

**THE NECKER CUBE:
A NEW PERSPECTIVE.**

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STATEMENT

I Karen Chilcott certify that this thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution and that, to the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

Signed...*K. Chilcott*.....

Karen Chilcott

Date...*27/1/95*.....

LITERATURE REVIEW
INTERPRETATION IN VISUAL PERCEPTION

Abstract

Attempts to explain any perceptual phenomena usually do so exclusively in terms of neurophysiological mechanisms on the one hand, or in terms of inferred cognitive processes on the other. Alternative theoretical approaches offer a combination of these positions. The realisation that numerous phenomena can be accounted for by both major theories has lead to confusion of interpretation. One example is the reduction of dominance of a percept of a reversible figure after prolonged exposure to an unambiguous stimulus. Typically, the percept which resembles the unambiguous stimulus is seen for a smaller proportion of the subsequent viewing period.

The neurophysiological account of this phenomenon holds that the groups of cells responding to the unambiguous stimulus become fatigued during adaptation so that during subsequent viewing of the ambiguous stimulus the most active group of cells will dominate. The alternative, cognitive explanation proposes that one of the effects of prolonged viewing or adaptation may shift the rate of accumulation of evidence for a particular perspective interpretation. Within this cognitive context one may speculate that prolonged inspection of an unambiguous stimulus simply creates a preference for whichever interpretation of the ambiguous stimulus is the more novel.

Proponents of these dichotomous approaches believe that every perceptual phenomena need only be explained by one theory. However, as some phenomena can be explained by both approaches, an integrated approach in which visual processing at a physiological level is influenced by cognitive processes may be warranted.

A modified experimental procedure to enable the independent manipulation of the physiological and cognitive components of this visual effect, was suggested.

1. Introduction and Aims

Since the 1950's a large body of research has been developed to enhance the understanding of the physiology thought to underpin visual perception. A further approach has developed an equally valid theoretical account of perception in terms of inferred mental processes or cognitive factors. In addition to these dichotomous viewpoints, several alternatives have been put forward, generally proposing a combination of the two major approaches, including a multilevel and a two stage account. Although not directly stated, a theoretical rift has developed between the proponents of the two major approaches. The literature also reveals that the conflict has been enhanced by a commonly adopted experimental procedure. This procedure, is variously termed selective-adaptation or transfer of decrement and is generally referred to as the adaptation paradigm. This paradigm reveals that contrary to the expectations of those who use it, it does not allow verification or falsification of either of the two major theoretical positions.

The objectives of this paper therefore are to examine the evidence in support of the major theoretical approaches in vision research and their alternatives. Specifically, the aim is to investigate the various interpretations of one phenomenon, a special case of perceptual alternations. The prolonged exposure of an unambiguous stimulus affects the relative dominance of the percepts in subsequently presented ambiguous figures. This adaptation effect will be detailed for several reasons. Firstly because it has been explained by both major theoretical positions and, secondly, it is generated by the contentious paradigm. Lastly, it is intended to consider the adaptation paradigm and detail how it may be modified to provide a resolution to the theoretical impasse in the interpretation of relative dominance changes.

Outline

The vast body of research in support of the dominant neurophysiological approach to visual perception will be briefly outlined in section 2. In section 3, the cognitive approach will be introduced, as this is generally considered to be the major theoretical position opposing the neurophysiological approach. Explanations of several phenomena including a special case of perceptual alternations will demonstrate this position. Research findings based on two alternative theoretical

approaches will be discussed in sections 4 and 5. In an attempt to determine which of the theoretical approaches to accept some researchers have looked to the experimental paradigms for answers. The adaptation paradigm is discussed in section 6. Section 7 will consider the approaches to visual perception and the adaptation paradigm. This section aims to clarify the issue of interpretation for the change in relative dominance that occurs when an ambiguous stimulus is presented after the prolonged inspection of an unambiguous stimulus. Finally, Section 8 will conclude by proposing an experimental strategy to resolve the issue of interpretation for relative dominance changes.

2. The Neurophysiological Model: The Link Between Single Cell Activity and Perceptual Effects

Throughout the recorded history of visual perception there have been repeated attempts to provide comprehensive theories of perceptual phenomena in terms of neural interaction (e.g., Kohler, 1940; McDougall, 1902, 1903a, 1903b, 1906). The current era of discussion of sensory phenomena in neurophysiological terms began with the pioneering work of Hubel and Wiesel in the 1950's. Recordings of single cell activity in the striate cortex of anaesthetised cats confirmed the existence of cells specific for position, size and movement (Hubel & Wiesel, 1968). Subsequently single cell activity was linked to perceptual effects in human vision.

Motion Aftereffect

Barlow and Hill (1963) were possibly the first to take Hubel and Wiesel's findings further. They confirmed the existence of cells selective for the direction of motion after observing that the firing rate of cells diminished with the repeated stimulation of a stimulus moving in one direction. Later studies reported that the prolonged viewing of a stimulus moving in one direction induced a strong sensation of opposite motion when a stationary test stimulus was subsequently viewed (Masland, 1969; Mayhew & Anstis, 1972). This motion aftereffect (MAE) is explained by the fatiguing of directionally specific cells in humans.

Spatial Frequency Shift

A further example of the stimulus specificity of visual cells was demonstrated by the 'spatial frequency shift'. Prolonged inspection of a striped pattern by an observer who then views a pattern of the same orientation with narrower stripes, perceives the stripes as narrower than they actually are, and broader stripes seem even broader. Blakemore and Sutton (1969) claimed that this effect implied evidence of a system of size-detecting channels in human vision.

The motion aftereffect and the spatial frequency shift are examples of perceptual phenomena that can be accounted for by the activity of neurones 'tuned' to one stimulus characteristic e.g., motion and size. Neurones sensitive to multiple stimulus characteristics have also been discovered.

Colour Contingent Aftereffects

McCollough (1965) reported a colour aftereffect (CAE) contingent on orientation. This effect was originally produced by exposing subjects to a grating of vertical black stripes on an orange background, alternated every few seconds with a horizontal grating on a blue background. When subjects were asked to view a test display of black and white vertical and horizontal gratings side by side, most reported seeing a desaturated blue green on the background of the vertical lines and orange on the horizontal portion. The generally accepted explanation of this effect, referred to as the McCollough Effect (ME) suggests that the colouration of the achromatic horizontal or vertical grid is the result of the adaptation or fatiguing of sensory cells sensitive to both colour and orientation.

For two of these effects, the MAE and the spatial frequency shift, a neuronal basis has been confirmed by recording the activity of single cells. An unfortunate consequence of this technological advance is that the majority of researchers now assume that *all* visual effects are explicable in neurophysiological terms even when evidence is provided to the contrary.

For example, Uhlarik et al. (1977) showed that the McCollough hues faded when observers intentionally caused the subjective organisation of the test stimulus to change, inferring that cognitive factors affect the hues in the ME. Broerse and Crassini (1981) had difficulty

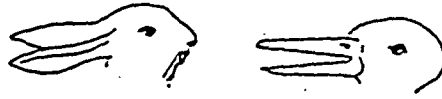
accepting this interpretation noting a 'bias in direction of causation' in Uhlarik et al.'s (1977) work. They commented that if the perceived organisation alters the appearance of the colours then it is equally likely that the colours may alter perceptual organisation, and pointed out that this possibility was not investigated. This may be correct but Broerse and Crassini (1981) appear to have overlooked a footnote added by Uhlarik et al. (1977) suggesting that explanations in terms of cognitive factors do not exclude nor are incompatible with neurophysiological descriptions. Broerse and Crassini (1981) nonetheless reject all cognitive interpretations of colour contingent aftereffects (CCAEs) and consider these explanations to be 'inadequate' and concluded that neurophysiological accounts are more 'parsimonious'. Whilst a neurophysiological explanation may be appropriate to account for CCAEs it is questionable whether only one explanation is tenable for every perceptual phenomenon. The most prominent alternative explanation of visual effects assumes the involvement of mental processes.

3. The Cognitive Model: The Link Between Perceptual Effects and Mental Processes

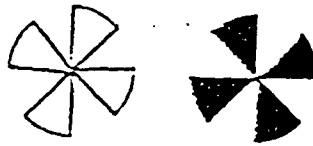
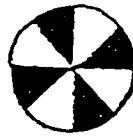
Perceptual Alternations

The cognitive approach can account for the characteristics of ambiguous stimuli and the perceptual effects that are reported when this type of stimulus is used. An ambiguous stimulus is one that, although physically stable, can be perceived in more than one way. When there is a perceived change from one version of the stimulus to the other a perceptual alternation occurs. A well known ambiguous picture is the rabbit/duck which can be seen as either a rabbit, on the left, or a duck on the right (Figure 1a). The most common types of ambiguous figures in vision research include figure ground ambiguity (Maltese Cross, Figure 1b), and perspective ambiguity (Necker cube, Figure 1c).

According to a cognitive model perceptual alternations depend on two logically separable processes. They may be attributed to a 'cyclic decision process' (Vickers, 1972), or a process of continuous trial-and-error on the part of the perceptual system (Rock, 1975).



a



b



c

Figure 1. Examples of (a) ambiguous pictures, (b) figure-ground reversals, and (c) perspective reversals.

Cyclic Decision Model

Vickers (1972) concluded that simple judgements such as would be involved in indicating the longer of two lines, seem to be mediated by a decision process. He argued that the process underlying any perceptual discrimination involves the accumulation of evidence from a series of inspections until some criterion is reached. This process recommences each time a decision is reached. When viewing any potentially ambiguous stimulus one percept will be periodically replaced by another when the decision process produces a different result.

Trial-and-Error

Rock (1975) conceptualised the alternating perceptions of the reversible figure as reflecting an active though non conscious trial-and-error problem solving process within the visual system. He proposed that as the two possible solutions of the reversible figure are essentially equivalent, the governing decision process oscillates between the two, effectively replacing one alternative with the other equally acceptable alternative.

These two explanations reflect the activity of spontaneous, generally active processes and conceptualises perceptual reversals as alternating solutions. Studies in support of the cognitive viewpoint have also shown that subjects not only are able to control the reversibility of ambiguous figures but also that the knowledge of reversibility, if withheld, affects the observers ability to perceive the alternative view of the stimulus (Girgus, Rock & Egatz, 1977; Reisberg & O'Shaughnessy, 1984).

Reversal Rate

One commonly reported finding is that perceptual reversals tend to occur more rapidly over an extended viewing period (Brown, 1955; Cohen, 1959; Long, Toppino & Kostenbauder, 1983; Price, 1967a, 1967b). From a cognitive viewpoint, the increase in reversals is attributed to the learning of alternate percepts, resulting in a shortening of the decision cycle. Further support for this approach is provided by the asymptotic curve depicting the number of reversals as a function of viewing time which is assumed to reflect a standard learning curve.

Relative Dominance

A widely reported phenomenon of reversible figures is the reduction of dominance of a percept after prolonged exposure to an unambiguous stimulus. Typically the percept which resembles the unambiguous stimulus is seen for a smaller proportion of the subsequent viewing period (Carlson, 1953; Hochberg, 1950; Virsu, 1975; Von Grunau, Wiggins & Reed, 1984). This affect is generally attributed to the fatigue of neurophysiological mechanisms.

Harris (1980), however, proposed that one of the effects of prolonged viewing or adaptation may be to shift the rate of accumulation of evidence for a particular perspective interpretation. Within this cognitive context one might speculate that prolonged inspection of an unambiguous stimulus simply creates a preference for whichever interpretation of the ambiguous stimulus is the more novel.

Colour Contingent Aftereffects

Ambiguous stimuli have also been incorporated into studies of colour contingent aftereffects including the McCollough effect (ME) (Uhlarik, Pringle & Brigell, 1977). Jenkins and Ross (1977) found that the ME was contingent on subjective changes in the organisation of a test pattern. As the organisation of the test pattern was consciously changed from one state to the other, the colour aftereffect switched in and out. Unlike the standard test pattern to measure the ME, Jenkins and Ross (1977) used a test figure with no contours separating regions of vertical and horizontal gratings. This figure could be seen as a set of concentric square 'channels' or as four large triangles converging to a point in the centre of the pattern (see Figure 2).

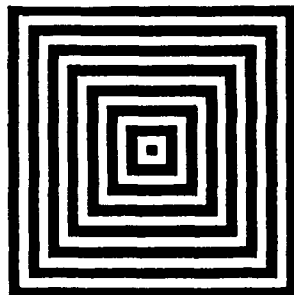


Figure 2. The pattern developed by Jenkins and Ross (1977) and used to test for the McCollough effect.

The ME was generated with vertical green and horizontal red gratings or the reverse. When the test pattern appeared as separate triangular regions the ME was observed with white stripes tinted with the hue complementary to that of the induction grating of the same orientation. When the pattern appeared as concentric square 'channels' and regionless, the McCollough hues faded. Thus when the switch occurred even though the same physical edges were present the ME diminished, a finding not consistent with a neurophysiological account of the effect.

The alternative explanation of the standard ME proposes an underlying cognitive process in which the pairing of a colour with a specific grid orientation comes to evoke a learned response in the visual system to the colour. Specifically, the red horizontal produces adaptation for red in conjunction with horizontal lines, so that after a number of pairings the line grid alone evokes the adaptive response (Murch, 1972). According to this approach mental processes are implicated, in which learning is assumed to have taken place.

Explanations of CCAEs as a learning process or conditioned response has met with much resistance from proponents of the neurophysiological approach. This shows no sign of relenting if recent studies of the ME, arguing in favour of this viewpoint are any indication (Savoy & Gabrieli, 1991; Bedford & Reinke, 1993).

The extreme application of researchers favouring the cognitive position was recently demonstrated by Horlitz and O'Leary (1993) who repeated an experiment by Hochberg (1950). Hochberg introduced the duration of the percepts of an ambiguous stimulus, a Maltese Cross (see Figure 1), as an indicator of neural fatigue. He found that after adaptation to the unambiguous stimulus that the first percept that was experienced in the test phase was the non inspected alternative. He also found that this percept that was reported for a longer duration than the other. This was taken as evidence that adaptation had resulted in neural fatigue. Using a figure ground reversible pattern of their own design Horlitz and O'Leary (1993) found that after adaptation to the unambiguous stimulus that each percept in the test phase was viewed for approximately fifty percent of the viewing period. Based on the assumption that all reversible figure phenomena can only be accounted for by cognitive processes, non

confirmation of Hochbergs finding was automatically accepted as evidence favouring the cognitive viewpoint.

Horlitz and O'Leary (1993) also speculated that a preference for novelty or a process of habituation may account for many of the phenomena of reversible figures including the duration of percepts, the acceleration of reversals and relative dominance changes. According to this position relative dominance changes occur when an unambiguous stimulus is viewed because the more novel alternative percept is preferred in the ambiguous test stimulus. They additionally claimed that habituation in vision: "is not a process that is color-specific....or location-specific...." (p.680). No reason is given for this caveat and they appear not to have taken the evidence into account. For example studies have shown change in relative dominance to be colour contingent (e.g., Hochberg, 1950; Mapperson & Lovegrove, 1989). Further, since location constancy is known to be acquired in infancy (see Keating & McKenzie, 1986), it is unclear why Horlitz and O'Leary (1993) would assume that visual effects would not habituated to location.

Location specificity was demonstrated in one of a series of experiments by Von Grunau et al. (1984) relative dominance changes were measured when an adaptation stimulus was presented in 0.5 degree steps above and below a centrally fixated test stimulus. At 1.5 degrees above and below the fixation point no significant change in relative dominance was reported. Von Grunau et al. (1984) interpreted this from the neurophysiological perspective concluding that the experiment had demonstrated the activity of retinally localised 'channels' for perspective orientation. Although Horlitz and O'Leary (1993) cite Von Grunau et al.'s (1984) study they appear to have overlooked the findings of this experiment.

4. A Multi Level Model

An additional theoretical position holds that a phenomenon may be attributed to multiple causes. As long ago as 1897 Chamberlain suggested that the scientific research of his era had become biased in favour of the theoretical perspective of the researcher. He warned that if this approach is adhered to researchers would ultimately shape their findings to confirm

the theory. Instead of a singular approach, with one hypothesis, Chamberlain proposed multiple hypothesis testing which puts forward and develops every tenable hypothesis.

According to the literature it would appear that vision research has developed through single hypothesis testing with a bias in favour of singular accounts of visual phenomena. The equally likely possibility that multiple factors may contribute to a phenomenon has been overlooked in most cases in favour of more 'parsimonious' explanations. A reductionist approach, as this has inadvertently become, may be unnecessary. Three phenomena the MAE, ME and relative dominance changes provide evidence for a multiple factor approach. Evidence drawn from both major theoretical perspectives demonstrate this position.

The Motion Aftereffect

The MAE is generally believed to be attributed to the fatigue of directionally sensitive cells (Barlow & Hill, 1963; Favreau & Corballis, 1976; Sekuler & Ganz, 1963; Sutherland, 1961). However mental processes have also been shown to influence this effect. Meyer and Sherman (1981) found that by 'effort of will' subjects were able to alter the magnitude of the aftereffect.

The McCollough Effect

The widely accepted explanation of the ME postulates that it may be attributed to adaptation or fatigue of neural structures that are feature specific (McCollough, 1965). The experiments of Jenkins and Ross (1977) reviewed previously, however, argue that the effect can be produced and controlled by mental processes.

Relative Dominance

Several studies have shown that change in relative dominance, under certain conditions (e.g., in monocular rivalry when one eye views alternating patterns), may at least partially be attributed to neurophysiological mechanisms. Harris (1980) however provided an equally plausible account of the effect in terms of cognitive factors.

Clearly, neither model can provide a complete explanation of these three effects and a finding in favour of one position does not necessarily preclude, or is incompatible with any other position. In the case of the

MAE, ME, and relative dominance any explanation must consider that, in addition to sensory input, cognitive factors have been shown to influence both the nature and extent of the processing of visual information.

5. A Two Stage Account

Based on the discovery that information transfer in the human visual system is multidirectional one further approach to vision research has developed. This '2 stage' or information processing account of perceptual phenomena argues against models of perception being exclusively in favour of either of the two major theoretical viewpoints (Chaundhuri, 1990; Mapperson & Lovegrove, 1984). According to this approach information transfers from higher levels to influence the first steps in visual processing (top-down) or from lower sensory levels to higher cognitive levels (bottom-up).

Top-down

Recently the MAE has been discussed in terms of cognitive (attentive) processes to account for a 'bottom-up' model of information processing in which input from sensory mechanisms influences cognitive processes. Braddick (1990) and Chaundhuri (1990) found that the MAE could be considerably reduced in duration when an observer was attending to another task. This finding in addition to the neurophysiological explanation of the MAE was taken as support for the 'top down' model of information processing in which input from cognitive mechanisms influences low level sensory mechanisms.

Bottom-up

Research findings have also reported the compatibility of the neurophysiological and cognitive approaches to account for a bottom-up model of information processing in which input from sensory mechanisms influences cognitive processes. For example Long, Toppino and Kostenbauder (1983) explain the switching of the percepts of an ambiguous stimulus, as a cognitive phenomenon and the reduction in dominance as due to the fatigue of the neurophysiological mechanisms. A similar account of the perceptual alternations and relative dominance changes of monocular rivalry, was put forward by Mapperson and Lovegrove (1984).

6. The Interpretation Dilemma and the Adaptation Paradigm

Sections 2 to 5 have outlined several theoretical positions currently adopted in vision research. With such varying viewpoints a rift has developed between researchers concerning the 'ownership' of some phenomena (e.g., reversal rate, relative dominance). In an attempt to determine which theoretical approach to accept, some researchers have looked to the experimental paradigms for answers (Long, 1988; Porac, 1989). The numerous theoretical accounts of perceptual alternations illustrates the dilemma.

Perceptual Alternations

An alternative to the cognitive account of perceptual alternations argues that any potentially ambiguous stimulus excites different sets of cells corresponding to different percepts, and that only the percept corresponding to the most active groups will be experienced (e.g., Kohler, 1940; McDougall, 1906; Orbach, Ehrlich, & Heath, 1963). This group of cells will become fatigued and their firing rate will decrease until some critical level is reached. At this critical level an unfatigued set of cells corresponding to an alternative percept will take over. This set will in turn become fatigued (while the original set recovers) until a further alternation occurs. This neural fatigue explanation reflects the activity of a passive process in which the stimuli share common physical features. Under certain conditions this interpretation appears to be justified.

Monocular and Binocular Rivalry

This explanation may be valid when a pattern of crossed gratings is perceived as alternating monocularly or binocularly. In the case of binocular rivalry it is known that the inspection of a single grating will reduce the dominance of a later grating only when the gratings are similar in both orientation and spatial frequency (Blake & Overton, 1979).

Reversal Rate of Ambiguous Stimuli

According to the neurophysiological model the increase in reversals over time, that occurs during the prolonged viewing of an ambiguous stimulus, is due to the build up of residual fatigue in channels/neurones that do not fully recover. The result of this fatigue is

an increasingly shorter time between reversals. However not all phenomena can be explained on this basis.

A review of numerous studies by Long (1988) revealed that proponents of both major theoretical positions based many of their findings on identical experimental procedures. Closer inspection of the paradigm and its use may demonstrate how multiple interpretations have been generated.

Selective-Adaptation and Relative Dominance

During the adaptation period of the selective-adaptation paradigm an unambiguous inspection figure is viewed for a period of two to three minutes. This is followed by an ambiguous test figure which shares certain features with the adaptation figure. Most frequently, any percept that resembles the unambiguous stimulus in the test phase becomes less dominant, that is it is seen for a smaller proportion of the viewing period. Thus the effect of adaptation changes the relative dominance of the percepts.

The Neurophysiological Approach

The neurophysiological approach necessitates that the adapting and test stimuli have features in common such as perspective orientation or colour. Adaptation effects have nevertheless been reported with stimuli that were in many aspects *not* similar to the test stimulus. Von Grunau, Wiggin and Reed (1984), in an attempt to provide evidence for channels for perspective orientation, adapted subjects to black/white photographs of a wooden box, positioned and illuminated to emphasize two perspective orientations (pointing up or down). Observers reported that the test stimulus (a line drawing of an ambiguous Necker cube) appeared for a longer time in the orientation opposite to the one experienced during adaptation. As they noted "it is remarkable that adaptation effects occurred with stimuli that were in many basic aspects not similar to the test stimulus, that is in contrast, orientation and presence of contours"(p.321).

Transfer-of-Decrement and the Muller-Lyer Illusion

The adaptation paradigm is referred to by proponents of the cognitive approach as transfer-of-decrement. Transfer-of-decrement therefore indicates that there is a decrease in the magnitude of an illusion that occurs within a prolonged inspection period. This is demonstrated most often using the Muller-Lyer figure.

Learning (Cognitive) Approach

Observers' measured illusion magnitudes decrease if they scan the Muller-Lyer stimulus for a short time. Five minutes of inspection of the standard Muller-Lyer figure invariably produces reductions in the original illusion magnitude estimation.

Illusion decrement has also been found to respond to traditional learning variables. For example massed as compared to spaced intervals of viewing produces illusion decrement (Dewar, 1968). Further, subjects asked to estimate the magnitude of the Muller-Lyer figure days or weeks after adaptation retain the previously learned underestimation (Girgus, Coren, Durant & Porac, 1975).

A further observation is that illusion reduction depends on the judged similarity between the adapting and test figures. Coren and Girgus (1974) showed that transfer of decrement in the Muller-Lyer figure varied as a function of perceptual similarity. Observers viewed the classic form of the Muller-Lyer illusion for 5 minutes to induce illusion decrement. They tested whether the decrement transferred to other variants of the illusion, all of which had been rated for their similarity to the standard form. They reported that there was transfer to the other configurations, with the figures that had been rated most similar to the inspection figure showing the largest effects and those that were most dissimilar showing the least transfer. These findings indicate the involvement of learning in illusion reduction. Adequate explanation concerning precisely how perceptual judgements of similarity are made and how learning takes place are not provided in the literature.

As the explanations of these phenomena show, the adaptation paradigm can be used to provide evidence in favour of either of the two major theoretical positions: a neurophysiological account of relative dominance and a cognitive account of the Muller-Lyer illusion. Adopting

this experimental approach has also resulted in some researchers, even when faced with 'remarkable' findings that do conform with the commonly reported data, to conclude in favour of an assumed theory (Von Grunau et al., 1984).

The continued application of this paradigm unfortunately maintains the dichotomy of approaches to vision research according to which a finding excluding one approach automatically provides evidence in favour of the other.

7. The Dichotomous Approach: Some Conclusions

The preceding discussion has provided a brief overview of the status of vision research with particular emphasis on the various interpretations of the characteristics of perceptual alternations. The search for explanations of some perceptual phenomena has unfortunately lead to a situation in which the conflict has come to embody a debate between researchers who hold dichotomous viewpoints. For example Broerse and Crassini (1981) explain all complex perceptual effects in terms of one neurophysiological mechanism or process at the exclusion of any other explanation. Other perception reseachers adopt an exclusively cognitive interpretation of all phenomena (Horlitz & O'Leary, 1993). One notable consequence of this conflict is an impasse in the inteprétation of visual effects produced by ambiguous stimuli.

Much of the impasse may be due to the nature of the evidence that supports the two major theoretical positions. On the one hand is the neurophysiological or 'hard evidence' e.g., psychophysiological recordings of cell activity. On the other is cognitive evidence which by its nature is largely subjective. For example in the case of the ME cognitive influence is demonstrated by an observers ability to consciously switch the organisation of the test stimulus and cause the hues to fade. Criticisms of the cognitive approach based on the absence of parametric measures, data and statistical analyses would appear warranted. Criticism however based on any alternative explanation being more 'parsimonious' is unfounded.

The dominance of the neurophysiological model led Harris (1980) to draw attention to the extreme application of the approach by advocating

the existence of yellow volkswagon detectors to explain how we perceive yellow volkswagons. A continuation of this approach is apparent with Von Grunau et al's (1984) proposal of channels for perspective orientation to account for the perception of boxes.

The two major theoretical approaches in vision research have developed valid theoretical accounts of many perceptual phenomena. Generally researchers have adopted the singular hypothesis testing approach with proponents of these dichotomous approaches believing that perceptual effects can be adequately explained by one theory and without rational consideration of any alternative explanations.

As there is clearly evidence for both theoretical approaches and both are able to explain the same phenomena, e.g., reversal rate of perceptual alternations, an integrated approach, in which visual processing at a physiological level is influenced by cognitive process, appears to be warranted.

8. Directions For Further Research

Long (1988) noted that the one experimental paradigm adopted by the proponents of both major theoretical approaches is unable to verify or falsify either position. Clearly the adaptation paradigm has enhanced the difficulty of interpretation for some researchers. In the case of relative dominance changes there appears to be little consensus of interpretation.

Additionally researchers have attempted to provide evidence to support a single hypothesis. For example Von Grunau et al's (1984) experiment, in which the adapting stimulus was placed in varying locations above and below the test stimulus, was based on the hypothesis that only neurophysiological mechanisms account for changes in relative dominance. This experiment was undertaken without considering that changing the perceived location of the stimulus would have an impact on the experimental outcome. Close inspection of Von Grunau et al.'s (1984) findings show that it was only in one condition, when the adapting and test stimuli were both centrally located and fixated, that the stimuli occupied the same retinal and physical location. Further it was in this condition that the largest adaptation effects were reported. On the basis of

Von Grunau et al.'s (1984) interpretation of localised channels for perspective orientation and an examination of their findings several hypotheses can be made.

Hypotheses and Experimental Strategy

Three experiments are proposed to investigate whether Von Grunau et al.'s (1984) interpretation of relative dominance changes in terms of localised channels for perspective orientation is appropriate or whether a cognitive account may be more valid. As will be recalled, cognitive explanations in terms of habituation (Horlitz & O'Leary, 1993) assume that learning of the unambiguous percept occurs in the adaptation phase. When the ambiguous test stimulus is subsequently viewed a preference is created for the unlearned and more novel alternative percept. Further, if the adaptation effect is location dependent this would account for the diminished effect reported by Von Grunau et al. (1984) when the adapting stimulus was moved away from the test stimulus.

The first experiment hypothesises that if only localised channels are involved then the magnitude of the change would be expected to be the same irrespective of whether the adapting and test stimuli are in the same perceived positions. Conversely if relative dominance can be attributed to factors under cognitive influence such as location, then it is also hypothesised that the magnitude of the change will be significantly different when the perceived (or spatiotopic) location of the stimulus is manipulated, irrespective of the retinal (or retinotopic) location.

Von Grunau et al.'s (1984) interpretation can be evaluated in the first experiment if an eye movement is introduced in the adaptation/test paradigm between the adapting and test periods when the test stimulus is located below the adapting stimulus. When the observer changes fixation from the centre of the adapting stimulus to the centre of the test stimulus it can then be ensured that the stimuli will fall on the same retinal area even though the perceived locations differ. This condition in addition to one used by Von Grunau et al. (1984) with retinally and spatially coincident stimuli tests the hypothesis that only localised channels are involved in relative dominance changes. If this is correct there will be no difference in the adaptation effect when the physical location is changed in the eye movement condition.

Further, if relative dominance changes can be attributed to factors under cognitive influence then it is hypothesised that the magnitude of the change will be significantly different when the perceived location of the stimuli is manipulated, irrespective of the retinal location. In this experiment an eye movement will be made between the adapting and test period. When the observer changes fixation from below the adapting stimulus to the centre of the test figure it can then be ensured that the stimuli occupy different retinal locations when the perceived location remains the same. This condition in addition to one used by Von Grunau et al (1984) with stimuli that were neither retinally nor spatially coincident tests the hypothesis that cognitive factors such as location may be involved in relative dominance changes. It is expected that there will be a significant difference in the adaptation effect when the physical location is changed, even though the retinal location differs in both conditions.

A third experiment proposes that if relative dominance is dependent upon location, then a more appropriate explanation may be in terms of a cognitive or learning process such as habituation. In this experiment the adapting and test stimulus occupy the same physical location. When the observer changes fixation from below the adapting stimulus to the centre of the test stimulus this ensures that the test stimulus occupies a different retinal location. Because of the established phenomenon of dishabituation (Thomson & Spencer, 1966) it is hypothesised that if a novel stimulus is presented before the test stimulus there will be an increase in reporting the adapted percept. It is also hypothesised that when this stimulus is presented on the next trial that it will have little effect on the observers' reporting of the adapted percept indicating that learning of the novel stimulus occurred on the first presentation. Further, as the stimuli in this experiment are in different retinal locations, any change in relative dominance can only be attributed to cognitive factors and not neurophysiological mechanisms such as localised channels.

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JOURNAL ARTICLE

THE NECKER CUBE: A NEW PERSPECTIVE

Abstract

A widely reported phenomenon of reversible figures is the reduction in dominance of a percept after exposure to an unambiguous stimulus. Von Grunau, Wiggin and Reed (1984) measured relative dominance changes when an adaptation stimulus was placed above and below a test stimulus. The adaptation effect diminished at 1.5 degrees from the test stimulus and it was proposed that reduction in dominance may be attributed to retinally localised channels for perspective orientation. In this study however it was taken for granted that only the retinal position of the stimulus was important. They were unaware that changing the position of the adapting stimulus manipulated both the retinal and the perceived location.

The present study hypothesises that if only localised channels are involved in relative dominance changes then the magnitude of the change would be expected to be the same irrespective of whether the stimuli are in the same perceived positions. Conversely if relative dominance can be attributed to factors under cognitive influence, such as location, then it is also hypothesised that the magnitude of the change will be significantly different when the perceived location of the stimulus is manipulated, irrespective of the retinal location.

Von Grunau et al.'s (1984) interpretation of relative dominance changes was evaluated in experiment 1 with the introduction of an eye movement between the adapting and test periods. It was then ensured that the stimuli will fall on the same retinal area even though the perceived locations differ. Further, in experiment 2 an eye movement to a different location ensured that the stimuli occupied different retinal locations when the perceived location remains the same.

Experiment 1 showed negligible reduction in dominance when the perceived location differed although the retinal location remained constant, a finding contrary to that predicted by Von Grunau et al. (1984). Experiment 2 showed a large reduction in dominance when the perceived location remained the same and the retinal location differed. This was taken to demonstrate that the effect was dependent on the coincidence of perceived location.

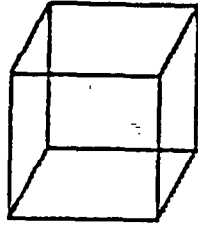
It was further hypothesised that if relative dominance changes could be accounted for by a cognitive process, such as habituation, then a phenomenon such as dishabituation may be demonstrated. Support for this hypothesis was provided in experiment 3. The wider implications of the procedure utilised in this study were discussed.

Ambiguous figures are a class of visual illusions that appear to change abruptly and spontaneously, even though the physical stimulus remains unaltered. Perhaps the best known example is the Necker cube (after Necker, 1832) which is illustrated in Figure 1, with the two alternate percepts. These changes, or 'perceptual alternations', have been explained by two competing approaches to visual perception: the neurophysiological model and the cognitive model.

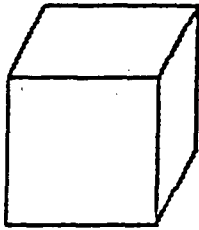
The neurophysiological model proposes that any potentially ambiguous stimulus excites different sets of cells which correspond to different percepts, and that only the percept corresponding to the most active group will be experienced (e.g., Orbach, Ehrlich & Heath, 1963; Brigner & Deni, 1992). This group of cells will become fatigued and their firing rate will decrease until some critical level is reached. At this critical level an unfatigued set of cells corresponding to an alternative percept will take over. This set will in turn become fatigued (while the original set recovers) until a further alternation occurs.

The cognitive model proposes that alternations are the result of a mental process which periodically switches between different interpretations of the stimulus (e.g., Gregory, 1966; Liebert & Burk, 1985; Rock & Mitchener, 1991). For example in Vickers' (1972) model, the initial emergence of any percept is the result of an accumulation of evidence from a series of inspections until some criterion is reached and a decision is made. Vickers (1972) proposes that this process is cyclic, recommencing automatically each time a decision is made. In the case of a potentially ambiguous stimulus, this will result in periodic changes in the percept when different decisions are reached on successive cycles.

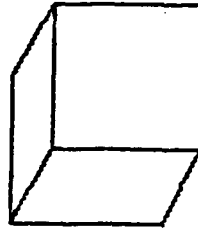
Following Hubel and Wiesel's (1959, 1962) findings on the neurophysiology of the visual system, the neurophysiological approach has tended to become dominant in studies of visual perception.



A



B



C

Figure 1. An ambiguous Necker cube (A) and the two alternate percepts (B) 'down', and (C) 'up'.

Although both the neurophysiological and cognitive explanations account equally well for many characteristics of perceptual alternations, there is a growing body of evidence that supports cognitive involvement in visual perception which has left some researchers irresolute as to the most adequate explanation. For example, Long and Toppino (1981) initially proposed a very specific physiological account of perceptual alternations. They later proposed a model incorporating elements of both views (Long, Toppino & Kostenbauder, 1983). In a later study they reverted to an exclusively physiological explanation of these phenomena (Toppino & Long, 1987).

Subsequently Long (1988) has recognised that the paradigm used in his experiments did not in itself allow discrimination between the two approaches. The commonly adopted procedure is variously termed the selective adaptation paradigm by neurophysiological proponents or transfer-of -decrement by proponents of the cognitive approach. During the adaptation period an unambiguous inspection figure is viewed for a period of 2 to 3 minutes. This is followed by a test figure which shares certain features with the adapting figure.

One special case of perceptual alternations demonstrates the paradigm. A widely reported phenomenon of reversible figures is the reduction in dominance of a percept after exposure to an unambiguous stimulus (e.g., Carlson, 1953; Harris, 1980; Mapperson & Lovegrove, 1978, 1989; Virsu, 1975; Von Grunau, Wiggin & Reed, 1984). Typically, the percept which resembles the unambiguous stimulus is seen for a smaller portion of the subsequent viewing period. This 'adaptation effect', according to the neurophysiological model, is the result of the unambiguous stimulus exciting one set of cells which fatigue over prolonged viewing. Thus, during the subsequent viewing of an ambiguous stimulus, the unfatigued set of cells predominates until the fatigued set recovers. This neurophysiological account only valid when the features of the adapting and test stimuli are similar. Adaptation effects have nevertheless been reported with stimuli that were in many aspects not similar to the test stimulus.

When adaptation to a Necker cube occurs with an unambiguous stimulus the ambiguous test figure is seen for a much larger proportion of time to be in the opposite orientation to adaptation figure. Von Grunau et

al. (1984) conducted several experiments in which such results were reported.

Observers were adapted with either an unambiguous line drawing of a Necker cube or a pair of black/white photographs of a wooden box. These were positioned and illuminated in such a way as to emphasise the two perspective orientations used previously. The test stimulus was an ambiguous outline drawing of a Necker cube. The effects of adaptation using photographs of boxes were similar that obtained for the outline drawings. They noted that "It is remarkable that the same adaptation effects occurred with stimuli that were in many basic aspects not similar to the test stimulus, that is in contrast, orientation and the presence of contours" (p.321). On the basis of this result they postulated the existence of channels for perspective orientation.

In another experiment Von Grunau et al. (1984) measured relative dominance changes when an adaptation stimulus, an unambiguous line drawing of a Necker cube, was placed in 0.5 degree steps above and below a centrally fixated test stimulus (a line drawing of an ambiguous Necker cube). At 1.5 degrees above and below the fixation point no significant change in relative dominance was reported. This was taken as evidence for channels for perspective orientation which are retinally localised, since the changes did not occur when the adapting stimulus was moved further than 1.5 degrees away from the test stimulus. Aside from being unsubstantiated by physiological evidence, it is difficult to conceive of the receptive field structure necessitated by this conclusion.

In the case of the adaptation effect, only two publications (Harris, 1980; Horlitz & O'Leary, 1993) suggest explanations other than neural fatigue. Harris (1980) proposed that: "one of the effects of adaptation may be to shift the criterion or rate of accumulation of evidence for a particular perspective interpretation" (pp. 455-456). More recently Horlitz and O'Leary (1993) suggested that a preference for novelty or a process of habituation may account for many of the phenomena of reversible figures including relative dominance. According to this position when an unambiguous stimulus is viewed the more novel alternative percept will be preferred in the ambiguous test stimulus. In the light of these suggestions Von Grunau et al.'s (1984) procedure requires examination.

In their experiments, it was taken for granted that a neurophysiological process was involved and hence that only the retinal position of the stimulus was important. Von Grunau et al. (1984) were unaware that changing the position of the adapting stimulus manipulated the retinal *and* the perceived location of the stimulus. Further it was only in one condition/position, when the adapting and test stimuli were both centrally located and fixated, that they occupied the same retinal and physical location. In this condition the largest adaptation effects were reported. As the adapting stimulus was moved away from the test stimulus the adaptation effect diminished.

Relative dominance may be due to habituation as Horlitz and O'Leary (1993) suggested. Habituation assumes that learning of the unambiguous percept occurs in the adaptation phase. When the ambiguous test stimulus is subsequently viewed a preference is created for the unlearned and more novel alternative percept. To account for the diminished adaptation effect as the stimulus was moved (Von Grunau et al., 1984), it may be that habituation or learning is dependent upon perceived location rather than retinal location.

Based on Von Grunau et al's (1984) findings and Horlitz and O'Leary's (1993) suggestions several hypotheses can be made. Firstly, if only retinal channels are involved in change in dominance then the magnitude of the change would be expected to be the same irrespective of whether the stimuli are in the same perceived positions. Von Grunau et al.'s (1984) interpretation can be evaluated if an eye movement is introduced in the adaptation/test paradigm between the adapting and test periods. It can then be ensured that the stimuli will fall on the same retinal area even though perceived locations differ. This condition in addition to one used by Von Grunau et al. (1984) in which the largest changes in relative dominance changes were reported, when the stimuli were retinally and spatially coincident, tests the first hypothesis in experiment 1. If this hypothesis is correct there will be no difference in the adaptation effect when physical location is changed in the eye movement condition.

If relative dominance changes can be attributed to factors under cognitive influence then the magnitude of the change will be significantly different when the perceived location of the stimuli is manipulated, irrespective of the retinal location. Therefore an eye movement between

the adapting and test period to a different location can ensure that the stimuli occupy different retinal locations when the perceived location remains the same. This condition in addition to one used by Von Grunau et al. (1984), in which no change in relative dominance was reported, when the stimuli were neither retinally nor spatially coincident, tests this hypothesis in experiment 2. It is expected that there will be a significant difference in the adaptation effect when the physical location is changed, even though the retinal location differs in both conditions.

Experiment 3 tests the hypothesis that if relative dominance changes can be accounted for by a cognitive process, such as habituation, then dishabituation may be demonstrated. This hypothesis predicts that learning (or habituation) of the adapted percept during adaptation will be interrupted when a novel stimulus is introduced, resulting in dishabituation. It is predicted that presentation of a novel stimulus will result in the recommencement of learning shown as a significant increase in the reporting of the adapted percept when the test stimulus is presented.

EXPERIMENT 1

Method

Subjects

Twenty first year Psychology students participated as part of course requirements.

Apparatus and Materials

Computer generated black and white line drawings of a Necker cube subtending a visual angle of 2 degrees, with an average luminance of 6 cd/m² and a contrast of 0.6 were presented in a Scientific Prototype tachistoscope. Following Brigner and Harris (1989), the front faces of the two alternative percepts of the standard ambiguous Necker cube (used as test stimuli) were outlined in either green or red to facilitate reporting. These percepts were either green and down, or red and up.

Of the two test stimuli, used for baseline and test measures, one was spatially coincident with the adapting stimulus and the other was 2 degrees below the adapting stimulus. The adapting stimulus, shown in Figure 2, was an unambiguous line drawing of a Necker cube,

corresponding to the 'down' percept, as used by Von Grunau et al. (1984). Viewing was binocular throughout. Observers indicated which percept was dominant by depressing either of two buttons on a response pad that activated electronic timers.

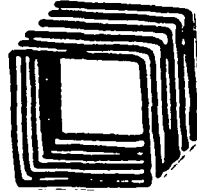


Figure 2. Unambiguous adapting stimulus corresponding to the 'down' percept of the Necker cube.

Design

This experiment was a within subjects repeated measures design. The independent variable was the perceived location of the stimuli. The dependent variable was the mean time in seconds that observers reported the 'down' percept. T tests were used to determine whether there was a significant difference in the change in 'down' percept when the perceived location of the stimulus was varied.

Procedure

Observers were familiarised with an ambiguous Necker cube. Whilst viewing the stimulus the two alternative percepts were described by the experimenter as being either a green box facing down and to the left or as a red box facing up and to the right. All subjects indicated that they could identify both Necker cube percepts.

Six 30 second baseline measures were taken on each of the two ambiguous test figures with observers maintaining fixation on a central spot. These figures required observers to fixate either 'low' or 'high'. The low figure was located 2 degrees below the high figure. In the experimental condition fixation was either in the centre of the adapting figure or 2 degrees below. Observers were informed that an eye movement would be required between the adapting and test figures.

Adaptation initially occurred for 150 seconds to the unambiguous cube. This was followed by a test period of 30 seconds and readaptation of 45 seconds. Test and readaptation occurred until a total of six 30 second measures were taken. The amount of 'down' percept was averaged for each subject for the two baseline and the two experimental conditions.

In condition 1 the adapting and test stimuli occupied the same retinal and perceived location. Fixation in the centre of the adapting stimulus was maintained when the test stimulus was presented. In condition 2 the adapting and test stimuli occupied the same retinal but different perceived locations. An eye movement was required to the fixation point in centre of the test stimulus which was 2 degrees below the adapting stimulus. These two conditions are shown in Figure 3.

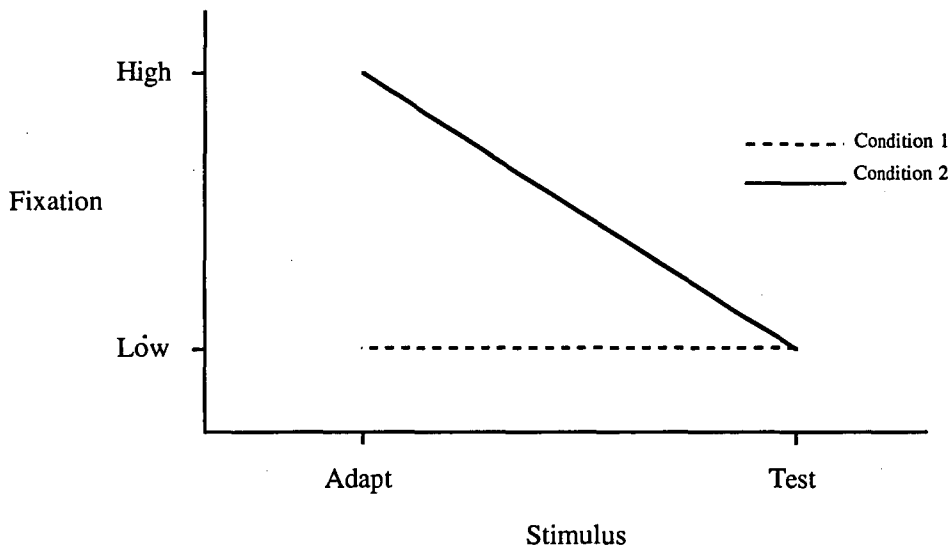


Figure 3 Eye movements required in Experiment 1.

Results and Discussion

The amount of 'down' percept was averaged for each subject for the two baseline and the two experimental conditions. For raw data see appendices A and B. The mean number of seconds that observers reported the 'down' percept in the baseline of condition 1 was 105.23, and the baseline of condition 2 was 108.97. The mean time in seconds observers reported the 'down' percept in condition 1 was 95.46 and in condition 2 was 106.2.

T tests showed a significant difference in the change in the 'down' percept when the perceived location was varied ($t=-4.9$, $p<0.01$, 2-tailed).

The reduction in 'down' percept from the averaged baseline of 107.09 seconds was calculated as a percentage and is shown in Figure 4.

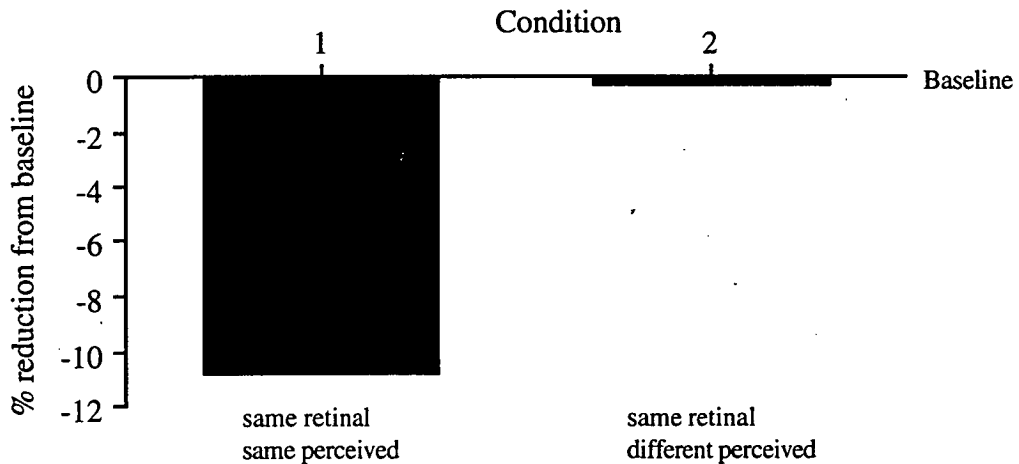


Figure 4. Reduction from averaged baseline calculated as a percentage.

The 10.8% reduction from baseline shown in condition 1, when the retinal and perceived positions were identical, was significant ($t=3.3$, $p<0.01$, 2-tailed). The 0.3% reduction in dominance when only the perceived location differed was non-significant ($t=0.9$, $p>0.05$, 2-tailed).

Contrary to von Grunau et al.'s (1984) findings of a retinally localised effect, condition 2 in which the stimuli were retinally coincident but spatially noncoincident, showed a minimal effect. Reduction in dominance therefore may be dependent upon the coincidence of perceived location irrespective of retinal location. This prediction was tested in experiment 2.

EXPERIMENT 2

If relative dominance can be attributed to factors under cognitive influence then it is predicted the magnitude of the change will be significantly different when the perceived location of the stimuli is manipulated when the retinal location of adaptation and test stimuli differ. An eye movement between the adapting and test period to a different location can ensure that the stimuli occupy different perceived locations whilst maintaining different retinal locations. This condition in addition to one used by Von Grunau et al (1984), in which no change in relative dominance was reported, when the stimuli were neither retinally nor spatially coincident, tests this hypothesis.

Method

Subjects

Twenty first year Psychology students participated as part of course requirements.

Apparatus and Materials

Apparatus and stimuli were the same as used in experiment 1.

Design

This experiment was a within subjects repeated measures design. The independent variable was the perceived location of the stimuli. The dependent variable was the mean time in seconds that observers reported the 'down' percept'. T tests were used to determine whether there was a significant difference in the change in the 'down' percept when the retinal location of the stimulus was varied.

Procedure

The procedure used in experiment 1 was followed. In condition 1 the adapting and test stimuli occupied different retinal but the same perceived location. Fixation was 2 degrees below the adapting stimulus. An eye movement was required to the centre of the test figure which was presented in the same location as the adapting stimulus. In condition 2 the adapting and test stimuli differed in retinal and perceived location. Fixation was 2 degrees below the adapting stimulus. Fixation was

maintained when the test figure was presented in a different location to the adapting stimulus. The two conditions are outlined in Figure 5.

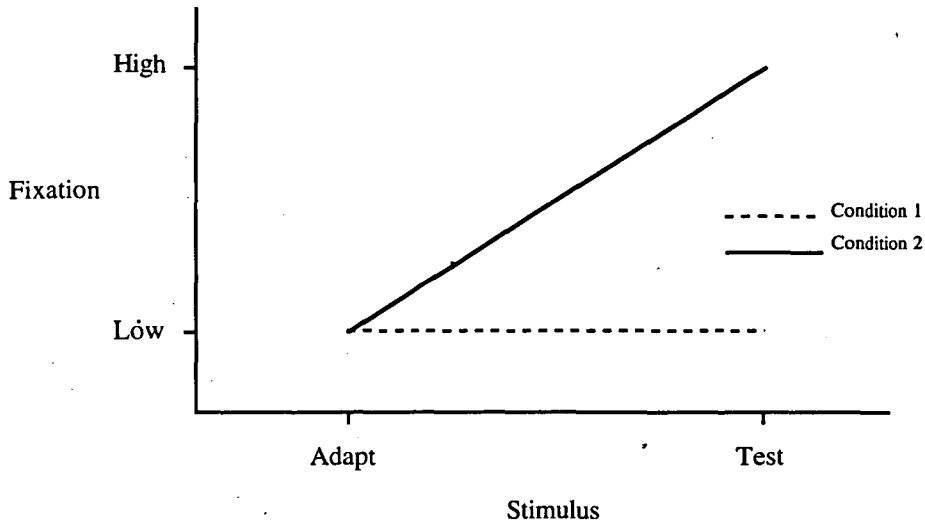


Figure 5. Eye movements required in Experiment 2.

Results and Discussion

The amount of 'down' percept was averaged for each subject for the two baseline and the two experimental conditions. For raw data see appendices C and D. The mean number of seconds that observers reported the 'down' percept in the baseline of condition 1 was 106.82, and in condition 2 was 107.89. The mean time in seconds that observers reported the 'down' percept in condition 1 was 93.31 and in condition 2 was 104.91.

T tests showed a significant difference in the change in the 'down' percept when the retinal location varied ($t=-3.2$, $p<0.01$, 2-tailed). The reduction from the averaged baseline of 107.35 was calculated as a percentage (see Figure 6).

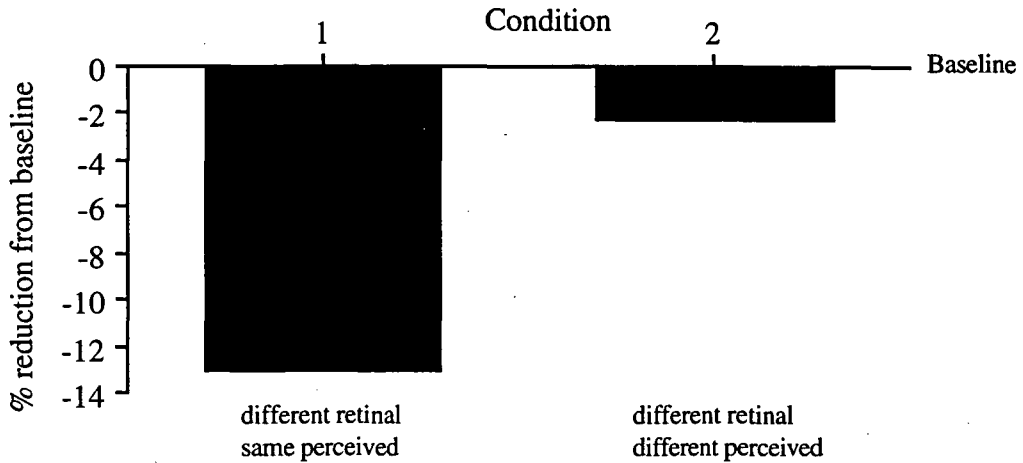


Figure 6 . Reduction from averaged baseline calculated as a percentage.

The 13.1% reduction from baseline shown in condition 1, when retinal positions differed and perceived positions were identical, was significant ($t=3.2$, $p<0.01$, 2-tailed). The 2.3% change when both the retinal and perceived location differed was non-significant ($t=0.8$, $p>0.05$, 2-tailed). This confirms Von Grunau's finding of little or no adaptation effect when the adapting and test stimulus occupied different in retinal and perceived location.

The finding of a large adaptation effect in condition 1 cannot be attributed to any known neurophysiological mechanisms or Von Grunau et al.'s (1984) hypothesised localised channels for perspective orientation. A third hypothesis based on an alternative explanation of relative dominance changes will be tested in experiment 3.

EXPERIMENT 3

Recently Horlitz and O'Leary (1993) proposed that the underlying processes of reversible figures may be attributed to habituation or learning. To test this suggestion it may be predicted that some well established and unique characteristics of habituation should be reproducible in an adaptation test paradigm.

One of the earliest attempts to distinguish the characteristics of habituation from neural fatigue was undertaken by Thomson and Spencer

(1966). They noted that the most widely reported phenomenon that distinguishes the two is 'dishabituation' which occurs when an unexpected stimulus is presented to an observer. In an adaptation paradigm, according to habituation theory, any learning of the percept during adaptation will be interrupted when a novel stimulus is introduced resulting in 'dishabituation'. However on subsequent presentations, as the novel stimulus becomes more familiar, its capacity to 'dishabituate' lessens.

Adopting the adaptation test paradigm of experiments 1 and 2, it is hypothesised that the presentation of an unexpected stimulus (an electric bell) will show the dishabituation of the habituated response (i.e., an *increase* in the 'down' percept) on the first presentation. On the second presentation it is hypothesised that the bell will have little or no effect i.e., that there will be a recovery of the original habituated response.

To test these hypotheses and to exclude interpretations of the outcome of this experiment in terms of retinally localised mechanisms, condition 1 of experiment 2 will be used. In this condition the adapting and test stimuli differ in retinal location but occupy the same perceived location.

Method

Subjects

Twenty first year psychology students participated as part of course requirements.

Apparatus and Materials

The apparatus and stimuli as for experiment 2 condition 1 were used.

Design

This experiment was a within subjects repeated measures design. The independent variable was the presentation of a bell as either 'early' or 'late'. The bell was presented twice in each of the two sessions to assess whether the position of the bell influences the adaptation effect. The dependent variable was the mean time in seconds that observers reported the 'down' percept. Analysis of variance was used to determine whether

there was a significant difference in the change in the 'down' percept when the bell was sounded.

Procedure

The procedure for condition 1 of Experiment 2 was used except that a 2 second interstimulus (ISI) interval occurred between each adapting period and the following 30 second test period. Subjects participated in two sessions of 6 trials each commencing with six 30 second baseline measures. A bell was presented twice in each session.

In one session a bell was firstly presented in the ISI preceding the second trial and again in the ISI preceding the third trial. In the other session it was presented firstly in the ISI preceding the fifth trial and again in the ISI preceding the sixth trial. There was a 15 minute interval between sessions. The sessions were counterbalanced with half of the subjects receiving the bell early (on the second and third trials) and the other half receiving the bell late (on the fifth and sixth trials).

An 88dB electric bell (intensity measured with a Dawes sound level meter) was demonstrated twice before commencing the experiment and the observers were informed that it would sound on several occasions during the experiment.

Results and Discussion

The mean number of seconds for which observers reported the 'down' percept in the six baseline and the six test trials for each session was calculated. For raw data see appendices E1 and E2 for baseline and appendix F for test trials. The mean baseline in the bell early session was 13.817 seconds and 15.001 seconds in the bell late session.

An ANOVA and paired comparisons using Newman Keuls were carried out on the test means. An ANOVA showed a significant interaction between the sessions and trials [$F(5,95)=11.41$, $p<0.0000$] indicating a significant difference in the observers reporting of the 'down' percept when the bell was presented. This indicates that any learning (habituation) of the adapted percept was interrupted when the bell was introduced. This resulted in dishabituation and the recommencement of learning of both percepts when the ambiguous test stimulus was

presented. It can be concluded that the position of the bell did not affect the reporting of the 'down' percept as the presentation of the bell similarly effected reporting in both positions.

The percentage change from baseline in the non-bell trials was calculated. In the bell early session on trials 1, 4, 5 and 6 the percentage change was 6.8, 2.0, 2.5, and 2.0. respectively. In the bell late session on trials 1, 2, 3 and 4 the percentage change was 4.5, 3.1, 3.6, and 3.0 respectively. Post-hoc tests revealed that the 'down' percept on the first bell trial in each session was reported for significantly longer than on all other trials. No other differences were significant especially when the bell was presented for the second time i.e. between trials 2 and 3 in the bell early session and between trials 5 and 6 in the bell late session.

Figures 7 and 8 show the percentage change from baseline in the two sessions.

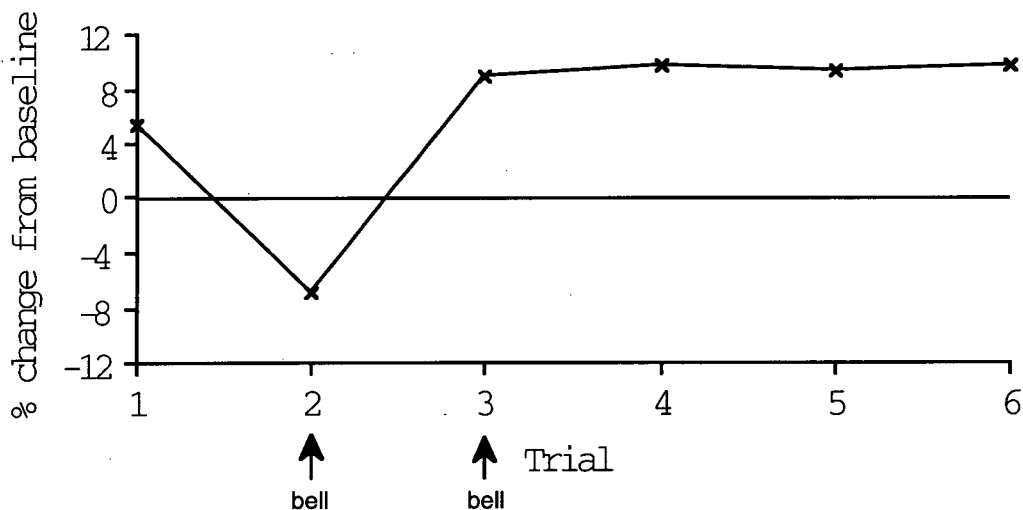


Figure 7. The percentage change from baseline, bell early.

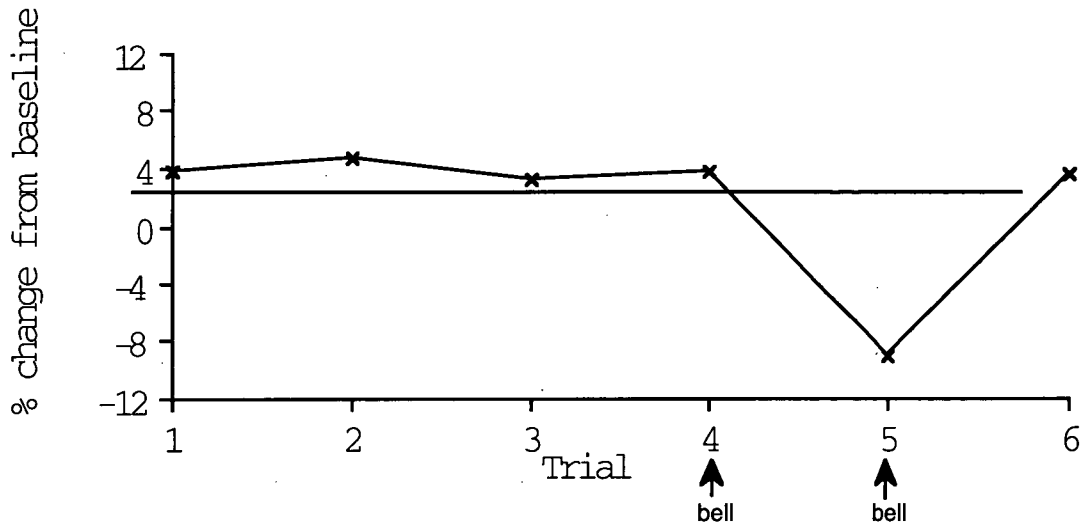


Figure 8. The percentage change from baseline, bell late.

As predicted the initial bell trial in each session caused a significant increase in the amount of 'down' percept. In bell early session, in the trial before the first presentation of the bell, observers reported the 'down' percept for 14.75 seconds. This increased to 17.51 seconds when the bell was presented. In the bell late session observers reported the 'down' percept for 15.45 seconds in the trial before the first presentation of the bell. This increased to 16.67 seconds when the bell was presented for the first time. The second presentation of the bell had little or no effect in both sessions with the amount of 'down' percept returning to the pre-bell level.

Summary Of Findings and General Discussion

Von Grunau et al. (1984) proposed that the reduction in dominance of a Necker cube percept after exposure to an unambiguous stimulus was due to retinally localised channels for perspective orientation. Experiment 1 in which the stimuli were retinally coincident but spatially non coincident produced negligible reduction in dominance. This finding refuted Von Grunau et al.'s (1984) interpretation of relative dominance changes and led to the proposal of an alternative explanation in cognitive terms.

It was therefore proposed that changes in relative dominance may be dependent upon the coincidence of perceived position irrespective of the retinal location. This proposition was tested in experiment 2.

Experiment 2 reported a large adaptation effect when the stimuli were spatially coincident but differed in retinal location. Data from this experiment provided evidence for a cognitive explanation of relative dominance. This agrees with some researchers who propose that reversible figure phenomena may be attributed to non-neural mechanisms (Reisberg & O'Shaughnessy, 1984; Girgus, Rock & Egatz, 1977; Rock & Mitchener, 1991). Recently Horlitz and O'Leary (1993) suggested that a preference for novelty may account for many of the phenomena of reversible figures including the duration of percepts, acceleration and relative dominance. Experiment 3 demonstrated several characteristics of habituation including dishabituation. This was shown when the sound of a bell presented after adaptation caused an increase in the reporting of the 'down' percept' when the test stimulus was presented. According to a neurophysiological explanation the bell should have had little if any effect on relative dominance.

Under certain conditions however relative dominance changes can be accounted for in terms of the fatiguing of neurophysiological mechanisms. For example when using crossed gratings in studies of monocular and binocular rivalry (Blake & Overton, 1979; Mapperson & Lovegrove, 1978, 1989) it has been established that there are cells selective for orientation that fatigue after prolonged exposure (Blakemore, Carpenter & Georgeson, 1970). These various explanations show that habituation is not the only process that can account for relative dominance as Horlitz and O'Leary (1993) suggested.

Horlitz and O'Leary (1993) additionally claimed that habituation in vision: "is not a process that is color-specific....or location-specific....".(p.680) and no reason is given for this caveat. Studies have however shown change in relative dominance to be colour contingent (e.g., Hochberg, 1950). Further, since location constancy is known to be acquired in infancy (see Keating & McKenzie, 1986), it is unclear why Horlitz and O'Leary (1993) would assume that visual effects would not habituate to location. Clearly experiment 2 demonstrated the location specificity of relative dominance changes.

Collectively these three experiments contrast the alternative explanations of the relative dominance changes that occur when using ambiguous figures that reverse in perspective. It can be concluded

therefore, that in this case a cognitive interpretation of relative dominance may be more appropriate.

Future Directions

Researchers from both major theoretical perspectives have noted a dilemma concerning the interpretation of findings in vision research, and that typically the adaptation paradigm has been used to provide support for both positions (Long, 1988; Porac, 1989). A modified strategy was successfully applied in this study in three experiments to independently manipulate the neurophysiological and cognitive components of changes in relative dominance. The methodology used in experiments 1 and 2 can be adapted to the investigation of other visual aftereffects for which the involvement of localised neurones has been claimed. Examples include the size aftereffect (Blakemore & Sutton, 1969), colour contingent aftereffects (Stromeyer, 1972 a, 1972 b.) and the motion aftereffect (Masland, 1969).

Using the experimental design that was subsequently adopted by Von Grunau et al. (1984), Masland (1969) investigated the location specificity of the motion aftereffect by positioning a moving adapting stimulus in 0.5 degree steps above and below a stationary test stimulus. The largest effects were found at 1.5 degrees above and below the test stimulus. Masland (1969) claimed the localised nature of the motion aftereffect without realising that the physical *and* the retinal location of the stimuli were varied.

The experimental approach of this paper can also be adapted to the investigation of characteristics of perceptual effects, other than position specificity e.g., size (Cohen, 1959), and orientation (Leguire, Blake & Sloane, 1982). In the case of perceived size, the manipulation of apparent distance cues may disentangle the components. Toppino and Long (1987) also appear to have overlooked habituation as a salient feature in the perception of rotating Necker cubes of different sizes. They found that acceleration rate diminished or was eliminated with changes of stimulus size.

McCollough (1965) reported that the coloured hues commonly observed in the McCollough effect desaturated when observers tilt their heads. Therefore similarly effective for the independent manipulation of cognitive and neurophysiological components in orientation specific phenomena, is the introduction of head tilt between the adapting and test phases. This manipulates only the retinal orientation of the stimulus. For direction of motion, eye tracking movements could be introduced in either the adapting or test phases so that the retinal images remains stationary whilst the physical object is moving.

These simple variations to the original experimental paradigm and the application of a modified paradigm, as this paper has demonstrated, introduces a means to contrast alternative hypotheses which may reveal that the accepted interpretations of many perceptual phenomena are at best only partially correct.

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APPENDICES

APPENDIX A
Baseline data for experiment 1.

SUBJECT NUMBER	EXPERIMENT 1 BASELINE HIGH	EXPERIMENT 1 BASELINE LOW
1	119.0	125.8
2	107.7	109.5
3	100.8	98.6
4	103.8	113.1
5	119.5	121.4
6	124.6	116.6
7	96.2	93.7
8	98.7	99.4
9	97.0	113.0
10	90.8	91.9
11	107.0	120.6
12	98.9	101.6
13	100.6	102.4
14	102.8	112.2
15	117.1	105.8
16	101.2	113.3
17	101.9	111.3
18	122.6	115.3
19	109.9	118.8
20	84.5	95.0

Dependent variable is the time in seconds that observers reported the 'down' percept.

APPENDIX B
Experimental data for experiment 1.

SUBJECT NUMBER	EXPERIMENT 1 CONDITION 1	EXPERIMENT 1 CONDITION 2
1	80.2	102.6
2	95.2	83.3
3	77.4	102.4
4	99.0	111.7
5	116.5	126.5
6	89.1	117.4
7	84.2	95.3
8	97.9	109.4
9	96.8	106.0
10	87.5	105.7
11	94.5	91.7
12	92.7	99.6
13	110.4	118.7
14	86.3	108.7
15	111.1	117.3
16	84.2	96.6
17	92.8	102.0
18	99.8	114.5
19	119.3	117.7
20	94.3	96.8

Dependent variable is the time in seconds that observers reported the 'down' percept.

APPENDIX C
Baseline data for experiment 2.

SUBJECT NUMBER	EXPERIMENT 2 BASELINE HIGH	EXPERIMENT 2 BASELINE LOW
1	120.0119.0	125.2
2	104.6	109.8
3	120.2	119.5
4	107.8	101.7
5	96.4	108.4
6	113.8	109.5
7	108.1	115.2
8	118.4	125.5
9	101.1	116.1
10	119.5	126.8
11	102.1	97.2
12	108.0	110.9
13	107.3	99.2
14	105.2	106.1
15	111.7	107.1
16	101.0	111.9
17	86.2	92.0
18	97.7	83.4
19	118.6	105.5
20	89.1	86.8

Dependent variable is the time in seconds that observers reported the 'down' percept.

APPENDIX D
Experimental data for experiment 2.

SUBJECT NUMBER	EXPERIMENT 2 CONDITION 1	EXPERIMENT 2 CONDITION 2
1	140.2	150.6
2	87.4	99.6
3	119.2	121.2
4	83.9	86.2
5	86.0	109.4
6	102.7	108.8
7	112.7	107.8
8	77.0	132.3
9	103.8	115.9
10	106.7	117.7
11	90.6	105.0
12	84.7	83.9
13	97.0	95.6
14	87.7	92.8
15	91.3	96.8
16	80.6	84.6
17	77.0	132.3
18	99.4	99.8
19	46.7	55.8
20	91.6	102.1

Dependent variable is the time in seconds that observers reported the 'down' percept.

APPENDIX E1
Baseline data, bell early.

SUBJECT NUMBER	BASELINE BELL EARLY
1	87.3
2	84.2
3	75.4
4	100.4
5	103.6
6	88.1
7	86.5
8	120.0
9	106.5
10	106.7
11	118.5
12	95.0
13	86.3
14	77.1
15	95.0
16	64.6
17	111.2
18	92.8
19	98.9
20	75.8

Dependent variable is the time in seconds that observers reported the 'down' percept.

APPENDIX E2
Baseline data, bell late.

SUBJECT NUMBER	BASELINE BELL LATE
1	100.5
2	97.6
3	75.0
4	104.1
5	109.8
6	91.4
7	94.2
8	122.2
9	93.2
10	98.9
11	122.8
12	111.8
13	72.9
14	89.7
15	104.4
16	59.2
17	114.9
18	99.0
19	102.2
20	83.4

Dependent variable is the time in seconds that observers reported the 'down' percept.

APPENDIX F
Experimental data for experiment 3.

Trials 1 to 6 in 2 sessions, bell early and bell late.

13.8	20.2	15.0	13.9	13.2	13.0	11.9	11.4	13.3	12.5	15.5	12.0
14.1	16.4	14.2	12.6	12.8	13.0	15.5	15.7	15.6	14.6	17.2	15.8
15.7	16.4	15.4	15.9	14.2	16.3	16.6	14.4	14.2	14.4	15.1	12.1
15.2	17.4	16.4	15.5	15.7	15.7	17.2	16.3	17.6	17.7	18.5	17.8
11.8	15.5	11.4	11.0	11.5	11.6	17.1	17.6	15.5	17.7	18.5	17.0
15.4	16.4	14.5	14.5	14.7	14.8	15.1	15.2	15.2	15.2	18.4	15.4
15.6	17.9	15.6	15.1	15.6	15.1	12.3	14.0	12.6	12.0	16.2	11.8
18.5	20.1	17.0	17.4	17.6	17.7	19.9	19.0	20.0	21.4	25.6	22.7
19.0	15.6	10.2	14.1	20.1	13.8	14.2	15.9	18.8	14.9	11.6	16.3
15.8	17.1	15.7	13.9	15.0	13.4	15.8	15.6	15.4	15.1	23.1	15.6
19.5	20.6	18.0	21.0	16.8	16.8	24.2	24.7	25.6	24.5	28.3	25.8
15.2	16.7	15.7	15.0	15.8	15.4	16.0	16.1	15.4	16.7	17.4	19.5
5.6	7.7	7.0	5.9	4.5	7.4	12.8	10.5	9.3	9.8	15.4	10.9
12.0	18.4	13.2	12.1	11.3	11.2	11.1	9.6	11.5	10.7	13.7	10.2
15.9	18.2	16.0	14.4	14.6	14.8	17.3	17.5	17.4	16.4	19.0	17.6
13.9	14.6	13.6	13.7	12.4	14.5	14.8	12.6	12.4	12.6	13.3	10.3
17.0	19.2	18.2	17.3	17.5	17.5	19.0	18.1	19.4	19.5	20.3	19.6
10.0	13.7	9.6	9.2	9.7	9.8	15.3	15.8	13.8	16.0	16.7	15.2
17.2	18.2	16.3	16.3	16.5	16.6	16.9	17.0	17.0	17.0	20.2	17.2
13.8	16.1	13.8	13.3	13.8	13.3	10.5	12.2	10.8	10.2	14.4	10.0