferred as it retains the flexibility of the visual cortex to respond to new information, without the impediment of prior associations.
As shown in figure 2.3, both processing loops are assumed to **operate** on a master map of locations. An implication of this arrangement is that the loops operate on information that is not currently selected. This is a logical necessity, as the function of both loops is to mediate a change in subsequent sampling. They must therefore operate on currently unselected information to determine whether that information should be selected or ignored.

![Figure 2.3: Functionality of the dual processing loops in the general framework.](image)

A further feature of figure 2.3 is that the Vigilance-Posterior loop **originates** in the master map of locations. This implies there can be a reduced tendency to select information that has never actually been selected. Justification for this assumption is derived from studies showing reduced interference with consistent distracters. For example, Lorch, Anderson and Wells (1984) demonstrated a speeding of reaction time in a categorization task when irrelevant patterns, which flanked the targets in the task, remained consistent. However, when
these patterns were subsequently changed, slower reaction times to the task emerged. Along similar lines, Tipper, Bourque, Anderson and Brehaut (1989) demonstrate RT gains in a standard Stroop task when irrelevant word stimuli remain consistent throughout the task. To capture this idea the Vigilance network is labelled as a context-ground system. This is intended to make explicit, the claim that habituation or the reduced tendency to select does not depend on stimuli being initially selected.\footnote{This does not deny the fact that sampling may decline to stimuli that are selected. It is merely a claim that selection is not a necessary condition to reduce the probability of selection in the future.}

By comparison, the Anterior-Posterior loop is assumed to originate at the selected object representation stage of Treismans' (1988) model. This implies that selection is necessary to enhance future encoding of stimuli. The main justification for this is an assumption that enhanced encoding depends on high quality sampling which is only obtained once a stimulus is selected. To capture this idea the Anterior network is labelled as a target-figure system. This is intended to make explicit, the claim that selection is necessary to enhance or tune future encoding.

To explore these ideas further the following chapter presents a simplified network model of the general framework. The model is developed to provide constraints on the interpretation of these changes and will subsequently be used as an aid in discussing the empirical findings.
Chapter 3

A GAIN Model

and the

Novel Popout Paradigm

"Thus, by our movements, we find it is the stationary form of the table in space which is the cause of the changing image in our eyes.

We explain the table as having existence independent of our observation because at any moment we like, simply by assuming the proper position with respect to it, we can observe it."

Helmholtz (1909/1924)
3.1 Overview

Within this chapter a network model of the general framework will be presented and discussed. This purpose of this model is to specify in more detail the computational functions of the Endogenous and Exogenous processing loops. In the second half of the chapter, the empirical problems in dissociating the processing loops will be examined. As a potential solution to these problems it is argued that a comparison needs to made of attentional responses to novel and familiar stimuli. One paradigm which makes this comparison is the Novel Popout procedure developed by Johnston et al. (1990). In the final section of the chapter the network model is applied to the empirical findings from the Novel Popout paradigm.

3.2 The Houghton & Tipper (1994) Opponent Process Model

The general attentional network is adapted from a selective attention model initially developed by Houghton and Tipper (1994). As originally conceived their model was designed to account for selectivity in response to Endogenous source signals. In particular it has been applied to situations in which the subject has prior information about the target to be selected. For example, if a subject is presented with a red and a green object, the model describes how selection can occur if the subject is told to select the red object.

As described in their model, the selection process is achieved through the interaction of a number of fields. The relationship between these fields and components of the general framework is illustrated in Fig.3.1. The Object Field is the primary recipient of external signals, and anatomically its nodes are taken to correspond to "features" represented in the dorsal and ventral streams of the visual cortex. By comparison, activation in the Target Field is taken to represent the properties of the internally generated target, (eg. RED), that acts as the source signal for Endogenous selection. The initial bias for selection is introduced through a matching process that compares incoming signals with an internal target representation. Thus, the Target and Matching Fields fulfill a target matching process that corresponds
functionally to Posners' Anterior network. Furthermore, Houghton and Tipper (1994) coincide with Posner on the underlying anatomy, citing evidence that certain prefrontal areas (e.g. principal sulcus, inferior convexity) are known to maintain "visual" representations (Fuster, 1980; Goldman-Rakic, 1987). In simple functional terms, the Target, Object and Matching Fields, compare what the subject is looking for (i.e. the target) with what is actually received (i.e. the objects). If a match is detected then a selection signal is generated by the Matching field and passed on to the ACF.

The selection process itself is induced by the Attentional Control Field or ACF. The ACF receives the selection signal from the Matching field and then feeds back to the Object Field to induce selection through an opponent process of amplification and inhibition. The opponent process which produces selection is illustrated in Fig. 3.2.

The basic architecture is a symmetrical interaction between nodes in the Object field and an opponent process in the ACF. The Object field nodes can be taken to represent any external signal (or vector) that is received due to stimulation. The two opposing nodes in the
ACF field are assumed to operate on this signal, to either amplify or inhibit its signal strength (or vector length). Amplification of a received signal is achieved by increasing the feedback from the ON-CELL in the ACF. This process corresponds the ENGAGE function of Posners' Posterior network. The inhibition of a received signal is achieved by increasing the feedback from the OFF-CELL in the ACF. This corresponds to the DISENGAGE function of Posners' Posterior network.

**Figure 3.2:** Opponent process interaction between the attention control field and object field.

In this model, engaging and disengaging attention is viewed as a process which biases the relative strength or GAIN of the received signals. Without selection bias, nodes in the object field receive equivalent excitatory and inhibitory feedback signals such that the null signal gain sums to zero. However, if a selection bias signal is introduced, (eg. to increase ON-CELL activation), then this balance will be perturbed, and a new equilibrium state will
3.3 The General Attentional-Intentional Network (GAIN)

The Houghton and Tipper (1994) attentional model was originally proposed as an account of **Endogenous** selection, where subjects have a prior target to search for. Within their model, the representation of a target in the Target Field acts as the source signal to bias the selection process. The GAIN model retains this architecture but also allows that past target representations may be activated directly by signals received in the Object Field. This addition is shown in figure 3.3. Thus, if an object has been previously selected, a representation of this target may develop in the Target Field. If this object is subsequently presented then the target representation may be reactivated. This indicates that a target is

![Figure 3.3: Adaptation of the Houghton & Tipper (1994) selective attention model.](image)

An interpretation of attention as the modulation of signal gain is not a necessary requirement of Houghton and Tipper (1994) model. For example, if engaging attention is viewed as a process which synchronises or locks signals to a particular frequency, (eg. Sokolov, 1975; Moran and Desimone, 1985), then the ON and OFF cell interaction can represent the modulation of this functional process.
present but not where the target is located. To locate the target, a the matching process is enacted to discover where sampling should be directed. With extended practice, the representation of the target will become tuned to the most informative aspects of the object. A consequence of this tuning is that the detection and matching functions will become more efficient such that a target is located relatively automatically. Another benefit of this extension is to provide a feedback signal to the target field that a match or mismatch has been made. Such information can provide a cue for the generation of subsequent targets. More important, however, the addition ensures that the whole model operates as a closed system. Thus, transformations in any given field can be explained with reference to the others.

Changes in **Exogenous** selection are ascribed to transformations in the Posterior and Vigilance networks of the general framework. This is incorporated into the GAIN model through the addition of a processing field that monitors incoming information and acts back on the ACF to tune out repeated events. The nature of this interaction is illustrated in Fig. 3.3. The function of the Monitor Field is analogous to the neural model in Sokolovs' (1975) orienting reflex arc. With extended experience repeated events in the object field will receive a reduction in gain from the ACF. Thus, when an unexpected or novel stimulus is presented, this stimulus will have an activation advantage in the object field which enhances its likelihood of selection.

To simplify matters, it is assumed that the Anterior (Endogenous) and Vigilance (Exogenous) loops modify separate components of the opponent process in the Attentional Control Field (ACF). The Anterior loop operates on the ON cells of the ACF to increase the gain of Object Field events when a match is made with the Target Field. By contrast, the Vigilance loop operates on the OFF cells of the ACF to decrease the gain of Object Field events as a match is made in the Monitor Field. In terms of function, the Anterior loop operates to enhance the selection probability of objects or events associated with current goals. By contrast, the Vigilance loop acts as a monitor of received signals so that unexpected objects or events will also have an enhanced probability of selection. To examine these issues, the following section explores the empirical problems in dissociating the two processing loops suggested in the GAIN model.
3.4 Empirical Issues and the GAIN Model

The studies in Chapter 2 show both a decline in sampling and an elaboration of associations as an event is repeated. This presents a considerable empirical problem in dissociating the two processes. For example, with a measure such as reaction time, enhanced encoding will speed RT to a stimulus whereas a decline in sampling will slow RT. Thus, with a unidimensional measure such as RT, it will be impossible to determine to what extent a change in RT is due to enhanced encoding or sampling decline. A potential solution to this problem is suggested by the GAIN model outlined above. According to the model, selection probability may be enhanced for two distinct reasons. First, if an object is repeatedly selected as a target then a representation of the object will become tuned in the Target Field. This tuning corresponds to an enhanced encoding of the object. Thus, when the object is subsequently presented, it will automatically activate the representation in the target field which biases towards selection of the object. Secondly, when events are repeated, the Monitor Field of the model will tune out these events in the Object Field. Thus, when novel events are presented, these events will have an activation advantage in the Object Field, which increases their probability of selection. The important point to note is that enhanced selection of a repeated target depends on changes in the Target Field. By contrast, enhanced selection of novel events depend on changes in the Monitor Field. The novel events will not be represented in the Target Field as they have not been previously selected. In view of this, it might be possible to dissociate the two processing loops by comparing the selection performance with novel and familiar objects.

3.5 The Novel Popout Paradigm

Recent work by Johnston and colleagues throws some light on this issue. Johnston et al. (1990) presented subjects with brief displays of four word arrays, probing 500ms later for the location of a word in the array. In all, three types of array were presented. All familiar arrays contained words that had been repeatedly presented together throughout the experiment. By contrast, all novel arrays contained four words that had never been presented
before. Finally, mixed arrays were composed of three familiar words and one novel word. The pattern of results obtained is presented in Fig.3.4. An inspection of the figure reveals that localisation accuracy is highest for all familiar arrays and lowest for all novel arrays. However, when the arrays contain a mixture of familiar and novel items, this pattern is reversed, the accuracy being higher for the novel items over familiar items. This effect was dubbed "Novel Popout".

Figure 3.4: Novel Popout results obtained by Johnston et al. (1990).

Two associative explanations of the effects considered by Johnston et al. (1990) are perceptual confusion and retrieval confusion. The perceptual confusion account assumes that associations are formed between word representations, as an array is repeated. One consequence of these associations is that activation of a single word representation will co-activate the other representations of an array. Thus, when a word representation from a familiar array is associated with a particular location, the other words in that array will also be associated with that location. Along similar lines, the retrieval confusion account notes that following repetition each familiar word has been seen many times at each location.
Consequently, when a familiar word is presented as a probe, the interference between locations associated with the probe will confound the retrieval process.

While both these accounts predict a novel popout effect when arrays contain a mixture of novel and familiar objects, they also predict poor performance when all the array words are familiar. This prediction is not supported, as localisation is actually superior in all familiar arrays. Consequently, Johnston et al. interpret their results in terms of two processes, perceptual fluency and attention redistribution. They claim that "perceptual fluency" builds up for objects that are repeatedly presented in a particular context. The consequence being that objects in familiar scenes will be perceived and localised with greater speed and accuracy than those in novel scenes. However, if a scene contains a mixture of novel and familiar objects there will be a segmentation of the field into fluently and non-fluently perceived areas. When this occurs attention will "flow rapidly and automatically" away from the fluently perceived areas towards the non-fluently perceived, resulting in enhanced processing of objects within this area.

Although this verbal account does predict the empirical findings, it suffers from a lack of specificity. No computational details are given as to how fluent perception is achieved or how "attention" becomes redistributed. To address these problems the following section examines how the GAIN model can be applied to the results of Johnston et al. (1990).

3.6 Novel Popout and the GAIN Model

The first effect to be explained is the localisation advantage of novel over familiar words in mixed arrays. This is the Novel Popout effect. The explanation of popout draws on evidence of the previous chapter suggesting a decline in sampling following repetition. Within the GAIN model, this is mediated by the Monitor Field and the ACF, which inhibits the gain control of events in the Object Field. Thus, if two objects are presented, one of which has been repeated, then activation in the Object Field will be greater for events associated with the novel object. On the assumption that object events compete laterally with each other, this
activation advantage will increase the probability of novel events being selected. In other words, the initial activation advantage in the object field will result in preferential sampling of the novel stimuli. Recent work by Miller et al. (1991) supports this interpretation. By measuring single neuron responses in IT cortex, they show that the responses to novel stimuli decline as the stimuli become familiar to the animal. Furthermore, work by Lin et al. (1993) suggests that subpopulations of IT cells serve as "adaptive mnemonic filters" for short term memory, with high levels of activation providing feedback signals to orienting systems so that sampling can be redirected. Therefore, the operation of GAIN provides a ready explanation of the popout effect, and is broadly consistent with known physiological processes.

The second difference to be addressed is the baseline localisation advantage of all familiar over all novel arrays. In the GAIN model, repetition of events in the Monitor Field will inhibit the gain control of these events in the Object Field. Therefore, if we only consider the Monitor-ACF processing route then performance should be worse with all familiar arrays and superior with all novel arrays. The fact that the opposite pattern is observed suggests that changes in another pathway contribute to the result.

However, a second consequence of repetition suggested in the literature is an elaboration on the encoding of stimuli. This is realised as an elaboration of target representations in the Target Field, which may take two forms. First, individual target representations will be better "tuned" to the incoming events. This will increase the speed of the matching process as less events are required to match (or activate) the target representation. A second consequence is that sequences of targets will become encoded in the field. Thus, when a match is made with a target, the sequential representations will prime the next target, again increasing the speed of the matching process. Therefore together, the Target Field encoding functions to increase localisation performance on all familiar arrays. The underlying assumption is that this encoding will overcome the depression of familiar events in the object field to produce "perceptual fluency" with all familiar arrays. To examine this account further the following chapter explores some implications of GAIN model in the context of the Novel Popout paradigm.
Chapter 4

Novel Popout and Task Demands

"One of these things is not like the other ones,
three of these things are kinda the same..."

Sesame Street (1974)
4.1 Introduction

In the GAIN model, there is an important functional difference between the operations of the Anterior and Vigilance processing loops. While both pathways involve a matching process, the Anterior route functions to facilitate selection of events that match target representations, whereas the Vigilance route functions to inhibit selection of events that match monitor representations. The facilitation is a bias towards events that are "relevant" or reinforced. By contrast, the inhibition is bias away from events that are "irrelevant" or unreinforced. An important prediction of this account is that the manipulation of relevance should modify bias from the Target-Matching fields of the model. To investigate this prediction, the present chapter examines the effects of task demand in the popout paradigm.

In the paradigm developed by Johnston et al. (1990), the arrays presented were always 'relevant' in that every array presented was probed for memory. As this procedure encourages extensive sampling of each array presented, it was conjectured that this will have an effect on associative formation. More specifically, it is assumed that representations in the Target Field of the GAIN model, will be elaborated to increase the efficiency of subsequent target matching. This will tend to boost performance on familiar words to produce the baseline advantage with all familiar arrays. Furthermore, it may mask the novel popout in mixed arrays through an enhancement of familiar word performance.

Another factor that may mask the novel popout effect is the use of randomised trials. In the Johnston et al. (1990) study, subjects were given a random sequence of all familiar, all novel and mixed arrays. Familiarisation was achieved by repeatedly presenting particular arrays throughout the study. This design was implemented to counteract any expectancy of array type but it may also attenuate the novel popout effect. Evidence from habituation studies with repeated distractors suggest there is some degree of dishabituation when new distractors are introduced (Lorch et al., 1984). Therefore, a mixing of different array types will produce less habituation than the consistent presentation of a particular array.
To address these issues two changes are introduced to the paradigm. The first change is to familiarise words during a preexposure phase. During this phase the arrays are repeatedly presented 5-8 times but subjects are not probed for a response. This is intended to make explicit the "irrelevance" of the preexposure period by removing any task dependant reinforcement. Under these conditions it is expected that a reduction in sampling will be observed.

Nested within the above manipulation is a second change designed to explicitly control relevance. This focuses on the task demands during the preexposure phase. One group of subjects are instructed to simply watch the arrays until probed. This is called the passive group. The second group of subjects are instructed to name the words in all the arrays presented. This is called the active group. Therefore, with the active group an attempt is made to reintroduce relevance of the words. Because all words are to be named, each array is always relevant to the required response. The prediction is that this will reintroduce the enhanced performance on all familiar arrays observed by Johnston et al. (1990).

These predictions are investigated in two studies. The first study examines the effect of the manipulations with mixed arrays. The second study focuses on the baseline difference between all familiar and all novel arrays.

4.2 Experiment 4.1

By removing the possibility of dishabituation it should be possible to induce a sampling decline following relatively few repetitions. In the Johnston study, familiar words were repeated 96 times throughout the course of the experiment, yet literature on the orienting response shows that 5-10 repetitions are sufficient to habituate a response (Sokolov, 1963). Therefore, a primary prediction of this study is that popout will be observed with only a few repetitions.
The second prediction of the study relates to the passive-active manipulation during preexposure. Specifically, it is anticipated that performance on familiar words will be enhanced in the active PX condition relative to the passive PX condition. Within the GAIN model, this is attributed to associative formation between "relevant" events in the target field that facilitates, or tunes, the target matching process. Therefore, the novel popout effect, (ie. the localisation difference between novel and familiar words in mixed arrays), should be larger with passive PX than with active PX.

4.2.1 Method

Subjects.

40 undergraduate and graduate students (Age: 18-38yrs). 31 Ss were female and 9 male. All were naive as to the purpose of the experiment.

Apparatus and Stimuli.

The stimulus set of 288 five letter concrete nouns (Kucera-Francis frequency range of 6-350) was compiled. From this set, words were randomly allocated to one of three subsets; the practice set, SET-P (n=48), the repeating set, SET-R (n=192) and the novel set, SET-N (n=48). Arrays comprised of four words were presented to subjects. Each word in an array subtended a visual angle of 1.9° horizontally, and 0.64° vertically from a viewing distance of 50cm. The entire array subtended an angle of 5.1° horizontally and 4.5° vertically. Array sequences were presented using MEL 1.0 running on IBM compatible 386 PC's.

Design and Procedure.

The experiment was a 2x2x4 mixed design. Within subject manipulations were Word Type (Novel vs Repeated), and Word Position (1-4). The between subject manipulation was PX Type (Passive vs Active). 20 Ss were randomly assigned to the passive condition and 20 to the active condition. All subjects received 6 practice trials and 48 experimental trials. Each trial was split into three phases Pre-exposure, Orienting and Probe. The display sequence for these phases is represented in Fig.4.1.
Figure 4.1: Display sequence and timing for Experiment 4.1
**Pre-exposure Phase:**

The stimuli array in the preexposure phase consisted of four words randomly selected from the repeating stimulus set, SET-R. Ss were presented with 5-8 repetitions of this array. The positions of words within the arrays were randomized with each repetition. The use of a variable number of preexposure displays was introduced to counteract expectancy of the subsequent orienting phase. (Practice trial stimuli were drawn from the practice set, SET-P)

**The Orienting Phase:**

Following 5-8 repetitions of the preexposure displays subjects were presented with an orienting display. On practice trials the orienting displays composed of four entirely new words drawn from the practice stimulus set, SET-P. For experimental trials the orienting display composed of three repeated words from the previous preexposure phase plus one novel word drawn from the novel stimulus set, SET-N. Positions of the repeated words were randomized relative to the previous preexposure display.

**The Probe Phase:**

The array presented in the Probe phase was composed of four identical stimuli. On practice trials the probe word was a randomly selected stimulus from the orienting display. On 12 of the 48 experimental trials the probe was the novel stimulus from the orienting display. For the remaining 36 trials the probe was a repeated stimulus presented in the previous orienting display. On all trials Ss were required to indicate where the probe stimuli had appeared in the previous orienting display. The probing of either repeated or novel stimuli during experimental trials was randomised with the restriction that novel stimuli were probed 25% of trials and repeated stimuli probed 75%. Both reaction time and accuracy to novel and repeated probe stimuli were recorded.

Ss in the passive preexposure condition were instructed to simply observe the displays until they were presented with a display containing four identical stimuli (the Probe array). When this display appeared, they were to indicate in which position the stimuli had appeared
in the previous display (the Orienting array). Responses were collected via the keyboard.

Ss in the active preexposure condition were instructed to vocalise the words in all displays apart from the Probe array. They were warned of the presentation of the probe array by the appearance of a red fixation cross. When the probe array was presented, they were also required to indicate where the stimuli had appeared in the previous display (the Orienting array). Responses were collected via the keyboard.

4.2.2 Results and Discussion

The proportion of words correctly localised in each condition were first calculated and then analysed as a 2x2x4 mixed model ANOVA. The effects of Word Type and Preexposure are illustrated in Fig.4.2. Inspection of the figure reveals that overall performance is superior with active than with passive preexposure [PX Type, F(1,38) = 16.55; p<0.05]. The 20% advantage in the active condition may reflect sampling differences or the addition of a verbal code. Of particular interest however, is that performance is enhanced for both novel and

![Figure 4.2: The effects of Preexposure and Word Type in Mixed Arrays.](image)
repeated words. This suggests a process that is blind to the repetition status of the words.

Another feature in the figure is the consistent localisation advantage for novel over familiar words. Thus, the novel popout effect observed by Johnston was replicated; across PX condition and with fewer repetitions [Word Type, $F(1,38) = 7.36; p<0.05$]. However, contrary to prediction, there was no evidence of an interaction between Preexposure and Word Type [$F<1$]. In other words, the novel popout effect is equivalent in both PX conditions. This suggests that the process generating popout is independent of the task demands during repetition.

The only other effect of interest is illustrated in Fig.4.3 using a spider plot. Points on the horizontal and vertical axes represent the mean localisation at the four array positions, for both active and passive preexposure. An examination of the figure reveals that the spatio-temporal distribution of attention is different across the two PX conditions. This was confirmed as a significant interaction in the analysis [ PX Type and Word Pos., $F(3,114)=4.60, p<0.05$].

![Figure 4.3: The effects of Position and Preexposure Type in Mixed Arrays.](image)

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The dominance of the horizontal axis during passive PX suggests an attentional pattern based on normal reading processes. But with active PX there is a redistribution of performance that produces a more symmetrical pattern across positions. These observations add empirical weight to the assumption that the PX instructions would affect sampling behaviour. However, the failure to show the third order interaction, again suggests that popout is independent of these changes.

4.3 Experiment 4.2

The second study investigates preexposure effects with all familiar and all novel arrays. Literature on the OR, stimulus repetition effect and latent inhibition suggests a decline in sampling with repetition. In the GAIN model this is mediated by the Monitor-ACF pathway that inhibits sampling of non-reinforced events. On this account, a sampling decline to all familiar arrays would be expected, resulting in inferior localisation. However, the fact that the opposite pattern was observed by Johnston et al. (1990) suggests another process is operating to enhance all familiar performance. One candidate process the enhanced encoding of repeated targets. In the GAIN model, this is realised as increased efficiency in the Target-Matching Field process. Thus, although repeated events produce weaker signals in the system, this is balanced by a tuning of the target matching process, such that fewer Object-Field events are required to activate an orienting signal.

An important variable thought to modulate this development is the "relevance" of the repeated objects. More specifically, it is assumed that the target-matching process is only enhanced if objects are continuously relevant. Consequently, if the preexposure period is passive, and therefore irrelevant to the task demands, there will be no development in the target-matching process. Empirically, this will eliminate the all familiar advantage to reveal an underlying all novel advantage due to the sampling decline. By contrast, if the relevance is reintroduced by requiring active selection during preexposure then the target-matching process will be reinforced to produce the all familiar advantage observed by Johnston et al. (1990) The present study investigates these predictions.
4.3.1 Method

Subjects.

40 undergraduate and graduate students (Age: 18-32yrs). 24 Ss were female and 16 male. All were naive as to the purpose of the experiment.

Apparatus and Stimuli.

The stimuli and equipment used were identical to those in Experiment 4.1. From the original set of 288 stimuli, words were randomly allocated to one of three subsets; the practice set, SET-P (n=48), the repeating set, SET-R (n=160) and the novel set, SET-N (n=80). Array sequences were presented using MEL 1.0 running on IBM compatible 386 PC's.

Design and Procedure.

The experiment was the simple 2x2x4 mixed design used in Experiment 4.1. Within subject manipulations were Word Type (Novel vs Familiar) and Word Position (1-4). The between subject manipulation was PX type (Passive vs Active). 20 Ss were randomly assigned to the passive condition and 20 to the active condition. All subjects received 6 practice trials and 40 experimental trials. As in Experiment 4.1 each trial was split into three phases Pre-exposure, Orienting and Probe. However, in contrast to Experiment 4.1, orienting displays could take one of two compositions, containing either four novel words (4:0) or four repeated words (0:4). Presentation and probing of novel vs repeated arrays was randomised with the restriction that each was tested on 50% of trials. The timing of displays within each trial was identical to Experiment 4.1 (See Fig.4.1). Both accuracy and reaction time were collected via keyboard responses.

4.3.2 Results and Discussion

The proportion of words correctly localised in each condition were first calculated and then analysed as a 2x2x4 mixed model ANOVA. The effects of Word and PX Type are illustrated in Fig.4.4. An inspection of the figure reveals the superior performance with active over passive preexposure [PX Type, F(1,38)= 4.93; p<0.05]. Again this may be attributed
to sampling differences or the addition of a verbal code. However, the mean effect size is only around 10% which is much less than the 20% difference observed in Experiment 4.1. This seems to indicate that the passive-active manipulation was not equivalent across the two studies.

![Figure 4.4: The effects of Preexposure in All Novel and All Familiar Array Types.](image)

On the main effect of Word Type, there was no evidence of an overall difference between all novel and all familiar arrays [Word Type, F<1]. Hence, the modification in procedure has eliminated the all familiar advantage observed by Johnston et al. (1990). This is attributed to the irrelevant preexposure period which fails to promote efficiency in the target matching process. However, the prediction that all familiar localisation would improve with active preexposure is not supported by the results. Although there is a trend towards an interaction, it is the reverse of that predicted [F(1,38)= 2.42; p = 0.13]. The direction of the effects suggest that all novel performance is inferior with passive PX but superior with active PX. This seems to indicate that the active naming during preexposure is actually less effective in reinforcing target matching. Thus, although subjects are required to actively name the words during preexposure, this naming is still essentially irrelevant to the task performance. The fact that subjects must act on these displays may enhance the sense of irrelevance.
Finally, the interaction between Position and PX Type is presented in Fig. 4.5. Graphically, there is no evidence of positional sampling differences between the two preexposure conditions, a conclusion reflected in the analysis \( F < 1 \). This contrasts with the results of Experiment 4.1 which illustrate preferential sampling along the horizontal in the passive condition. Again, this failure to replicate the effect in Experiment 4.1 indicates nonequivalence of the passive-active manipulation across experiments.

One possible explanation, is that in this study subjects were tested on two distinct array types, all novel and all familiar, whereas subjects in the first study always received the same mixed array type throughout. The contrast of array types in this study may therefore induce more "active" sampling in the passive condition. Empirically this hypothesis is supported by sampling pattern and performance similarity across PX conditions.
4.4 General Discussion

The novel popout in mixed arrays observed by Johnston et al. (1990) was replicated and survived a number of methodological changes. Firstly, the popout effect is observed with both passive viewing and active naming. Secondly, the observation that effect size is unaffected by this manipulation suggests that popout is independent of active attention processes. In other words, the popout phenomena is an automatic effect that occurs when novelty is introduced into an otherwise repeating display. Thirdly, the popout effect can be observed with a small number of prior repetitions. The repetition rate of 5-8 used in this study contrast with a maximum repetition rate of 96 used in Johnstons' experiment.

All these findings are consistent with the proposal of the GAIN model, that the Object Field events are inhibited with repetition. Specifically, it is suggested that the gain of an event is modified by an opponent process. With repetition, there is an increase in the negative weighting function that dampens activation to an event. Thus, when a novel event is presented with repeated events, the novel event will elicit a larger response. As sampling is assumed to depend on a competition between responses, the novel event will be sampled in preference to the repeated events. Empirically, this is reflected in the superior novel word performance with mixed arrays.

The results of the Experiment 4.2 suggest that the baseline advantage for all familiar arrays can be eliminated when array repetition is irrelevant to the task demands. The attempt to reintroduce relevance through active selection during preexposure did not prove effective, and if anything, reduced localisation for familiar words. An alternative explanation, is that there was insufficient repetition to develop the all familiar advantage observed by Johnston et al. (1990). However, a recent paper by Johnston, Hawley and Farnham (1993) shows that six prior repetitions are sufficient to elevate performance on all familiar arrays over all novel. Yet here again, each array presentation was probed for a response and therefore the words were continuously relevant to the task demands. Consequently, the failure to observe an all familiar advantage in Experiment 4.2 is attributed to the irrelevance of the PX period.
These findings are broadly consistent with the GAIN proposition that target-matching is only enhanced when selected events are relevant to the current task demands. In other words, the development of bias in favour of repeated events depends on whether these events match the current goal state of a subject. This proposal is also compatible with the consistent/varied mapping effects observed in the automaticity literature (Shiffrin & Schneider, 1977). Thus, when an event is consistently associated with a goal state there is a development in selection bias. Yet when an event is associated with both goal and non-goal states little development in selection bias is observed.
Chapter 5

Category and Novel Popout with Picture Stimuli

"a message will reach the same perceptual and discriminatory mechanisms whether attention is paid to it or not; and such information is then grouped or segregated by these mechanisms"

Deutsch and Deutsch (1963)
5.1 Introduction

Further work by Johnston et al. (1993) revealed another popout effect which he terms Odd Popout. Odd popout or OPO refers to the observation that a single familiar word will popout when presented with three other familiar words that have been preexposed together. The effect cannot be attributed to familiarity per se as all words have been preexposed. Rather, Johnston suggests it depends on the unitization of array words exposed together. Thus, if a familiar word is presented in an array of unitized familiar words, the non-unitized word will be sampled in preference to unitized words. These findings cast some doubt on the claim of the GAIN model that novel popout can be attributed solely to modification of gain control in the Object Field. In the OPO procedure, a reduction in gain should occur with all repeated words therefore no popout would be predicted. The important variable modulating OPO is whether words are preexposed together. Therefore, with OPO, an associative account is necessary to account for the selection bias.

These findings should be contrasted with yet another type of popout, namely the "Category Effect" (Kahneman & Treisman, 1984). Initially observed by Brand (1971), the basic finding is that it is easier to find a letter among digits or a digit among letters than to find a letter or digit among items of the same category (Egeth et al., 1972). Deutsch (1977) suggested the effect may be explained by associative connections among members of the same category. In pointing out that the categories of digits and letters are small, he suggested that the associative connections among members of these categories are exceptionally strong. Thus, when either a letter or a digit is designated as a target, it is likely to prime all members of its corresponding category (Taylor, 1978). One consequence of this priming is that items of the same category as the target will tend to attract attention. Thus, search will be more difficult for a target among items of the same class. In contrast, if the target is presented among items of a different class it appears to "pop out" of the display producing a flat display size function.

This involuntary spread of priming to items associated with the target may also help explain the "oh-zero" effect (Deutsch, 1977). When a target is designated as "zero" it is harder
to find among digits than letters. In contrast, if the target is designated as "oh" it is harder to find among letters than digits (Jonides & Gleitman, 1972). The spreading of activation account also fits with observations that pop out is abolished when two targets are specified. For example, if the subject is instructed to "Search for D or 7" then there is no advantage for a target among items from a different class (Jonides and Gleitman, 1978). This is to be expected as the two potential targets will prime items from both categories.

Such priming effects may help explain an apparent failure to obtain novel/odd popout in an experiment by Biederman, Mezzanotte and Rabinowitz (1982). Using pictorial stimuli, their results suggest that detection of objects is suppressed when they are presented in unfamiliar contexts. In their study a drawing of a naturalistic scene (exposed for 150ms) was preceded by the name of a target object, such as SOFA, and followed by a location probe. Subjects were asked to report whether the target had appeared at the probed location. Their data show that speed and accuracy of detection is decreased if the object was incongruent with the rest of the scene (e.g. a sofa in a street scene). In other words, subjects were poor at detecting the presence of a lone object that was associatively incongruent with the rest of the scene. Furthermore, the detection of a congruent object was not suppressed by the presence of an incongruent object.

Initially, these findings seem completely at odds with the findings of Johnston et al. (1990) and those of the present Experiment 4.1. However, there are a number of methodological differences between the paradigms that may resolve the conflict. Firstly, Biederman et al. (1982) employed a directed attention task in which subjects were provided with prior (word) information of the target identity. The evidence from semantic priming studies suggests that such presentation of a word can semantically prime subsequent picture identification (Sperber et al., 1979; Stenberg et al., 1995). Therefore, if presentation of the word sofa semantically primes other objects that are likely to appear with a sofa then the subsequent presentation of a street scene would be novel in the context of the currently active cognitive representations. Thus, an alternative interpretation is that incongruent object perception was poor because of novel/odd popout of aspects of the street scene.
The second methodological difference concerns the nature of familiarisation. In the Biederman study, observers were not familiarised to the scenes through preexposure. The pictures were only familiar to the extent that they were stereotypical representation of naturalistic contexts. Therefore, it remains possible that novel popout may only be obtained if Ss become familiar with a particular scene within the experiment, as in the Johnston studies and Experiment 4.1. Other results however, suggest that presentation of stereotypical scenes may indeed bias sampling. For example, in a study by Friedman (1979), subjects were presented with detailed line drawings of six stereotypical scenes (city, farm, kindergarten, kitchen, living room and office). The scenes consisted mainly of expected objects but also contained a few unexpected objects (e.g. an octopus in a farmyard). From records of eye movements Friedman showed that the duration of the first look was almost twice as long for unexpected objects than for expected objects. Furthermore, on a subsequent recognition test subjects rarely noticed missing or changed expected objects even when only objects the subjects had looked at were considered. In contrast, missing of changed unexpected objects were nearly always detected. Thus according to Friedman (1979), "The episodic information that is remembered about an event is the difference between that event and its prototypical, frame representation in memory". Despite numerous methodological differences, this conclusion concords with those from the popout paradigm. This tends to suggest that the decrement to unexpected objects observed by Biederman et al. (1982) may indeed be due to the pre-cuing procedure.

These considerations urge an empirical distinction between two types of associations: i) associations assumed to already exist and ii) associations formed during the experiment. The word experiments on novel popout and odd popout can be explained through associations between objects exposed together. In other words, associations between events that have been part of the same episode. It is not possible to explain the popout effect through existing associations between words as the array compositions were randomised throughout. However, the results of Biederman et al. (1982), Friedman (1979) and the category popout effect do suggest that attention can be modulated by existing associations formed between objects from previous episodes. This type of associative structure corresponds to the notion of a schemata (Norman & Shallice, 1980). Thus, when a target or goal is pre-specified these
schematic structures may exert a large influence on subsequent selective processes\(^1\). The first experiment in this chapter investigates these two types of association by comparing the relative effects of existing associations with those formed during preexposure. Specifically, it was expected that a selection bias would be introduced by existing associations and by those formed during preexposure.

### 5.2 Experiment 5.1

The aim of comparing "category effect" popout with "novel popout" within the same paradigm raises a methodological problem. In paradigms showing the category effect, subjects are provided with prior information of a target to search for in the display. On Deutsch's (1977) account of the category effect the popout is attributed to priming by this target item. This type of paradigm may be described as a pre-cuing procedure. By contrast, subjects in the novel popout paradigm are post-cued about a target's identity when the probe array is presented. Thus the category experiments may be described as an active attention paradigm whereas the novel popout studies may be described as a passive attention paradigm. In an initial study by Johnston et al. (1990, Exp 1) these two types of procedures were directly compared. When subject were passively presented with mixed arrays of 3 familiar and 1 novel word the usual popout of the novel word was observed. However, when one of the familiar words was designated as a target and informed that it would be probed on 70% of trials, the effect was reversed, showing a 15% advantage to the familiar word over novel words. These results show that prior instructions biased towards a familiar word will eliminate the novel popout effect. For this reason a post cuing procedure was adopted to test for both effects. It remained unclear however whether category popout would be observed without prior target specification.

\(^1\) Of concern in this thesis is how these structures may become activated or formed in the absence of instructions, i.e. how endogenous selection may arise through exogenous selection.
Out of a general concern for ecological validity and a specific concern to link with the picture studies above it was decided to adopt the Snodgras (1980) picture set as stimuli for the present experiment. The use of pictorial stimuli also offered the possibility of extending the range of the novel popout effect. An additional difference between this paradigm and the word studies was the use of a continuous preexposure period rather than several discrete preexposures. The use of repetitive brief preexposures characteristic of Experiments 4.1, 4.2 and previous studies is useful in that control is exerted over the number of times stimuli may be sampled during preexposure. However, the design is ecologically artificial as in naturalistic conditions visual stimuli will be continuously present. Sampling under natural conditions may therefore follow a different course to that which occurs when repetitive stimulation is used. This presents the possibility that popout is an artifact of an imposed sampling process rather than a normal brain function. Consequently, a single PX period of ten seconds was adopted in the present study as an additional test of the boundaries of popout.

In this initial study only two picture categories were used, animals and furniture. The aim of the experiment was to directly compare selection in displays with semantic conflict to those with both semantic and episodic conflict. The basic structure of the study was identical to Experiment 4.1, consisting of a preexposure phase, an orienting phase and a probe phase. Subjects were tested on two distinct array types during the orienting phase. The orienting array could either contain only semantic conflict. This consisted of three pictures from one category and one picture from the alternate category. Alternatively the orienting array could contain both semantic and episodic conflict. The additional episodic conflict was introduced by preexposing pictures from the majority category item in the orienting array. For example, with simple semantic conflict subjects might be tested with three animal pictures and one furniture picture. However, with both types of conflict, subjects would first be preexposed to four animal pictures and then tested with three animal and one furniture picture. Thus, in the orienting phase, three of the pictures would be familiar and one would be novel. It was predicted that priming effects would favour the lone category item with just semantic conflict, despite the absence of prior instructions. Furthermore, when episodic effects were introduced during preexposure a novel popout effect was predicted which would further enhance performance on the lone category item.
5.2.1 Method

Subjects

120 undergraduate subjects participated in the study as part of their course requirements. 76 subjects were female and 44 were male. The mean age of subjects was 19.6 yrs.

Apparatus and Stimuli

Displays were presented using Mel Lab 1.0 running on 386 PC's. Stimuli consisted of 8 pictures drawn from the set composed by Snodgrass (1980). The eight pictures were divided into two sets of four. Set-A comprised of four pictures of animals (dog, cat, horse and cow), Set-F was composed of four pictures of items of furniture (bed, chair, desk and drawers). Each picture was presented in a frame which subtended visual angles of 9.8° vertically and 5.7° horizontally, from a viewing distance of 50cm. The centre of each picture was at an angle of 11.4° from fixation and the entire array subtended angle of 29° horizontally and 17.7° vertically.

Design and Procedure

The experimental design was a 2x2x2 independent ANOVA, the factors being Probe Picture (Single vs Grouped), PX Type (Preexposure vs No Preexposure) and Stimulus Set (Animals vs Furniture). Subjects were divided into 8 groups of fifteen and randomly assigned to one of the eight conditions.

Four control conditions tested for attentional effects of a single picture in the context of three pictures from a different category. The displays and timing for these four conditions are presented in Fig. 5.1. Each trial consisted of a preexposure phase, an orienting phase and a probe phase. All the control groups where preexposed to four blank rectangles for 10 secs. For the orienting arrays, two of these groups were presented with arrays composed of 3 set-A and 1 set-F items, the other two groups received arrays of 3 set-F and 1 set-A items. Between the two groups subjects were either probed on the single category item in the display or on the grouped category item that appeared on the opposite diagonal to the lone item.
Figure 5.1: Display sequences and timing for the four control conditions in Experiment 5.1.
Figure 5.2: Display sequences and timing for the four experimental conditions in Experiment 5.1.
The four experimental conditions investigated the effects of preexposure on performance. The displays and timing are presented in Fig. 5.2. Two groups were preexposed to four set-A items, followed by an orienting array of 3 set-A and 1 set-F items. The other two groups received preexposure to four set-F items and oriented to an array of 3 set-F and 1 set-A items. As with the control groups Ss were probed for localisation of either a single category item or a grouped category item on the opposite diagonal.

Initially Ss were informed that they would be presented with four pictures/rectangles which they were to simply look at. Further instructions were provided on presentation of the Probe array. Each subject was then asked to indicate where the probed picture had appeared in the display that flashed up. Ss indicated their response by placing a small sticker on one of array locations on the screen. All subjects received only a single trial.

5.2.2 Results and Discussion

As each subject received only a single trial on which they were scored as correct or incorrect the data was dichotomized and categorical in form. The ANOVA was thus performed using the method suggested by Li (1982), which involves calculation of a chi-square value for each of the effects to be analysed. The effects of Probe Picture and Preexposure are presented in Fig. 5.3. Inspection of the figure reveals that localisation is superior for single category than for grouped category items. This was confirmed as a reliable effect in the analysis, \( \chi^2(1) = 5.07; \ p < 0.05 \). The observation of a category effect supports the prediction that category popout would be observed without prior instruction. However, although the graph suggests that popout is enhanced following preexposure, the analysis revealed that this interaction was not reliable, \( \chi^2(1) = 0.56; \ ns \). Therefore, there is no overall evidence of a novel popout effect in addition to the category effect.
A further breakdown of the data reveals a more complex picture as the effects are contingent on the particular categories used. Examination of Fig.5.4 reveals equivalent performance on Set-A and Set-F items without preexposure but a substantial advantage on Set-A items following preexposure. This interpretation is also suggested in the analysis, as the interaction between PX Type and Stimulus Set approached significance, $\chi^2(1) = 3.53; p = 0.064$. An examination of the raw data revealed that the interaction is primarily driven by the preexposure effects on arrays containing 3 SET-F and 1 SET-A items. As can be seen in Fig.5.5, performance on SET-F and SET-A items is roughly equivalent without preexposure. However, when subjects are tested following PX to four SET-F items, there is a dramatic decline in localisation of SET-F items and a slight enhancement of SET-A items. Two post hoc tests support this description. Without preexposure there is no association between proportion correct and the probed picture, $\chi^2(1) = 0.133; ns$. But with identical orienting arrays preceded by picture preexposure there is a strong association between proportion correct and the probed picture, $\chi^2(1) = 8.89; p < 0.05$. The observed pattern supports the hypothesis that there is a decreased tendency to orient or attend to repeated features.
Figure 5.4: Localization performance by Picture Set and Preexposure Condition.

Figure 5.5: Preexposure effects with orienting arrays displaying 1Set-A and 3 Set-F pictures.
however the failure to replicate the pattern with displays of 3 SET-A and 1 SET-F items indicates that the effects are dependent on which features are repeated. More specifically, attention seems to decline rapidly to repeated furniture but there is no evidence of a decline to repeated animals! While it would be tempting at this point to produce an ecological monograph of why this might happen it is probably more prudent to restrict the conclusions to the scope of the experiment.

To summarize, the current study shows that a 3 to 1 category conflict within a display results in superior localisation of the lone category item. The failure to observe consistent evidence of popout contingent on preexposure is difficult to interpret because of the numerous methodological differences between the present and previous studies. For instance it may be due to the continuous PX period, the use of pictures, or the increased spatial separation of stimuli. What seems clear however is that existing associations between representations of stimuli will produce attentional bias independent of any preexposure manipulation. Therefore, with category popout the bias cannot be attributed to reduced activation gain (ie. as in the GAIN model) or to associations formed during preexposure, because it occurs when all pictures presented are novel.

5.3 Experiment 5.2

An alternative reason for the failure to show novel popout is that the effects of semantic and episodic associations operate in the same direction. Therefore, if prior semantic associations induce a strong attentional bias, any additional effect of episodic associations may not be observed because bias towards the lone item has already reached ceiling level. In order to test this possibility the present study minimised the semantic associations between items in an array. This was achieved by ensuring that each array composed of pictures from four distinct categories. By reducing any bias due to semantic associations it was predicted that effects of episodic associations formed during preexposure would emerge. A further consideration was the use of only non-living categories. This was motivated by the results of
the previous study which suggested that changes in sampling behaviour may well depend on the categories used. This difference may well reflect underlying differences in the organisation of memory, for which there is considerable evidence in the clinical literature. For example, Nielsen (1946) described a patient who had greater difficulty identifying inanimate objects than identifying living things. A second patient showed the reverse dissociation. In more recent quantitative investigations Warrington and Shallice (1984) showed that two patients with medial temporal lobe damage performed very poorly when identifying living things (6.5%) compared to identifying non-living objects (74%). Other studies apparently show the complementary deficit in that picture-word matching is much worse for objects than with animals (Shallice, 1988; Warrington and McCarthy, 1983). On the basis of these and other findings Warrington and McCarthy (1987) argue that different processing channels may have different weightings in the identification process. Successful identification will therefore depend on whether there are sufficient channels preserved to produce a clear response to one item in a category. Therefore, the selective impairments described above are accounted for in terms of selective damage to separable input channels. If this is accepted, then the findings of Experiment 5.1 suggest a further possibility. Following preexposure there was a decline in the sampling of repeated non-living objects but not to repeated living objects. In other words, any modification of sampling with repetition may be specific to the channel which is activated. As there was no prior evidence of sampling decline to repeated living objects it was considered prudent to restrict the present experiment to non-living objects. The basic trial design of the study was identical to that of Experiment 5.1. However, for reasons of efficiency the single trial design was replaced by a multi-trial design so that the range of popout effects could be tested within subjects.

5.3.1 Method

Subjects

38 undergraduate subjects participated in the study as part of their course requirements. 22 subjects were female and 16 male. The mean age of subjects was 20.1 yrs.
**Apparatus and Stimuli**

Displays were presented using Mel Lab 1.0 running on 386 PC's. Stimuli consisted of 40 pictures drawn from the set composed by Snodgrass (1980). The 40 pictures were divided into two sets, a PX Set (20), and Novel Set (20). The 20 PX Set pictures were further subdivided into five subsets of four. Each subset was used as a preexposure array during the experiment. These preexposure arrays composed of one picture from each of the categories Kitchen Utensils, Clothing, Tools and Musical Instruments. One PX array was used consistently during practice trials, the other four were used during experimental trials. The five PX arrays are illustrated in Fig.5.6. The 20 Novel set pictures composed of five pictures from each of the categories, Transport, Toys, Furniture and Weapons. Four of these pictures were used consistently during practice trials. The remaining sixteen were introduced as lone novel items during experimental trials. The Novel set pictures are illustrated in Fig.5.7. Each picture was presented in a frame which subtended visual angles of 9.8° vertically and 5.7° horizontally, from a viewing distance of 50cm. The centre of each picture was at an angle of 11.4° from fixation and the entire array subtended angle of 29° horizontally and 17.7° vertically.

**Design and Procedure**

The experimental design was a 2x4 mixed ANOVA. The within subject factor was Probed Picture (All Novel, One Novel, Three Familiar and All Familiar). The between subject factor was Exposure Time (50ms vs 100ms). Subjects were divided into 2 groups of 19 and randomly assigned to one of the two exposure conditions. Each subject received 5 practice trials and 24 experimental trials. A single trial was split into three phases, Preexposure, Orienting and Probe. The display sequence for these phases is represented in Fig.5.8. Responses to All Novel arrays were assessed during practice trials, the remaining conditions (One Novel, Three Familiar and All Familiar) were randomly assessed on experimental trials.
Practice Trial PX Array

Experimental Trial PX Arrays

Figure 5.6: Preexposure arrays used in Experiment 5.2.
**Figure 5.7:** Novel Pictures used in Experiment 5.2
Figure 5.8: Display sequences and timing for Experiment 5.2.
**Practice trials**

During a practice trial each subject received preexposure to the four pictures in the practice PX Set (See Fig.5.6). This was followed by an orienting array of four pictures from the Novel Set (See Fig.5.7). Subjects were subsequently probed for their location memory of a picture in the orienting array. Thus, during practice trials, a measure was taken of localization performance in All Novel arrays.

**Experimental trials**

During an experimental trial each subject received preexposure to one of the PX set arrays. Each of the four PX arrays was presented 6 times throughout the experiment. On All Familiar trials the PX array was followed by an orienting array composed of a randomized reconfiguration of the PX array. The subsequent probe array tested localisation performance on All Familiar trials. All Familiar arrays were tested on 8 of the 24 experimental trials. The remaining 16 trials tested performance on mixed arrays. On mixed array trials, the orienting array composed of a random configuration three pictures from the preceding PX Set and one picture from the Novel Set. On half of these trials subjects were probed for the locations of the One Novel item. On the remaining trials subject were probed for the location of a familiar item (Three Familiar).

All subjects were informed of the display sequence prior to the task and told that the initial PX pictures were irrelevant to the task. On appearance of the probe array they were required to indicate their response via the keyboard.

**5.3.2 Results and Discussion**

The proportion of words correctly localised in each condition were first calculated and then analysed as a 2x4 mixed ANOVA. The effects of Exposure Time and Probe Picture are presented in Fig.5.9. An examination of the figure suggests that localisation is marginally superior at the longer exposure duration. However, the analysis revealed that this difference was not reliable, \( F(1,36)=2.04, \) ns. In other words, there was no evidence of a performance difference between the 50 and 100ms exposure times. On the other main effect of Probe
Picture there are clear differences among the different array conditions \( F(3,108)= 6.96; p<0.05 \). A breakdown of the effect suggests that localisation of a novel picture is enhanced when presented in the context of familiarised pictures. In other words, a lone novel picture among three familiar pictures is localised better than a novel picture among other novel pictures. This description was confirmed by a post-hoc test, \( t(37)= 2.59; p< 0.05 \). The graph further illustrates that familiar pictures are localised more accurately in all familiar arrays than in mixed arrays. This is reminiscent of the all familiar baseline advantage observed in Johnston's word studies (Johnston et al., 1990; Johnston et al., 1993). Again the effect was confirmed in a post-hoc analysis, \( t(37)= 2.77; p< 0.05 \)

The advantage for novel words in mixed arrays, over those in all novel arrays, is attributed to a redistribution of sampling towards the novel picture. However, because the all novel trials occurred at the start of the study, the difference may be nothing more than a practice effect. If localisation generally improves throughout the experiment then performance will be poorer during the practice phase when all novel arrays are assessed. This possibility was examined by looking at the performance change throughout the experiment.
As can be seen in Fig. 5.10 there is a general improvement in localisation throughout the experiment. This was confirmed with a secondary analysis which revealed a significant relationship between accuracy and trial number\(^2\) (F(1, 27) = 21.72, p<0.05, R^2 = 45\%). Thus, the practice account cannot be dismissed.

![Graph showing performance change across the trials of Experiment 5.2.](image)

**Figure 5.10:** Performance change across the trials of Experiment 5.2.

Although a practice effect may explain the performance differences for novel pictures it does not account for the decreased localisation of familiar pictures in mixed arrays. Again this is attributed to a redistribution of sampling towards the novel picture that enacts a cost to familiar pictures in mixed arrays. By contrast, when all pictures in the array are familiar there is no attentional bias resulting in superior performance. Therefore, on the grounds of parsimony both sets of effects are attributed to a sampling redistribution towards the novel picture in mixed arrays. By removing the explicit semantic bias in arrays, present in Experiment 5.1, the current study reproduced, using pictorial stimuli, the range of effects observed by Johnston et al. (1990).

\(^2\) The analysis for the general improvement over trials was conducted on the exponentiated values of accuracy and trial number. This decision was based on the following reasoning. Firstly, it is well established that the function relating reaction time and trial number is log-linear in form (Logan, 1988). Secondly, it was assumed that improvements in accuracy would be directly related to the speed up in reaction time with practice.
**General Discussion**

Experiment 5.1 illustrates that sampling can be biased by existing associations between the representations of pictures in an array. When subjects are briefly presented with three pictures from one category and a lone picture from an alternate category, localisation performance indicates a sampling bias towards the lone category item. These results extend the findings of Friedman (1979) with displays too brief for eye movements. It remains possible that Friedmans results reflect a "novel lingering" effect rather than a novel popout effect. In other words the extended looking times and enhanced memory might be attributed to changes that occur after an unexpected object is sampled, rather than to changes which direct sampling in the first place. While the present study rules out this possibility for sampling due to eye movements, it does remain a possibility that there is a "novel lingering" effect following attentional movements. Current estimates of attention switching times stand at around 50ms (Eriksen, 1990), therefore, at durations of 100ms, the advantage to the lone item might still be explained as a post attentional effect.

Experiment 5.2 illustrates that sampling can be biased by associations formed between representations during the experiment. When subjects are briefly presented with three pictures that have been preexposed together and a lone novel picture, the localisation performance shows a sampling bias towards the lone novel item. The finding of a popout effect at display durations of only 50ms replicates with pictures brief display data obtained by Johnston et al. (1993). In this paper (Exp.7) novel popout was observed with displays of 33, 50, 67 and 200ms. The differentiation of stimuli with such brief exposure suggests that novel popout is a reflection of a bias in sampling behaviour rather than an effect that occurs after an object is sampled (ie. novel lingering). According to the estimates of attention switching, a display duration of only 50ms should only allow that one object is attended in each orienting array. Therefore the biases observed must reflect differences in how this initial selective process occurs.

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3 This distinction is analogous to the pre vs post identification distinction made in the early vs late selection debate.
Combined with the findings of Johnston et al. (1993) these results argue for a unified associative account of popout phenomena. To investigate this possibility the following chapter explores how associative effects could be incorporated in the GAIN model.
Chapter 6

Associations in the GAIN Model

"... it is entirely possible that we may learn about the operations of thinking by studying perception."

Irvin Rock (1983)
6.1 Introduction

All the popout effects discussed so far may be described by suggesting: "an attentional bias is observed towards an object among three other objects when these three objects can be meaningfully grouped together". With novel popout from three familiar objects, this can be understood in two distinct ways. The three familiar objects can be grouped either because (i) they have been presented repeatedly or because (ii) they have been presented repeatedly together. Of these possibilities the GAIN model placed emphasis on the former by implicitly assuming that the repetition effects are object specific. However, the subsequent finding of Odd Popout (OPO) shows that bias may be introduced when the three objects cannot be grouped by repetition alone. With Odd Popout, all four objects are repeatedly presented which suggests the critical factor is that three objects are repeated together. Furthermore, with category popout all the events are novel, so here again repetition alone cannot be the critical factor.

One way to integrate these results is to propose that all popout effects depend on three objects being associated in some way. For Novel and Odd popout such associations will depend on the familiar objects being repeated together. Evidence for this claim is provided by Johnston et al. (1993, Exp.4). They demonstrate that a novel word with three familiar words preexposed separately is localised less accurately than the familiar words. A representation of this result is presented in Fig.6.1. Thus, when there is no opportunity for associative formation between the familiar words the novel popout effect is eliminated and replaced by a novel sink-in effect. This effect is not predicted by the GAIN model, as popout should occur whether the familiar words are repeated together or separately.
6.2 What Type of Association?

The conclusion that popout is an associative phenomena raises interesting questions about the nature of these associations. For instance, "early" selectionists such as Treisman (1988) have claimed that "attention" or selection provides the glue to associate features within an object. A possible inference from this claim is that attention to or selection of two objects is necessary to associate features across objects. However, with novel popout this is difficult to reconcile with the empirical data. For example, novel popout has been observed at exposure durations of only 33ms (Johnston et al., 1993). With such brief exposure it should only be possible to select a single word with any one presentation. Therefore, in this case, it is unclear how associations between array words might ever develop, as only a single word is selected from each array.

If associations are indeed fundamental to novel popout then the inference to be drawn from the empirical data is that unattended or ignored objects are also subject to associative formation. A caveat within early selection theories that can accommodate this is the
proposition that unattended information might automatically activate previously learnt (associated) representations of an object. One expression of this is found in Kahneman and Treisman's (1984) notion of Object Files. They suggest that when a stimulus is attended, its physical attributes (e.g. colour, size, location, motion, etc...) are brought together in a temporary object file, that maintains the identity and continuity of an object perceived in a particular episode. However, they also suggest that once an object file has been created through selection the file may be automatically activated by information that is not currently attended. In other words, selection is necessary for the initial creation of an object file, but once a file has been created it may be activated without selection. Given this, it remains possible that associations might be formed between previously learnt representations that are activated but not actually selected.

In the GAIN model unselected information can be processed in two distinct ways. In accord with Kahneman and Treisman (1984), the model claims that representations of previously selected "target" stimuli can be automatically activated by currently unselected information. This is depicted as a direct route from the Object Field to the Target Field of the model. For the word and picture stimuli used in the popout paradigms there will be existing representations in the Target Field that are automatically activated when an array is presented. As shown in Fig.6.2, the concurrent activation of these representations may result in associative formation between them. However, in terms of the function of the model, it is unclear how such associations could produce the empirical results from the popout paradigm. Although novel popout might be explained as associative interference between familiar items, this account does not explain the performance advantage when all the items are familiar (i.e. in All Familiar arrays).¹

¹ Johnston et al. (1993) makes a similar point in discussing the limitations of the perceptual and retrieval confusion accounts (See Chapter 3).
A second possibility in the GAIN model is that unattended stimuli can be processed via the Monitor Field. In this case prior selection of an object is not a prerequisite of representation. As described in the General Framework, this processing loop records the visual context in which selections are enacted. This can be conceived as an Unstructured Distribution of the features that are visually present, as compared to the Structured Distribution of features visually selected. To examine what this means in terms of associations the following section explores how associative effects can be incorporated into the GAIN model.

### 6.3 Associated Features In The GAIN Model

Associated representations can be conceived in at least two distinct ways which I will term Intrinsic and Extrinsic. The section on Intrinsic association deals with the attentional effects of existing associations, or architecture, on selection. By comparison, the section on Extrinsic associations tackles the problem of how associations are initially formed through experience.
6.3.1 Intrinsic Association

Intrinsic association is characterised by any two or more nodes that detect the same or similar physical events such as the dots illustrated in Fig. 6.3. One perceptual consequence of such shared identity is that equivalent objects are grouped together as a perceptual unit or Gestalt. To account for this phenomena the GAIN model assumes that the nodes receiving equivalent physical events in the Object Field are associated with an Abstraction node in the Matching Field. As shown in Fig.6.3, the Abstraction node receives activation from many different nodes or viewpoints in the Object Field. In a spatial sense, this can be understood as an integration of information over a larger spatial scale.

The mapping of information to the Abstraction node is MANY:FEW (or X:Y where X>1; Y=1) in character, and because of this there is information loss in the transformation. For example, in a spatial sense, the Abstraction node might indicate that an event is present, but there is a loss of resolution as to where the event is. To recover this lost information a reverse mapping procedure is proposed which is FEW: Many (or Y:X where Y=1; X>1) in character. This is illustrated as a feedback loop via the ACF that RE-PRESENTS the information to the Object Field to discover where the events are present. If an event is received by a node of the Object Field, then the gain control of the ACF can modulate the activation produced by that event. But if no event is received by an Object Field node then there will be no activation in this node to modulate. As a generalisation, the two mappings are equivalent to the processes of Induction and Deduction. The mapping to the Abstraction node is equivalent to a process of Induction as it is a mapping from the particular to the general. By comparison, the re-presentation of information back to the Object Field nodes is equivalent to a process of Deduction, being a transformation from the general to the particular.
These processes are applied to grouping effects in the following way:- If a node in the Object Field is activated by the "ON" gain control mechanism then any equivalent or similar objects that are present will be co-activated through activation of the Abstraction node which feeds back onto the gain control nodes. Similarly, if a node is deselected by the "OFF" gain control unit there will be a spreading of inhibition mediated by the Abstraction node that results in the deselection of equivalent object nodes.

One implication of this architecture is that gain control or "attention" operates on perceptual groups as suggested by Duncan (1984), Kahneman and Henik (1981) and Baylis and Driver (1992) among others. Furthermore, the model appears to predict the effects of target-distractor and distractor-distractor similarity outlined by Duncan and Humphreys (1989). In brief, they suggest that a target stimulus is harder to select from distractors that are similar to the target. According to the GAIN model, this is due to the spreading of activation through the "ON" units of equivalent vectors. Therefore in attempting to select a target there will also be a tendency to select distractors that share features with that target. The same logic
can also be applied to the similarity of distractors. Thus, when the distractors share common features they will be selected or deselected as a perceptual unit. The effects that this has on selection performance will depend on the relationship between the designated target and the non-targets (i.e. the Target-Distractor similarity). For example, if the distractors are highly similar to the target selection will be impaired, but if they are highly dissimilar selection will be facilitated.

Such grouping effects may help to explain the category popout observed in Experiment 5.1. For example, on the assumption that pictures of the same category share common physical features (Rosch et al., 1976; Sperber et al., 1979), such a mechanism would predict greater difficulty in selecting an item from members of the same category than in selecting an item from another category with less featural correlation or overlap. This will occur because the three pictures from the same category activate common Abstraction nodes. Therefore, when the abstraction nodes feed back to the object nodes they will tend to select all three pictures simultaneously. Hence, the grouping mechanism interprets category popout as response interference between these simultaneous selection responses.

6.3.2 Extrinsic Association

Extrinsic association occurs when a set of feature nodes (or vectors) become associated with a common node or nodes because of co-activation through time. In this case there need be no Intrinsic similarity of the features themselves, what is important is whether the nodes receiving the signals have correlated activity in time. In the sections below it is suggested that Extrinsic association can take two distinct forms in the GAIN model. This follows from the proposition that associations may be formed in either of the two processing loops.

Following, Kahneman and Treisman (1984) it is proposed that the selection of an object results in associative formation between features of the object. In the GAIN model the selection process operates by introducing an activation gradient or differential between sets of nodes receiving signals in the Object Field. In other words, selection is process which
introduces Structure into the previously undifferentiated Object Field nodes. Once a subset of Object Field nodes has been differentiated, or selected, it is argued that associations are formed between nodes that represent the information they have received. In the GAIN model, this associative process is assumed to occur in the Target Field of the model. It corresponds to the associations between features of a Selected or Structured object. To identify this fact the nodes that become associated are called S-nodes. A brief description of S-nodes in the GAIN model is outlined in the section below.

**6.3.2a S-node Association**

In the GAIN model, S-nodes are only formed in response to facilitated or selected activation. For example, given any two objects A and B, the possible states are (1) A(Selected); B(Not Selected) or (2) B(Selected); A(Not Selected). In either of these states, S-nodes would only to associate signals from Object Field nodes in a selected state. Thus, in State (1) above the S-node would associate source nodes receiving signals from object A, but in State (2) they would associate the source nodes of object B. A diagram illustrating the first possibility is shown in Fig.6.4. Functionally, the S-nodes effectively Integrate the activity across the source nodes of a selected object and feedback on them to facilitate future selection. This may be conceived as a process that enhances the signal value (S) of selected stimuli.

With reference to the empirical findings from the popout paradigm, S-nodes help to explain both the baseline advantages for an all familiar array and observations of novel sink-in with three familiar words exposed separately. For example, when four words are repeatedly presented, these words are likely to be repeatedly selected. When a word is selected, associations will be formed via S-nodes that enhance the future selection efficiency for this word. However, when an all novel array is presented, these words will not have been previously selected. Therefore, no associations via the S-nodes will have developed to enhance selection efficiency.
Similarly, if a novel word is presented with three words familiarised separately, the S-nodes will enhance the selection of the familiar words but not the novel word, as it has not been previously selected. So again, superior localization of the familiar words over the novel word is expected.

Although the concept of S-nodes provides a ready explanation of performance advantage to familiar stimuli, it does not account for the crucial novel popout effect, where superior performance is observed to the novel stimulus. More seriously however, there is a conceptual problem with the model outlined so far. The problem emerges from the claim that S-node associations depend on a structuring of the input set through selection. The question is:- How does this structuring initially occur?

Under many circumstances it could be argued that structuring is introduced by S-node representations created from previous selections. But, this still leaves a question as to how the prior representations were initially formed. One possibility is that Intrinsic association or architecture operates to differentiate the input set. The second possibility is that changes
in the Vigilance loop of the GAIN model may introduce structure into the input set. To expand on this, the following section argues that associations formed in the Vigilance loop function to bias towards the selection of Novel structure. Thus, the input set can become structured without any prior (S-node) representation of this structure.

6.3.2b N-node Association

As shown in Fig.6.5, N-nodes in the Monitor Field maintain a record of the distribution of features that are present. Psychologically, this may be thought of as a record of the visual context in which selections are enacted (Pribram, 1993). In contrast to S-node association, the state of the source nodes in the Object Field (Attended vs Unattended) is irrelevant. In other words, N-nodes will associate features irrespective of whether they are selected or not.

When the N-nodes are repeatedly activated they feedback to the source nodes in the Object Field to reduce the gain of events detected by these nodes. In line with the earlier

![Figure 6.5](image.png)  Reduced gain of repeated features via N-nodes.
proposal, this is a process that reduces signal noise from repeated events. However, the model departs from the earlier conception by removing the assumption that feedback is object specific. In other words, the N-nodes integrate activity across multiple "objects" in a scene.

In essence, the N-nodes correspond to Sokolovs' (1975) conception of novelty neurons that receive activation from a large number of cortical receptors. Their function in the GAIN model is to reduce the gain of, or tune-out, repeated events in the Object Field. This results in a redistribution of activation in the Object Field such that repeated events have a reduced chance of capturing attention compared to novel events.

When a set of four words is presented in the popout paradigm, they will activate a set of N-nodes in the Vigilance system. With subsequent repetition the N-nodes function to reduce the probability of these words being selected. Thus, when a novel word is presented with three familiar words, the novel word will be selected in preference to the familiar words. An analogous situation occurs in the Odd Popout effect. The three familiar words repeated together are again assumed to set up a N-node representation that reduces their selection probability. However, because the lone familiar word is insufficient to activate its N-node representation, the Odd familiar word in the display will have a selection advantage over the other three. Thus, by assuming that a single word is insufficient to activate an N-node representation, both novel and odd popout can be accounted for.

6.4 Summary

The preceding sections describe three distinct ways in which events in the object field can be associated. The notion of Intrinsic association was introduced to account for observations of category popout when all the stimuli presented are novel. More generally however it is an implementation of how objects may be grouped by similarity. S-node association implements the notion that encoding of selected objects will be enhanced with repetition. This is introduced to account for the localization advantage for familiar words in (i) all familiar arrays and (ii) in mixed arrays when the familiar words are preexposed
separately. Finally, N-node association implements the earlier proposal that the tendency to select events is reduced with repetition. However, it expands the earlier proposition in suggesting that the reduced tendency to select operates across objects in a scene and occurs irrespective of whether these objects are attended. These assumptions are introduced to explain (i) why novel popout depends on familiar words being repeated together and (ii) novel popout with very brief exposure. The relationship between each of these nodes and the functional domains of the GAIN model is illustrated in Fig.6.6.

Figure 6.6 The revised GAIN model with associative nodes.
Chapter 7

Novel Popout in Dynamic Displays

"The heart of the problem is time. Cognitive processes and their context unfold continuously and simultaneously in real time. Computational models specify a discrete sequence of static states in arbitrary 'step' time \( t_1, t_2, \text{ etc.} \). Imposing the latter onto the former is like wearing shoes on your hands. You can do it but gloves fit a whole lot better"

Van Gelder and Port (1995)
7.1 Introduction

Two primary predictions can be generated by the revised GAIN model. First, the concept of Intrinsic association suggests that novel popout may be a function of the similarity between the familiar and novel words. In the popout experiments with words all the stimuli are constructed from the same visual set. Similarly, in the studies with pictorial stimuli, all the pictures were constructed from simple lines. Consequently, the size of the popout effect may be masked due to the intrinsic similarity of the stimuli used. In other words it will be more difficult to detect a stimulus as novel if it is highly similar to a familiar stimulus that it replaces. Conversely, it will be easier to detect a stimulus as novel if the similarity between novel and familiar stimuli is minimized.

The second prediction of the model is derived from the operation of the N-nodes in the Monitor Field. The description of N-nodes suggests that novel popout is not dependent on the repeated stimuli being attended. In other words, it should be possible to manipulate an attentional bias by changing stimuli that are never actually selected. These two predictions are tested in the experiment described below.

7.2 Experiment 7.1

As outlined above, previous paradigms may have masked the magnitude of the popout effect due to the intrinsic similarity of the stimuli used. One way to minimize such similarity is to define each of the objects in an array by a unique perceptual dimension. In the present study, this was attempted by defining each of the array objects by a unique colour. The justification for using colour was based on the fact that there are three distinct receptor types on the retina which combine to give four distinct perceptual dimensions, ie. Blue, Red, Green and Yellow. Therefore, if each of the four array objects was defined by each of the four colours it was thought that similarity among the array objects would be minimized.
However, in order to replicate the novel popout effect, a minimum of five distinct dimensions are needed. A dimension is needed for each of the four familiar objects in an array and an extra dimension is needed for the novel object introduced to an array. One simple solution to this problem would be to investigate popout with arrays of three objects rather than four. However, this solution was rejected as it would alter the configural aspect of the arrays which may make comparison with the previous studies more difficult. To retain the configuration of four objects, the set of colours defining array objects was extended to five by introducing the colour Cyan (Blue/Green). But by assigning Red as the colour of the novel object it was ensured that there was no dimensional overlap with the colours of the familiar objects (ie. Blue, Green, Yellow, Cyan).

The prediction that attention to the repeated stimuli is unnecessary was addressed by maintaining the irrelevance of the colours throughout the task. This was an attempt to return to the functional questions addressed in Chapter 4. Here it was argued that novel popout is induced by a mechanism which functions to filter out "irrelevant stimuli". But in previous studies the stimuli used have been both irrelevant and relevant at different points in time. Consequently, there is no conclusive evidence that irrelevant stimuli can induce popout.

To maintain the irrelevance of stimuli throughout the task a variation on the cue-target paradigm was devised. As in previous popout studies the target stimuli are words that subjects must locate at one of four positions in the display. However, unlike previous studies, the four positions are now pre-cued by non-target colour stimuli in the display. The colour stimuli were four square blocks on which the target words were written. The cuing effect was achieved by expanding the spatial resolution of the display to give the impression of four blocks approaching from a distance. At a low spatial resolution objects appeared "far away" so that the word stimuli could not be identified but the colour of the square blocks could. However, as the spatial resolution increased and the objects "approached", the subjects were able to identify the target words. Thus, the coloured blocks served as multiple simultaneous cues of the target word locations. By manipulating the familiarity of these blocks it was
intended to bias selection to favour one block location above the others.¹

In all, four conditions of bias were examined. In the One Novel condition three colour cues are familiar but one is novel. According to the revised GAIN model the familiar cues should activate an N-node representation which reduces their probability of selection. As a consequence, a bias is expected to the lone novel cue. In the All Familiar and All Novel conditions, all colour cues have equivalent preexposure history, (or equal valence²), therefore no selection bias is expected. Finally, in the One Familiar condition a lone familiar cue is presented with three novel cues. In this case the lone familiar cue will be insufficient to activate an N-node representation and again no selection bias is expected.

7.2.1 Method

Subjects.

40 undergraduate and graduate students (Age: 18-32yrs). 26 Ss were female and 14 male. All were naïve as to the purpose of the experiment.

Apparatus and Stimuli.

The displays presented to subjects comprised of a series of short animated clips. Each animation depicted four square blocks, all identical in size. The blocks could vary in colour

¹ As a real life analogy to the task consider walking down a high street in search of a Midland bank. Each of the buildings in the street has its own sign, identifiable by words and colours. But, at a distance the words on the signs will be unreadable. In this case search may be guided by a simple visual feature such as the colours blue and yellow which characterise the Midland bank sign. In other words, a selection bias is introduced through colours which have associated with a particular goal. In the present study, an attempt is made to induce a similar bias by manipulating the familiarity of colours. However, in this case, the colours themselves have never been associated with the goal.

² New English Dictionary: VALENcy

The power or capacity of certain elements to combine with or displace..... other elements. "I think it will probably be found that the atoms of high valency are really molecules." (1881). "The molecule is a body in which all the attractions or valencies are satisfied, leaving the combined atoms to act as a whole from one centre." (1869).
and upon each was either a five letter word or a non-word. In total eleven animations were constructed. Four were assigned to orienting trials and seven to the PX trials. The orienting trial animations had two words and two non-words superimposed on the blocks (See Fig.7.1). The PX trial animations had four non-words superimposed on the blocks (See Fig.7.2). A detailed description of the block colours is presented in the following section. All animations were constructed on a 3-D modelling package (3-D studio) and presented with a multi-media animation player (Soundscript).

To create the animation, blocks were viewed from a "camera" position that moved along an axis perpendicular to their faces and passing through the centre of the configuration. When presented as an animation, the camera motion creates an impression of four blocks looming from a distance towards the subject. Rendered frames to illustrate this effect are presented in Fig.7.3. Each animation composed of 30 frames and was presented at a rate of 20 frames/sec. Thus, a complete animated clip had a duration of 1.5 seconds. The visual angles subtended by the whole configuration of blocks varied from a 5.0 deg to 20.2 deg, horizontally and vertically.

**Design and Procedure.**

The forty subjects were randomly assigned to one of four conditions, One Novel, All Familiar, One Familiar and All Novel. Subjects in all conditions were presented with a continuous sequence of twenty-four animations. The sequence composed of a repeating cycle of five PX trials (PX-T) followed by a single Orienting trial (OR-T). The four Orienting trials were identical across conditions. As shown in Fig. 7.4, they were constructed from a single template by replacing each of the four colours with the colour RED. The subject's task throughout was to look for words in the display. When they detected a word they were to name it out loud. During PX trials no words could be detected as only random letter strings were present on the blocks. However, on Orienting trials the blocks contained two words and two random strings. The crucial measure was which of the two words in an Orienting trial the subject selected first. To bias this selection process the four conditions manipulated the relationship between block colours in PX and Orienting trials.
Figure 7.1: Sample frame from an orienting array.
Figure 7.2: Sample frame from a preexposure array.
Figure 7.3: An example of an approaching array.
Figure 7.4: The construction of Orienting displays from a template.
7.2.2 Colour Manipulation

The diagram in Fig. 7.5 illustrates the manipulations for One Novel and All Familiar conditions. Letters on the blocks indicate their colour. The shading of blocks indicates whether they contain words or non-words. In the One Novel condition a bias is introduced by changing the block colours between PX and Orienting trials. Thus, on each Orienting trial one of the word blocks stays the same colour as on the previous PX trials whereas the other block is changed to the novel colour RED. By contrast, in the All Familiar condition the block colours remain consistent as the displays progress from PX to Orienting trials. Therefore, in this condition, there is no bias in the relative familiarity of block colours. The diagram in Fig. 7.6 illustrates the manipulations for One Familiar and All Novel conditions. Again letters on the blocks indicate their colour, and shading of blocks denotes the presence of words. In the One Familiar condition a bias is introduced by keeping the colour Red consistent from PX to Orienting trials. Thus, on Orienting trials, the Red word block is a familiar colour whereas the other is a novel colour. By comparison, there is no colour bias for word blocks in the All Novel condition as all colours are novel on Orienting trials.

**Figure 7.5:** The first twelve displays in the One Novel and All Familiar conditions.
To investigate selection bias between word blocks, a Bias Index (BI) was calculated for each subject. The index was simply the difference in the number of words selected on the two word blocks. This difference was then scaled by a factor of four to give a number between +1 and -1. For example, in the One Novel condition, if a subject always selects from the novel block their index will be: \( BI = (4-0)/4 = 1.0 \). By comparison if the subject selects only two words that are never from the novel block their index will be: \( BI = (0-2)/4 = -0.5 \). Thus, without selection bias the mean Bias Index across subjects is expected to be zero but if a bias is present then the mean BI will significantly deviate from zero.

The Bias Indices for each condition are presented in Fig.7.7. As shown in the figure, a clear selection bias to the Red block is observed in the One Novel condition. This is attributed to the novel popout of the Red block as the colour changes from PX to Orienting trial. By comparison, no bias to the Red block is observed when the colours are All Familiar. In the remaining two conditions, no bias is observed when only the Red block remains
familiar from PX to Orienting, but there is a suggestion of bias when the colours are All Novel. The last result indicates there may be an automatic preference for the Red block when all block colours are novel. However, the failure to observe any bias in the either the One Familiar or All Familiar conditions suggests that this bias is eliminated with repetition. To confirm these descriptions four t-tests were performed to investigate whether the BI was significantly different from zero. Consistent with the account above there was a significant bias towards the Red cue in the One Novel condition, $t(9) = 7.15$, $p<0.05$. However there was no evidence of a significant selection bias in either the All Familiar, One Familiar conditions, $t(9) = 1.18$; ns; $t(9) = 1.00$; ns. In the All Novel condition the bias index approached significance, $t(9) = 1.88$; $p=0.09$.

![Graph showing bias indices for four conditions](image)

**Figure 7.7:** Bias indices for the four conditions of Experiment 7.1.

The results obtained are consistent with the revised GAIN model outlined earlier. In the One Novel condition, the three familiar blocks are sufficient to activate the N-node representation of these blocks that reduces their probability of selection. Consequently, a
strong bias towards locations occupied by the lone novel block is observed. By contrast, in
the One Familiar condition the lone familiar block is insufficient to activate the N-node
representation and no bias in selection is observed. The failure to observe a sink-in effect with
a lone familiar block is also consistent with the claim that popout and sink-in depend in
configural factors. For the All Familiar condition no bias is predicted, as the N-node
representation should act on all four colour cues in the array. The only effect of concern was
the tendency towards bias in the All Novel condition. This suggests that selection bias may
be colour specific such that some colours are selected above others irrespective of
preexposure history. The effect also reveals a major problem in the study in that the
manipulations are always specific to the colour RED. It is possible therefore that the biases
observed are specific to this colour and will not generalise when other colours are used as the
novel stimulus. To investigate this issue further, a second study was run to test for novel
popout across a range of stimuli colours.

7.3 Experiment 7.2

The aim of this study was simply to replicate the effects in the previous study and test
for popout with novel colour cues other than Red. The design and displays were identical
to those of the previous study except that template displays were created for all possible
combinations of the set of five colours. For example, if Red is the novel colour cue of interest
then the preexposure display would be constructed from Cyan (C), Yellow (Y), Blue (B) and
Green (G). Similarly, if Yellow is the novel colour cue then the preexposure display contains
the combination B, G, R, C. In this way it was possible to test for novel popout for each of
the five colours in the set.

7.3.1 Method

Subjects.

40 undergraduate and graduate students (Age: 18-26yrs). 31 Ss were female and 9
male. All were naïve as to the purpose of the experiment.
Apparatus and Stimuli.

Apart from the block colours, the displays presented were identical to the previous study and composed of four square blocks identical in size. Also as before, PX trial blocks displayed four non-words and orienting trial blocks displayed two words and two non-words. Four orienting trials animations were created for each of the five colour combinations. Thus, each subject was measured on a total of twenty orienting trials.

Design and Procedure.

The forty subjects were randomly assigned to one of four conditions, One Novel, All Familiar, One Familiar and All Novel. Subjects in all conditions were presented with a continuous sequence of a hundred and twenty animations. The sequence composed of a repeating cycle of five PX trials (PX-T) followed by a single Orienting trial (OR-T). As before, the twenty Orienting trials within the sequence were identical across conditions. Each was constructed from a template colour combination by replacing one of the combination colours with the remaining colour of the set (See Fig. 7.8). The full set of displays used are also shown in Table 7.1. The ordering of letters in the table corresponds to the block positions top, right, bottom and left respectively. Thus, the code YBGR represents a display with a Yellow top block, Blue right block, Green bottom block and a Red left block. The ordering of trials in Table 7.1 is almost identical to that actually presented to subjects. However, within each block of four orienting displays, the order was randomised to illuminate any predictable sequence of word position. Due to technical limitations of the software used, subjects in all conditions were tested on the same display sequence.

The subject's task throughout was to look for words in the display. When they detected a word, they were to name it aloud. During PX trials no words could be detected as only random letter strings were present on the blocks. However, on Orienting trials the blocks contained two words and two random strings. The crucial measure was which of the two words in an Orienting trial the subject selected first. To bias this selection process the four conditions manipulated the relationship between block colours in PX and Orienting trials. The manipulations were identical to those of the previous study. In the One Novel condition only a single colour changed from PX to Orienting trials. In the All Familiar condition all
Figure 7.8: The construction of twenty orienting displays from five templates.
Table 7.1  Display sequences across the four conditions.

<table>
<thead>
<tr>
<th></th>
<th>One Novel</th>
<th>All Familiar</th>
<th>One Familiar</th>
<th>All Novel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PX x5 OR</td>
<td>PX x5 OR</td>
<td>PX x5 OR</td>
<td>PX x5 OR</td>
</tr>
<tr>
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<td>RYBG</td>
<td>RYBG</td>
<td>WWWWW</td>
</tr>
<tr>
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<td>CYBG</td>
<td>CRBG</td>
<td>CRBG</td>
<td>WWWWW</td>
</tr>
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<td>CYRG</td>
<td>CYRG</td>
<td>WWWWW</td>
</tr>
<tr>
<td>4</td>
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<td>CYBR</td>
<td>CYBR</td>
<td>WWWWW</td>
</tr>
<tr>
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<td>YBGR</td>
<td>CBGR</td>
<td>CBGR</td>
<td>WWWWW</td>
</tr>
<tr>
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<td>YCGR</td>
<td>YCGR</td>
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</tr>
<tr>
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<td>YBCR</td>
<td>WWWWW</td>
</tr>
<tr>
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</tr>
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</tr>
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<td>BGYC</td>
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</tr>
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<td>BGRY</td>
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<td>BRCY</td>
<td>WWWWW</td>
</tr>
<tr>
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<td>GBCY</td>
<td>GBCY</td>
<td>WWWWW</td>
</tr>
<tr>
<td>15</td>
<td>GRCY</td>
<td>GRBY</td>
<td>GRBY</td>
<td>WWWWW</td>
</tr>
<tr>
<td>16</td>
<td>GRCY</td>
<td>GRCB</td>
<td>GRCB</td>
<td>WWWWW</td>
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<td>GCYB</td>
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<td>WWWWW</td>
</tr>
<tr>
<td>18</td>
<td>RCYB</td>
<td>RGYB</td>
<td>RGYB</td>
<td>WWWWW</td>
</tr>
<tr>
<td>19</td>
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<td>RCGB</td>
<td>RCGB</td>
<td>WWWWW</td>
</tr>
<tr>
<td>20</td>
<td>RCYB</td>
<td>RCYG</td>
<td>RCYG</td>
<td>WWWWW</td>
</tr>
</tbody>
</table>
colours stayed the same. For the One Familiar condition only a single colour remained the same from PX to Orienting trials. Finally, in the All Novel Condition all colours changed from PX to orienting trials.

### 7.3.2 Results and Discussion

To explore the issue of selection bias a Bias Index was calculated for the five colour cues using the method outlined in Experiment 7.1. An examination of Fig. 7.9 reveals a pattern of biases observed with a Red cue that replicates the effects of the previous study. When the Red cue is novel, a significant selection bias is observed, $t(9) = 8.33; p<0.05$. However, there is no evidence of bias in either the All Familiar or One Familiar conditions. Finally, when all the colour cues are novel, a significant selection bias is observed towards the Red cue, $t(9) = 2.37; p<0.05$. The last result adds weight to the previous claim that there is an automatic preference for Red when all colours are novel. However, the important points to note are that this bias is exaggerated when the Red cue is presented in a familiar context, and eliminated with repetition.

![Selection biases relative to the Red colour cue.](image)

**Figure 7.9:** Selection biases relative to the Red colour cue.
The indices for the CYAN colour cue are presented in Fig.7.10. As with the Red cue there is a bias towards a Cyan cue when it is novel among familiar colours, $t(9)=2.75; p<0.05$. But somewhat unexpectedly there is bias away from the Cyan cue when all the colours are familiar, $t(9)=2.24; p=0.05$. It is not exactly clear why this should be the case. One possible explanation is that Cyan is a combination of the colours Blue and Green. Therefore a gain reduction for "Blue" and "Green" vectors may be additive for the colour Cyan to compound the reduced signal gain. Such an account would also predict an attenuation of the novel popout effect as the reduced gain of the familiarised Blue and Green would transfer to the novel Cyan. Thus, although post-hoc, this account might also explain the relatively weak selection bias in the One Novel condition. In the remaining conditions there is no significant selection bias when either Cyan is the One Familiar cue or when the cues are All Novel.

Figure 7.10: Selection biases relative to the Cyan colour cue.
Selection biases with the Yellow colour cue are illustrated in Fig. 7.11. Consistent with the results for both Red and Cyan cues, a significant selection bias was observed in the One Novel condition, $t(9) = 3.36$, $p<0.05$. Furthermore, there was no evidence of bias in either the All Familiar, One Familiar or All Novel conditions.

![Figure 7.11: Selection biases relative to the Yellow colour cue.](image)

With the Blue colour cue a very different pattern of biases was observed. As shown in Fig. 7.12, there appears to be a bias away from the Blue cue in all the conditions. Although this was not significant in the One Novel condition, $t(9) = -1.77$, ns, it still fails to replicate the popout observed with the previous colour cues. For the other three conditions a significant bias away from the Blue cue was consistently observed ($t(9) = -3.21$, $p<0.05$; $t(9) = -4.74$, $p<0.05$; $t(9) = -2.58$, $p<0.05$). One explanation of this bias is that the words are more difficult to select on the Blue blocks because of colour contrast. In other words, because the target words are written in black, there is less contrast between the word on the Blue block which may make the target on this block more "difficult" to select (See Fig. 6.7). A related possibility is that subjects gradually learn that targets are more difficult to select with Blue
colour cues. Thus, although in the All Novel condition the Blue cues are novel relative to the preceding pre-exposure displays, these Blue cues have been seen previously in the experiment.

![Figure 7.12: Selection biases relative to the Blue colour cue.](image)

Finally, for the Green colour cue no significant selection bias was observed in any condition (See Fig. 7.13). Again this may be due to learning effects developed over the previous displays. For example, on Orienting displays, when subjects select a target word cued by one of the five colours, they may learn that some colours are more relevant than others in cueing a target word. This problem is compounded by the fact that displays were presented in a fixed sequence. Therefore, colours tested earlier in the sequence have a greater opportunity to gain "relevance" than colours tested later in the sequence. Such an account would therefore explain the absence of novel popout for the colours Blue and Green which are probed towards the end of the sequence. To explore this issue the conditional probabilities of a word being associated with a colour were calculated for the One Novel condition.
Figure 7.13: Selection biases relative to the Green colour cue.

The diagram in Fig. 7.14 shows the probabilities of a target word, conditional by colour cue and calculated prior to each orienting trial. An examination of the figure reveals marked differences in these probabilities which were not controlled for in the study. The most prominent feature of the graph is large conditional probability for the Red colour cue which is tested first in the sequence. It might therefore be argued that novel popout with the Red cue is in fact a learning effect over the first four trials. However, this would not explain novel popout with a Yellow colour cue, where two of the other colour cues (i.e., Red & Cyan) have a greater prior probability of predicting a target word. To investigate this issue further a diagram was constructed to illustrate the probability of selection over the four trials each colour served as the novel cue. If the biases observed are indeed related to target expectancy, then a monotonic increase in selection probability is expected over the four trials each colour cue is probed.
Figure 7.14: Conditional Probabilities in the One Novel Condition

Orienting Trial

Prob(Word/Colour)

Cue Tested
Figure 7.15: Selection Probabilities for the Novel Cue

- Red
- Cyan
- Yellow
- Blue
- Green

Cue Tested

Orienting Trial

- Significant Selection Bias
However, as shown in Fig. 7.15, for all colours except Blue, a strong bias towards the novel cue is observed on the first trial each colour is tested. In other words, novel popout is apparent when subjects have had no opportunity to develop a colour specific expectancy. Therefore, whatever role expectancies might play in the study, they do not account for the first trial popout observed with four of the five cues.

### 7.4 General Discussion

Experiment 7.1 reveals a clear selection bias towards a novel Red cue among three familiar colour cues. However, there is also a tendency towards a Red bias when all cues are novel. This suggests there may be a bias towards Red irrespective of familiarity. The results of Experiment 7.2 replicate this pattern for the Red cue and reveal a first trial popout effect for all but the Blue colour cue. Broadly speaking, these results accord with the GAIN prediction that novel popout could be obtained by manipulating the familiarity of irrelevant objects. Furthermore, for all but the Blue cue no bias was observed in the One Familiar condition. This adds further weight to the claim that repetition effects are not object specific.

Despite these promising results there are a number of anomalies and design problems that caution against strong conclusions. First, the results obtained with the Blue cue suggest that colour contrast between the blocks and words is a factor that has not been controlled for. Secondly, although the use of colours minimised cue similarity within an array, the repeated use of these cues throughout the study maximises the similarity across displays. This similarity may attenuate novel popout and introduce interactions of effects across displays. Thirdly, the fixed sequence of displays employed and the block testing of colour cues introduces problems of learning or expectancy that cannot be fully discounted from the results.

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3 The significance of bias was calculated by assuming that selection of either the novel or familiar word block was binomial with $P = 0.5$. 

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Overall however, the two experiments provide tentative evidence that popout can be obtained by manipulating the relative novelty of colour cues that are irrelevant to the subject's goals. The studies also offer a direct measure of popout that does not rely on post cuing techniques, and extend the study of popout to displays that mimic the dynamic information flow experienced in real world environments. Perhaps the strongest conclusion to be drawn, is that selection bias observed in identical displays depends critically on what subjects have previously been exposed to. The paradigm explored in this chapter represents a first step in investigating such dynamics with continuous visual displays.
Chapter 8

Motion in Mind

"Right across cognitive science, researchers are applying the concepts and tools of dynamics to the study of cognitive processes. The strategy itself is not new; the use of dynamics was prominent in the 'cybernetics' period (1945-1960), and there have been active dynamical research programs ever since."

Port and Van Gelder (1995)
8.1 Summary

The focus of the thesis is to investigate how attention or selection bias might initially develop and change over time. In addressing this question it is argued that a linear information processing framework fails to account for the source or origins of selection bias. This issue has been ignored in the many selection paradigms because the source of bias is usually the experimenter. In other words, subjects are provided with a description of the target to select prior to the presentation of stimuli. Therefore, in this case, the question asked is how bias has its effect on subsequent processes rather than on the cause of bias in the first place. At a more abstract level, this distinction concerns the origins of psychological structure. Thus, while it is true that the activation of preexisting structures can induce selection, this does not tell us why the structures become activated or how they were acquired initially. In other words, if we are told (or decide) what to select, then we can use this description or structure to guide selection. But how do we initially acquire such descriptions or structures in the first place?

To solve this problem a cyclic information processing framework is suggested as the starting point. The advantage of the cyclic framework is its emphasis on the role of movement in the sampling process. Thus, by adopting a cyclic framework the premise is made that structure is a general property or consequence of motion. To break down the problem further Posners' distinction between Endogenous and Exogenous factors is drawn on. To paraphrase this distinction, Endogenous factors govern attention to internal goals whereas Exogenous factors govern attention to external circumstance. In terms of motion, Endogenous bias is driven by internally generated motion (emotion) whereas Exogenous bias is driven by externally generated motion (commotion). To account for the two sources of bias, a cyclic framework with two processing loops is proposed. The Vigilance loop monitors changes in external motion and the Anterior (or target) loop generates changes in internal motion. To specify the operations of these processing loops in more detail, a range of literature is reviewed to explore how selection bias changes with experience. The studies examined suggest that extended exposure can lead to opposing changes in behaviour. These are described as (i) the reduced tendency to sample events further, and (ii) a tuning of the sampling process.
Drawing on Posners' anatomical framework of attention, these empirical consequences of repetition are associated with two separable brain functions. The reduction in sampling is equated with changes in Posners' Vigilance network. A function of this network is to reduce the selection bias towards repeated or expected structure. One consequence of this change is a relative increase in the bias towards novel or unexpected structure. By comparison, the tuning of sampling behaviour is equated with changes in Posners' Anterior or "target" network. The function of this network is to tune internally generated biases to incoming information structures. A consequence of this change is that objects will be processed with greater efficiency.

By contrasting the two proposed functions, it is inferred that a behavioural comparison needs to be made between biases towards familiar and novel objects. Under conditions of repetition changes in the Vigilance loop will decrease the sampling bias towards familiar objects relative to novel objects. However, changes in the Anterior network will compensate for decreased sampling bias by increasing the efficiency of the sampling process. Therefore, if subjects are presented with novel and familiar stimuli under time pressure there is a conflict between sampling a novel object to expand the sampled domain or sampling the familiar objects more efficiently.

A useful way to understand this conflict is to depict novel and familiar domains in terms of space. This space can be understood either as an external "real" space which the organism explores or as in internal "processing" space which the organism explores. For example, in Fig. 8.1 the inner circle depicts the known territory of an organism in which the distributions of events are well represented, whereas the outer circle depicts novel distributions of events that are not represented by the organism. If the organisms goals (emotions) are fulfilled by the events within the inner circle there may be no need to expand the territory further. However, if the goals are not fulfilled the organism may venture out to

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1 Efficiency can be defined as the ratio of the successes to attempts (S/A). With a novel object, a large set of received object events may be used to predict the future behaviour of the object. However, with increased experience, this set will modified as good predictors are reinforced and poor predictors decay. In this sense, increased efficiency is can be viewed as decreasing the number of object events used to predict object behaviour.
Figure 8.1: The expansion of a familiar domain into novel territory.

Figure 8.2: A novel intrusion into a familiar domain.
expand the extent of its domain. The illustration in Fig. 8.2 depicts another possibility. In this case the familiar domain is intruded on by a novel distribution of events. The organism must therefore select whether to continue goal fulfilment in the familiar domain or to sample and evaluate the novel intrusion. For example, this dilemma might involve a choice between continuing to search in the familiar places for food or attending to a potential predator.

To investigate such selections empirically, the novel popout paradigm developed by Johnston et al. (1990) is adopted. Within this paradigm subjects are briefly presented with an array of four objects that must be identified and localised. If all the array objects are familiar then localisation performance is superior to when they are all novel. Within the cyclic framework, this difference is attributed to the enhanced sampling efficiency of familiar objects mediated by the Anterior loop. However, if a lone novel object is introduced into a familiar array then this pattern is reversed, showing superior localisation of novel, relative to familiar objects. This effect, known as Novel Popout, is attributed to a difference in selection bias to novel and familiar objects mediated by the Vigilance loop.

To examine this interpretation Experiment 4.1 explores the effects of internal bias on the Novel Popout effect. Specifically, it is suggested that an active bias towards familiar words may mask the bias towards the novel word. However, the results reveal that novel popout is not affected by the response required during familiarisation. Therefore, on the basis of this finding, it is claimed that the novel selection bias is an automatic effect of novel intrusion.

Experiment 4.2 examines the effect of internal biases on the baseline difference between All Familiar and All Novel arrays. Specifically, it is suggested that passive preexposure will eliminate the localisation advantage in All Familiar arrays as there will be no tuning of the sampling process. Although the results support this prediction, there is also no baseline effect when words are actively named during preexposure. This is accounted for by noting that, in both passive and active PX conditions, the preexposure period is irrelevant to task performance. In other words, the baseline difference may only emerge when the familiarisation period is relevant to the current goals. In the Johnstons' paradigm, this condition is satisfied as subjects are probed for localisation performance after each exposure of an array.
Further work by Johnston and colleagues revealed a phenomenon termed Odd Popout or OPO. OPO refers to the observation that a single familiar word will popout when presented with three other familiar words preexposed together. This result suggests that selection bias is an associative phenomenon, dependent on whether the familiar objects have been preexposed together. Drawing on this interpretation, it is suggested that a selection bias may also be induced by existing associations between representations. To explore this possibility, Experiment 5.1 tests for selection bias induced by existing associations, or by those formed during the study. The results reveal a selection bias when three members of one category are presented with a lone member of another category. However, there is no additional bias contingent on preexposure history. In other words, there is no evidence of a novel popout effect.

A possible reason for this finding is that the category bias and novelty bias operate in the same direction. Therefore, any additional bias from associations formed in the study may be masked by the strength of the category effect. Experiment 5.2 examines this account by testing for novel popout with four pictures from different categories. Consistent with this interpretation, the results reveal a novel popout effect when the category associations between array items are removed. Furthermore, novel popout is observed with picture stimuli at display durations of only 50ms. In conjunction with novel popout effects with words, at only 33ms exposure (Johnston et al., 1993), these results support the interpretation of novel popout as a reflection of sampling bias rather than an effect that occurs after an object is sampled.

Chapter 6 examines some of the theoretical consequences of the empirical findings. Of most interest is the possibility that associations might be formed between objects without selection of the objects. This is inferred from (1) the observation that popout is an associative phenomenon and (2) that associations can be formed with very brief exposure, where only a single object could be selected. Building on these findings, three types of association are suggested. The concept of **Intrinsic** association is introduced to account for the effects of existing structure or architecture on selection bias. By comparison, the concept of **Extrinsic** association is introduced to explain the effects of associations formed during the study. It is suggested that Extrinsic association can take two distinct forms, termed S-node and N-node. S-node association refers to associations formed in the Anterior loop of the model. In line
with Kahneman and Treisman (1984), these S-nodes associations depend on objects being selected or attended. The function of the S-nodes is to tune subsequent sampling of familiar stimuli. However, to account for the associative effects in the popout paradigm, associations that **do not depend on selection** are also proposed. These are referred to as N-node associations. The function of N-nodes is to create a structure from the entire set of signals received. This structure subsequently acts back on the received information to decrease the bias towards expected or familiar signal structure. A consequence of this process is a relative increase in the bias towards novel signals received by the perceptual systems.

An abstract illustration of this process is illustrated in Fig. 8.3. The large circles represent the entire set of signals received at any moment in time. As time passes, the lightened shading of elements in this set corresponds to a reduction in the strength (or vector length) of signals that are repeatedly present. The effect of this change is shown at t(3), where the small circle represents a set of novel signals. The darker shading of elements in this set illustrates that the novel signals have a greater signal strength. Because of this **differential** in signal strength, the novel signals constitute a region of bias that directs the sampling process. In this way, the structure present in the novel set of signals can be recovered, evaluated and recorded.

![Figure 8.3: An abstract illustration of the logic of popout.](image-url)
In the final empirical chapter, the novel popout effect is examined using dynamic visual displays. The question addressed here is whether a change in goal irrelevant features can alter selection bias. Using colour as the irrelevant feature, Experiment 7.1 provides evidence of a strong selection bias towards a novel but irrelevant red colour cue. However, there was also evidence of a weaker bias towards the red cue when all the colours are novel. This suggests there may be an intrinsic selection bias towards the colour red. Experiment 7.2 replicates these results and provides evidence of novel popout with three other colours. Although the dynamic selection paradigm employed in these studies requires considerable development, the initial results are very promising. For example, in both studies, a significant selection bias is observed with only a single subject measurement from ten subjects. This suggests that free selection choice, with simultaneous moving goals, is a very sensitive measure of changes in attentional bias.
Bibliography


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