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THE PRIMING OF VISUAL FEATURE INTEGRATION AND ILLUSORY CONJUNCTIONS

GRAHAM DEREK SMITH

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SMITH, GRAHAM DEREK

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GRAHAM DEREK SMITH

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Graham Derek Smith

Whether non-spatial previewing can interact with the process of integrating visual features and thereby affect the formation of illusory conjunctions was studied. A series of ten experiments were undertaken that employed methods borrowed from the illusory conjunction and visual previewing paradigms. Participants reported the identities of two briefly presented target objects. Preview stimuli were presented prior to the to-be-reported target stimuli. The preview objects and target objects were colour-filled geometric shapes.

The effects of two types of non-spatial previewing were investigated; feature previewing and conjunction previewing. In feature previewing the preview stimuli were congruent or incongruent with one of the target stimuli on a single stimulus dimension. The results suggest that feature previewing does not affect the production of illusory conjunctions. In conjunction previewing the preview display contains an object composed of two features that also appear in the subsequent target display. A *congruent* conjunction preview display contains an object that is identical to one of the target objects. An *incongruent* conjunction preview display contains an object composed of a colour and a shape that appear in different target objects. The results suggest that incongruent conjunction previews cause more illusory conjunctions than congruent conjunction previews do. Conjunction previews appear to priming of the process of visual feature integration. Alternative explanations of the results were ruled out by subsequent experiments.

The finding of the conjunction preview effect has implications for the current theories of visual feature integration and illusory conjunctions; e.g., feature integration theory (Treisman 1990; Treisman & Gelade) and location uncertainty theory (Ashby, Prinzmetal, Ivry & Maddox, 1996; Prinzmetal & Keysar, 1989).

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AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award.

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Signature

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Date

CHAPTER 1: VISUAL FEATURE INTEGRATION AND VISUAL PREVIEWING

1.1 Overview of Thesis

This thesis is concerned with the process of visual feature integration[1]. *Feature integration theory* (Treisman, 1990; Treisman & Gelade, 1980) and *location uncertainty theory* (Ashby et al., 1996; Prinzmetal & Keysar, 1989) are the foremost theoretical accounts of visual integration. Both of these theories predict the existence of *illusory conjunctions*. An illusory conjunction is the non-veridical perception of a conjunction of features that actually belong to separate objects (Treisman & Schmidt, 1982). A series of experiments was undertaken to investigate the effects of non-spatial visual previewing upon the generation of illusory conjunctions. The results of these experiments suggest that previewing can affect the number of illusory conjunctions that occur. The implications of the experimental findings for theories of visual integration are explored.

Chapter 1 reviews literature regarding visual integration, illusory conjunctions and visual previewing. Section 1.2 introduces visual feature integration and object tokens, and discusses their functions within the visual system. This section also describes the phenomenon of illusory conjunctions and reviews the experimental evidence supporting their existence. Section 1.3 introduces Treisman's (1990; Treisman & Gelade, 1980) feature identification theory, Prinzmetal's (Ashby et al., 1996; Prinzmetal & Keysar, 1989) location uncertainty theory and Green's (1991) recurrent architecture network model. Section 1.4 reviews the implications for these theories of the experimental findings of effects upon illusory conjunctions of attention, inter-item distance and perceptual organization. Section 1.5 introduces visual previewing and suggests that this may also affect the formation of illusory conjunctions. The main conclusions of the chapter are summarised in Section 1.6.

Chapter 2 describes three experiments that investigated whether previewing of a visual

[1] In this thesis the terms *visual feature integration* and *visual integration* denote the hypothetical perceptual process that bring together the properties of a visual object to produce an internal representation of the object.

feature can facilitate the subsequent integration of that feature. In each experiment a single feature was previewed prior to the presentation of a two-object probe display. In Experiment 1 more conjunction errors (an indirect measure of illusory conjunctions) occurred when the previewed feature appeared in one of the probe objects than when it did not. However, it appears that this effect was caused by participants using a strategy rather than by the priming of visual integration. This conclusion was supported by the findings of Experiments 2 and 3, in which the strategy was not available and no preview effects were found. It was concluded that previewing a single task-relevant feature does not facilitate visual integration.

The three experiments described in Chapter 3 were conducted to determine whether previewing a conjunction of features can affect the likelihood that illusory conjunctions will occur. In these experiments, the preview object consisted of two features that were also present in the probe display. A *congruent conjunction preview* was a preview object composed of two features that were also in one of the probe objects. An *incongruent conjunction preview* was a preview object whose features were in separate probe objects. In Experiment 4, more illusory conjunctions were found with incongruent conjunction previews than with congruent conjunction previews. The other experiments reported in this chapter were undertaken to determine whether this preview effect was mediated by bottom-up or top-down priming processes (Posner & Snyder, 1975a, b). In Experiment 5 there was some evidence a 1.5 sec delay between the offset of the preview display and the onset of the probe display reduces the magnitude of the conjunction preview effect. In Experiment 6, predictive validity (i.e., the ratio of congruent to incongruent preview trials) was manipulated to affect the participant's expectation of the probe display. A significant effect of conjunction previewing was found only in the high predictive validity condition[2]. It was concluded that conjunction previewing can have bottom-up and top-down priming effects upon the generation of illusory conjunctions. The implications of the conjunction preview effect for theories of visual integration are discussed.

[2] In this condition there were three congruent conjunction preview trials to each incongruent conjunction preview trial.

Chapter 4 describes two experiments in which cost-benefit analysis was performed to investigate the effect of conjunction previewing upon conjunction error scores. In both experiments, conjunction previewing was compared to two control conditions in a cost-benefit analysis. In all conditions the preview display contained two preview objects. These experiments also investigated whether it is necessary for the task-relevant features (i.e., features that are properties of the probe objects) in conjunction preview displays to be properties of a single object for the conjunction preview effect to occur. In Experiment 7 the cost-plus-benefit preview effect upon conjunction error scores was not significant, however, the locations of the preview items may have caused the preview effect to be absent. In Experiment 8, the preview objects were located centrally and did not indicate the locations of the forthcoming probe objects. Again, there was no evidence of a cost-plus-benefit preview effect upon conjunction error scores.

Chapter 5 describes two experiments that were conducted to investigate whether the conjunction preview effect might be caused by priming of a lexical representation of the stimuli, by features migrating from the preview display or by an object guessing strategy. Experiment 9 investigated the effects of reversing the presentation order of the preview and target stimulus displays on the whole report of the target objects. It was reasoned that if the priming of feature integration hypothesis were true then presenting the target display before the "preview" display would interfere with the priming of feature integration. It was also reasoned that if the object guessing strategy or temporal illusory conjunction accounts of the conjunction preview effect were true then the reversed order of presentation of the target and "preview" displays would still result in a conjunction preview effect on conjunctions errors. There was evidence that intrusions from the post-target display take place. Experiment 10 investigated the effects of lexical previewing upon conjunction errors during the whole-report of two target objects. The lexical previews described the conjunction of a colour and a shape. It was reasoned that if either bottom-up priming or temporal illusory conjunctions mediate the effect of conjunction previewing, then there would not be a lexical conjunction preview effect. It was also thought that if top-down priming or the object guessing strategy cause the effect of conjunction previewing then a lexical conjunction preview effect would also occur. It was found that lexical congruent conjunction previews caused fewer conjunction errors than lexical incongruent conjunction previews.

Chapter 6 summarises the main experimental findings of this thesis and their implications for theories of visual feature integration. Suggestions and recommendations for future work are made.

1.2 Visual Integration and Object Tokens

Visual feature integration and *visual segmentation* are two of many related terms[3] used to describe a visual process that is thought to divide the visual scene into meaningful regions, in particular those regions that correspond to objects. This process is presumed to involve the extraction of information contained in low-level representations of the visual input in which objects are only implicitly encoded. The output representation of the process explicitly encodes this object information. In other words visual segmentation is a perceptual process the function of which is to generate a representation of the visual scene that explicitly describes which features belong to which objects. It has been suggested that the function of visual integration is to generate an *object token* for each object in view at any given time (Fox, 1977; Kahneman & Treisman, 1984; Marr, 1976). An object token is a representational unit that encodes the current available information regarding the visual properties of a single object (Kahneman & Treisman, 1984; Treisman, 1990). Object tokens are distinguished from *object types* that are "representations stored in a long term recognition network, which are used in identifying and classifying objects." (Kahneman, Treisman & Gibbs, 1992, p. 176).

Object tokens are thought to serve three functions for the visual system (Kahneman & Treisman, 1984). First, they are believed to be necessary to account for the *phenomenological* experience that the visual scene is divided into objects. Second, they are thought to mediate the spatiotemporal continuity of visual objects. Third, they are considered to represent information in the form that is required for visual object recognition. These functions of object token representation are discussed in more detail below.

1.2.1 The Functions of Object Tokens

It has often been suggested that the visual world is experienced as being composed of

3 Other synonymous terms include *unit formation* (Wertheimer, 1974), *perceptual grouping* (Hummel & Biederman, 1992), *image parsing* (Hummel & Biederman, op. cit.), *feature integration* (Treisman & Gelade, 1980), *feature linking* (Grossberg & Somers, 1991), *feature grouping* (Mozer, Zemel & Behrmann, 1991) and *binding* (Crick, 1994; Treisman, 1995, 1996).

many independent objects (e.g., Rock & Palmer, 1990; Spoehr & Lehmkuhle, 1982; Wertheimer, 1974), each of which possesses phenomenological *integrity*, i.e., an object's parts have an apparent affinity for each other. Spoehr & Lehmkuhle (1982) were describing this concept when they wrote;

> When you look at a tree, what do you see? You might describe a tree as composed of a trunk, branches, leaves, and perhaps blossoms or fruit. Each of these parts is a pattern that you would easily recognize by itself in the absence of the other parts. Yet when you look at an entire tree you are not immediately conscious of each individual part, rather you are aware of the overall object. (p. 63)

It is difficult for us to imagine what the experience of visual objects would be like without phenomenological integrity. Perhaps the visual world might appear, as James (1890) described, as "one blooming, buzzing confusion.... potentially resolvable, and demanding to be resolved, but not yet actually resolved into parts." (p. 29).

However, the integrity of a visual object is not a property of the stimulus array. The visual world does not come to us, like a "bar of chocolate", grouped into chunks and readily segmented (Wertheimer, 1974). A scene is conveyed by the array of light that is reflected by physical objects (Gibson, 1950; 1979). Wertheimer (1974) drew an analogy between this sensory input and a mosaic;

> In a mosaic, one piece of glass doesn't say to the observer, "I belong with this one that's just above me and to the left, but do not belong to the one that's below me and to the right." Nor do various parts of the mosaic tell the observer that they belong together to form a unit which happens to look like a horse, while other bits of glass are to be organized together so as to be perceived as a sword. In the same way, a nerve impulse along one fibre, activated perhaps by the reflection from one brilliant piece of glass which the artist intended as part of the horse has no way of conveying to the observer that its message should be sorted out as belonging together with particular other messages in the optic nerve at the time, and not with still a different set. (p. 76)

Given that the integrity of phenomenal objects is not a property of the mosaic sensory input, the Gestaltists concluded that the division of the visual scene into objects must be undertaken by the visual system (Rock & Palmer, 1990).

It is widely assumed that the phenomenological existence of visual objects is a reflection of the functional properties of visual information processing (e.g., Kahneman & Treisman, 1984; Marr, 1982; Treisman, 1986, 1990). For us to experience seeing an object, information about that object must be internally represented in some way. Treisman (1992) assumes that;

> ...conscious awareness depends on the object files [i.e., object tokens] and on the information they contain. It depends, in other words, on representations that collect information about particular objects (p. 115).

Phenomenally, objects are extended in time as well as being extended in space. For example, a tree does not appear as a sequence of fleeting instantaneous trees, it is experienced as one tree existing over time. This apparent temporal unity occurs even though the attributes of a visual object can change. These attributes can change for several reasons. First, the retinal locations of an object's features can change due to motion of the viewer, the viewer's eyes or the object (Rayner & Pollatsek, 1983, 1992). Second, an object might rotate to reveal new surfaces and occlude previously visible parts. Finally, many objects are capable of changing shape or colour, (e.g., a tree in the wind or a chameleon at a disco). Therefore, a second functional role of object tokens is to internally represent the continued existence of visual objects (Kahneman & Treisman, 1984; Treisman, 1992; Kahneman et al., 1992; Henderson, 1994). In other words, an object token acts as a "temporary episodic representation within which successive states of an object are linked and integrated" (Kahneman et al., 1992, p. 175).

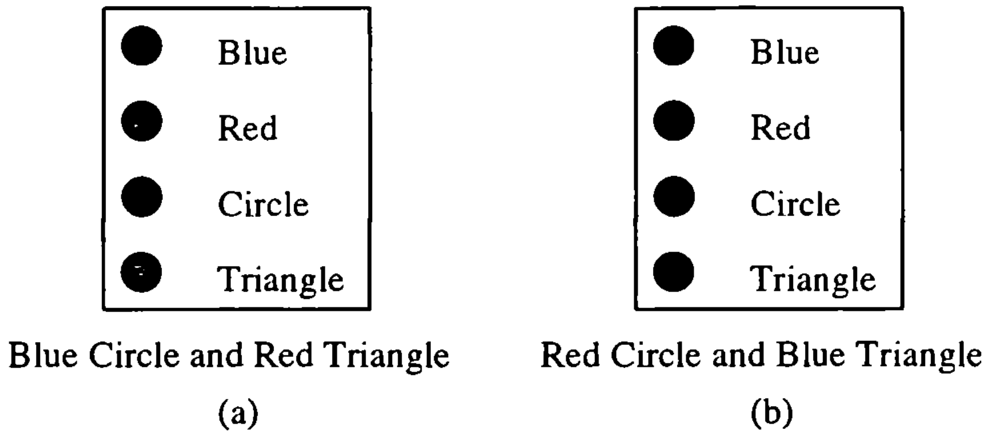

Figure 1.1. Superposition catastrophe of distributed representations. A filled black circle signifies an active unit.

A third role of object tokens is to separate the attributes of a given visual object from the attributes of the other objects in a scene, to permit the identification of the object. Visual object identification can be defined as the process that determines the membership of a object to a class of objects, on the basis of the object's visual properties alone[4]. It is widely accepted that the input representation of the object recognition system is in the form of a featural description of the visual scene (e.g., Green, 1991; Hubel & Wiesel, 1962; Kahneman & Treisman, 1984; Marr, 1982; Selfridge, 1959). But a feature module (Green, 1991) or display-board representation (Kahneman & Treisman, 1984) of a scene may not encode which features belong to which objects. Imagine an observer is presented with a scene comprised of a blue circle and a red triangle. The featural representation of a blue circle and a red triangle would be the same as the representation of a red circle and a blue triangle. This is a special case of the superposition catastrophe problem (von der Malsburg, 1986); i.e., the problem of how separate but coherent objects can be represented in a distributed representation[5].

Distributed representations are able to encode single objects but it is not obvious how multiple object tokens can be simultaneously represented in distributed form. Imagine a distributed representation of a simple two-object scene in which each object is composed of only two representational elements (see Figure 1.1). For ease of exposition these elements can be thought of as being a two colours (red or blue) and two geometric shapes (circle or triangle). To represent objects from this simple domain requires a unit for each of the features blue, red, circle and triangle. The object token for the blue circle would be the activation of the *blue* and *circle* units and the object token for the red triangle would be the

4 It is also possible to classify an object according to non-perceptual information. For instance, a schoolboy might be able to classify photographs of footballer's faces according to the player's team. However, the players of a team do not look alike. Presumably, the identification task would involve the recognition of the player and the retrieval of knowledge about which team they play for.

5 Van Gelder (1991) has identified several different senses of the term *distributed representation*, however, it is sufficient for our current purposes to use the standard definition. Hinton, McClelland & Rumelhart (1986) define this style of representation as one in which "each entity is represented by a pattern of activity distributed over many computing elements, and each computing element is involved in representing many different entities" (p. 77). Van Gelder (1991) observed that to avoid the obvious circularity of this definition one should read "distributed" as "spread over". Consequently, representation can be said to be distributed whenever information about a compound token is spread over parallel resources; for example, when different properties of a stimulus is handled by parallel visual pathways or when a stimulus is encoded by the activities of a set of feature detectors, neurons or units.

activation of the *red* and *triangle* units. However, simultaneous representation of these two object tokens results in an unordered set of elements. All four feature units would be active but there would be no way of determining whether this stood for a blue circle and a red triangle or a blue triangle and a red circle.

Several theorists (e.g., Crick & Koch, 1990; von der Malsburg, 1986) have concluded that to avoid superposition catastrophe what is needed is some means of grouping together those units or elements that belong to an assembly or compound token. The problem of how the activity of a distributed representation can encode such groups of features has been called the binding problem (e.g., Bechtel & Abrahamsen, 1990)[6].

Obviously, veridical object recognition relies upon receiving an input that encodes which features belong to which objects. For Kahneman & Treisman (1984), object tokens act as the input representation for the object identification process. They proposed that during identification, each of the currently held object tokens is compared with a set of stored object types. An object is identified when its token is 'matched' with an object type. The comparison process is undertaken by a "recognition network" that "specifies the critical attributes of cats, trees, bacon and eggs, one's grandmothers and all other familiar perceptual objects, allowing access to their names ..." (Treisman, 1992, p. 115).

1.2.2 Illusory Conjunctions

Object tokens need not always veridically encode the objects in a visual scene. It has been suggested, originally by Treisman, Sykes & Gelade (1977) and Wolford (1975), that under certain conditions the features abstracted from two or more objects might become

[6] Binding (Horn, Sagi & Usher, 1991; Lumer & Huberman, 1992; von der Malsburg, 1996; Treisman, 1995) and its related terms have been defined in many overlapping and sometimes contradictory ways. These related terms include *variable binding* (Barnden & Pollack, 1991; Hinton et al., 1986; Sejnowski, 1986; Smolensky, 1990), *dynamic binding* (Hummel & Biederman, 1992; Shastri & Ajjanagadde, 1993), *role-filler binding* (Barnden & Pollack, 1991) and *tag-assignment* (Strong & Whitehead, 1989). There is no single definition acceptable to all who use these terms. Some of the confusion surrounds whether these terms relate to the representation of compound objects in a distributed form (e.g., Hinton et al., 1986; Smolensky, 1987; Hummel & Biederman, 1992) or the processing of stimuli to determine what features belong together (e.g., Treisman, 1995; Horn et al., 1991). The first of these meanings is adopted in this thesis.

incorrectly conjoined, thereby causing a non-veridical object to be perceived and reported. These incorrect feature combinations are commonly known as *illusory conjunctions*. Since the landmark study by Treisman & Schmidt (1982), illusory conjunction research has become a major paradigm for investigating visual feature integration. This research can be considered to be a breakdown approach (Humphreys, Riddoch & Boucart, 1992) for the study of integration.

In a typical illusory conjunction experiment, participants are shown tachistoscopically presented displays that contain two or more visual objects. These objects have two or more dissociable attributes. The participants are required to make a report based on the perceived conjunction of the attributes of one or more of the objects. Indirect measures of the frequency of illusory conjunctions are obtained from participants' reports. A variety of visual tasks and stimuli have been employed thereby providing converging evidence for the existence of illusory conjunctions.

Four different types of experimental task have been used in illusory conjunction research; whole report tasks, partial report tasks, presence-absence detection tasks and same-different matching tasks. A whole report task (Sperling, 1960) was used in Treisman & Schmidt's (1982) Experiment 1. As an introduction to the illusory conjunction paradigm the method used in this experiment shall be described in some detail. On each trial of the experiment, a participant viewed a briefly displayed horizontal linear array of three coloured objects flanked by black digits. The objects' features were drawn from a pool of five letters (T, S, N, O and X) and a pool of five colours (blue, brown, green, pink and yellow). The digits were required for a primary task. Treisman & Schmidt thought the primary task could cause illusory conjunctions of the coloured letters because of its demands upon the participants' focal attention. The participants were instructed to report only those coloured letters that they were confident of having seen. These reports were categorized into correct reports and various types of error. A *conjunction error*[7] was the

[7] In fact Treisman & Schmidt (1982) used the terms *illusory conjunction* and *conjunction error* interchangeably. Furthermore, in using these terms they did not distinguish between two concepts that clearly require different terms. One concept is the non-veridical product of visual integration (i.e., a

report of a non-existent object whose features were actually in separate objects. A *feature error* was the report of a non-existent object possessing a feature that was not present in the display on that trial. For example, if the display had comprised a green *T*, a blue *S* and a yellow *X*, then reports of a green *T* or a blue *S* would have been classified as correct reports. Reports of a blue *T* or a green *X* would have been classified as conjunction errors and reports of a brown *T* or a blue *O* would have been classified as feature errors.

Treisman & Schmidt (op. cit.) found that participants frequently made conjunction errors. However, this finding in itself is does not establish the existence of illusory conjunctions. This is because conjunction errors are only an indirect measure of illusory conjunctions. It is possible for conjunction errors to be caused by other means. First, the abstraction of non-veridical features may cause conjunction errors (Treisman & Gelade, 1980). The features of briefly presented displays are occasionally identified incorrectly suggesting that feature abstraction is a data-limited process (Treisman & Gelade, 1980). Treisman & Schmidt (1982) called these incorrectly abstracted features *feature errors*, but in this thesis they are referred to as *feature misidentifications* or *illusory features* (by way of analogy to illusory conjunctions) to distinguish them from the type of incorrect report that Treisman & Schmidt also term *feature errors*. It is possible for an illusory feature to cause a conjunction error. In the previously mentioned example, where the display contains a green *T* and a blue *S* and a yellow *X*. the report of a blue *T* would have been classified as a conjunction error. The same report would be made if the participant incorrectly perceived the colour of the green *T* to be blue.

Second, conjunction errors may also occur if participants are forced to guess the identities of some features (Prinzmetal, 1981; Butler & Morrison, 1984). Guessing might be defined as the use of high-level cognitive processes to select between appropriate options. Participants may guess the identities of certain features to enable them to make a complete

hypothetical construct) and the other is a category of incorrect report (i.e., an operationally defined observable behaviour) (also see Gallant & Garner, 1988, on this point). In this thesis, to aid clarity, the term *illusory conjunction* refers to the hypothetical construct and the term *conjunction error* refers to the classification of observable behaviour.

report although the sensory impression of the feature was ambiguous or non-existent. The decision process is assumed to result in an approximately random selection from the alternatives, however, task knowledge may bias the process that determines the set of alternatives (e.g., Simon, 1971). Furthermore, the sensory impression need not be completely ambiguous rather it may suggest a subset of responses to select from. In illusory conjunction experiments, guessing might occur if a participant was unable to confidently determine the identity of a feature. In this event the participant might select at random a feature from the pool of features used in the experiment. Using the previously mentioned example again, where the display contains a green *T*, a blue *S* and a yellow *X*, a blue *T* would be classified as a conjunction error. The same report would be made if a participant was unable to determine the colour of the *T* and guessed that it was blue given the available options.

Given that illusory features and feature guesses may cause conjunction errors, it is necessary to determine whether the observed numbers of conjunction errors could be accounted for by illusory conjunctions or not. Treisman & Schmidt (1982) devised a method for estimating the number of conjunction errors that were the result of illusory features and feature guesses. This estimate is known as the *baseline* level of conjunction errors (Cohen & Ivry, 1989). A variety of similar methods have been used to estimate the true number of illusory conjunctions (e.g., Cohen & Ivry, 1989; Ashby et al.; 1996; Prinzmetal, Henderson & Ivry, 1995). Treisman & Schmidt's (1982) method treats the number of feature errors as an independent estimate of the number of illusory features and feature guesses. With a display containing the following items, a blue *T*, a yellow *S* and a pink *N*, an illusory feature or a guess on a particular item (e.g., the yellow *S*) could produce four possible feature error responses (i.e., yellow *X*, yellow *O*, green *S* and brown *S*) or four possible conjunction error responses (i.e., yellow *T*, yellow *N*, blue *S* and pink *S*). Treisman & Schmidt assumed that each of these outcomes was equally likely and therefore concluded that the baseline or expected number of conjunction errors caused by illusory features and guessing was equal to the observed number of feature errors. In their

Experiment 1, Treisman & Schmidt (1982) found that there were significantly more conjunction errors than this baseline, demonstrating that some of the conjunction errors were not attributable to illusory features or guessing. They concluded that illusory conjunction caused the extra conjunction errors. Eglin (1987) and Tsal, Meiran & Lavie (1994) have also found evidence of illusory conjunctions with whole-report tasks.

However, Treisman & Schmidt (1982) recognised that the above-baseline numbers of conjunction errors might have been caused by "failures in recall" (p. 139) rather than by illusory conjunctions (also see Tsal, 1989a, b; Tsal et al., 1994). Perhaps the object token representation of the visual display is veridical but subsequent processing involved in the production of the report causes conjunction errors to occur. In whole-report task experiments, the display is no longer present when the participant responds. Consequently, the report may be determined not by a visually coded representation, but perhaps verbally by some coded representation that may be prone to decay in the short-term. This account is supported by Virzi & Egeth's (1984) finding of many *propositional* conjunction errors; i.e., the report of the word *heavy* in brown ink when a display contains the word *brown* in red ink and the word *heavy* in green ink. The account is also indirectly supported by Stefurak & Boynton's (1986) finding that verbally encoded colour and shape identities are well remembered although their conjunctions are not.

However, evidence supporting the existence of illusory conjunctions over these alternative explanations has come from experiments using tasks other than whole-report. Many researchers have found evidence of illusory conjunctions using partial-report tasks (Ashby et al., 1996; Cohen & Ivry, 1989; Ivry & Prinzmetal, 1991; Prinzmetal et al., 1995; Prinzmetal & Keysar, 1989; Snyder, 1972; Treisman & Schmidt, 1982; Tsal et al., 1994). The memory demands of a partial report task is considerably less than those of a comparable whole report task (Sperling, 1960).

Researchers have also found evidence of illusory conjunctions when presence-absence detection tasks (Briand & Klein, 1987; Gallant & Garner, 1988; Kleiss & Lane, 1986; Lasaga & Hecht, 1991; Maddox et al., 1994; Prinzmetal, 1981; Prinzmetal, Presti & Posner, 1986) and successive and simultaneous matching tasks (Treisman & Schmidt, 1982, Experiment 2 & 3) are performed. The memory demands of these tasks are even less than those of comparable partial report tasks. Furthermore, the reports in these tasks do not require object identities to be verbally encoded. It has recently been found that illusory conjunctions can occur when stimuli are presented peripherally for 1.5 sec (Prinzmetal et al., 1995). The long exposure duration in this experiment would allow ample time for the stimuli to be rehearsed so that memory errors should be infrequent.

Evidence of illusory conjunctions has been found with many types of visual stimuli, suggesting the dissociability of colour and geometric shape features (Treisman & Schmidt, 1982; Tsal, et al., 1994), colour and letter shapes (Ashby et al., 1996; Cohen & Ivry, 1989; Eglin, 1987; Ivry & Prinzmetal, 1991; Prinzmetal et al., 1995; Prinzmetal, Hoffman & Vest, 1991; Prinzmetal & Keysar, 1989; Prinzmetal & Millis-Wright, 1984; Prinzmetal, Presti & Posner, 1986; Rapp, 1992; Keele et al., 1988; Seidenberg, 1987; Snyder, 1972), line segments and other simple shape features (e.g., Gallant & Garner, 1988; Lasaga & Hecht, 1991; Maddox et al., 1994; Prinzmetal, 1981; Treisman & Paterson, 1984; Wolford & Shum, 1980), and sub-letter features (Briand & Klein, 1987; Butler, Mewhort & Browse, 1991; Fang & Wu, 1989; Kleiss & Lane 1986; Prinzmetal Presti & Posner 1986). Parietal cortex damage can cause people to experience frequent illusory conjunctions even under ordinary viewing conditions (Cohen & Rafal, 1991; Freidman-Hill, Robertson, & Treisman, 1995).

In summary, the occurrence of above-baseline numbers of conjunction errors appears to be a highly robust phenomena. It is thought that this effect is caused by illusory conjunctions. Converging evidence for their existence comes from experiments involving different tasks and with many different types of stimuli. The results of these experiments favour the conclusion that illusory conjunctions are a perceptual phenomenon. and are not caused by non-veridical feature abstraction, the guessing of unknown features or verbally mediated memory errors.

1.3 Theories of Visual Integration and Illusory Conjunctions

Three current theories of visual integration have offered explanations of how illusory conjunctions occur: feature integration theory (FIT; Treisman & Gelade, 1980; Treisman, 1990), location uncertainty theory (LUT; Ashby et al., 1996; Prinzmetal & Keysar, 1989) and Green's (1991) recurrent architecture network (RAN) model. These theories agree that illusory conjunctions are caused during the process of visual integration. The theories disagree on what kind of process visual integration is, on how these processes cause illusory conjunctions and on how object tokens are encoded. FIT and LUT dominate illusory conjunction and visual integration research. The RAN model has received little attention in the literature.

A fourth theory, feature perturbation theory (Wolford, 1975; Wolford & Shum, 1980), has also sought to account for illusory conjunctions, (otherwise known as *feature perturbations*). However, this theory does not provide an account of the process of visual feature integration. The theory is similar to LUT in that both theories propose that illusory conjunctions are a consequence of locating visual features incorrectly. However, the mechanisms that cause features to be mislocated are different in the two theories. Wolford (1975) argued that features are mislocated because of the decay, over time, of an iconic representation of the visual scene. As such illusory conjunctions are not considered to be caused by non-veridical feature integration. LUT appears to have superseded feature perturbation theory. Feature perturbation theory will not be considered in detail in this thesis as it does not hold that illusory conjunctions are caused by visual feature integration.

The next three sections review FIT, LUT and the RAN model respectively. Particular regard is made to how illusory conjunctions are said to occur and how objects are represented within these different theories.

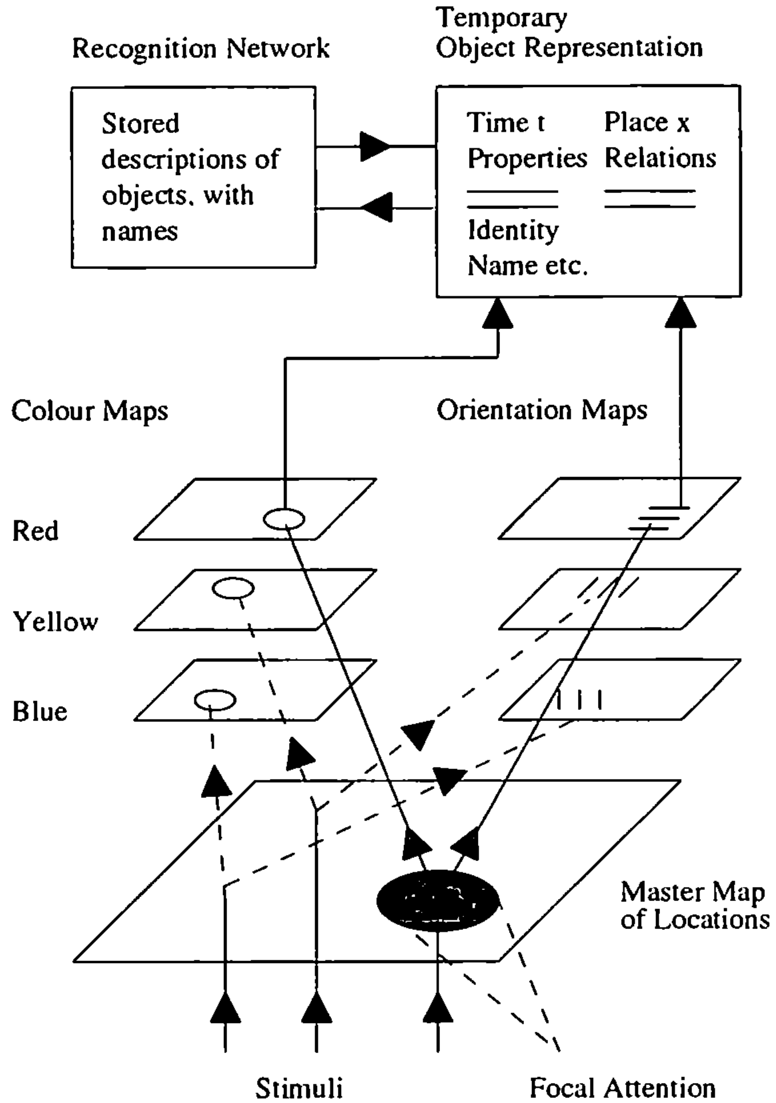

Figure 1.2. Feature Integration Theory (FIT; Treisman, 1988)[8]. Early vision extracts useful visual properties and encodes them in feature modules. The modules encode spatial relationships but this information is not available to subsequent processing. A serial attentional spotlight integrates the features of an object. Each object file encodes the attributes of a single visual object and functions as the input to the object recognition process.

8 Treisman (1986) has also presented a similar diagram in which the feature maps are at the lowest level and their connections feed upwards into the master map of locations.

1.3.1 Feature Integration Theory

The feature integration theory (FIT), of Anne Treisman and colleagues (Treisman et al., 1977; Treisman & Gelade, 1980; Treisman & Schmidt, 1982; Treisman, 1985; Treisman, 1986; Treisman, 1988; Treisman & Gormican, 1988; Treisman, 1990), is currently the foremost theoretical account of early visual processing (See Figure 1.2). The theory has been developed to account for the findings of the visual search (e.g., Treisman & Gelade, 1980, Duncan & Humphreys, 1989), texture segregation (e.g., Beck, 1982; Julesz, 1981) and illusory conjunction paradigms (e.g., Treisman & Schmidt, 1982, Ashby et al., 1996). Recently, the concept of object files (Kahneman & Treisman, 1984), which has been used to account for the recognition and reviewing of objects over time (Gordon & Irwin, 1996; Henderson, 1994; Henderson & Anes, 1994; Kahneman et al., 1992; Treisman, 1988, 1992, 1993), has been incorporated into the FIT framework (Treisman, 1990). Together, the FIT and object file accounts of visual perception have an impressive scope.

FIT contains the assumption that the processes of feature abstraction and feature integration occur in separate stages. Treisman & Gelade (1980) describe the two stages of early vision thus; "features are registered early, automatically, and in parallel across the visual field, while objects are identified separately and only at a later stage, which requires focused attention." (p. 98).

According to FIT, two representations provide the input for visual feature integration; a set of topographically organised feature maps or modules and the so-called *master map of locations* (Treisman, 1990). The individual feature maps register a particular visual attribute in every location in which it can occur. There are separate feature maps for the various colours, orientations, shape properties, object size, stereoscopic depth etc.. Although the feature maps explicitly encode the locations of features, this information is said to be unavailable to later processing (Treisman & Gelade, 1980). Only the pooled activity from each map is available, signalling which features are present but not where they are located. To quote Treisman (1986);

> "The visual system begins by coding a certain number of simple and useful properties in what can be considered a stack of maps. In the brain such maps ordinarily preserve the spatial relations of the visual world itself. Nevertheless, the spatial information they contain may not be directly available to the subsequent stages of visual processing. Instead the presence of each feature may be signalled without a specification of where it is." (p. 115).

The master map of locations is an array that depicts the locations of boundaries between areas containing different features, but does not encode the identities of these features. The master map was proposed to account for certain findings from the visual search paradigm that suggest that the search of a display is guided towards regions defined by discontinuities in a dimension. (e.g., Treisman & Gormican, 1988; Wolfe, Cave & Franzel, 1989). Treisman (1990) has said that the separation of the input representation into the feature maps and the master map of locations corresponds to the neurophysiological separation between the 'what' and 'where' visual pathways (Ungerleider & Mishkin, 1982; Mishkin, Ungerleider & Macko, 1983).

FIT holds that the primary method of visual integration involves the application of an attentional spotlight or window to the representation of the visual scene in the feature maps. To integrate a multiple object scene attention must be applied serially to the location of each object. This idea was first suggested by Neisser (1967). The attentional spotlight must filter or isolate the features of a single object from all the other features present. The selection of an object's features is mediated by the master map of locations and the links from it to the various feature maps (Treisman, 1992). Treisman (1992) said that; "Attention makes use of this master map, simultaneously selecting, by means of links to the separate feature maps, all the features that currently are present in a selected location." (p. 115).

The attentional spotlight proposed by FIT has a variable aperture (Treisman & Schmidt, 1982; Treisman, 1988). "Attention can be spread over a large or a small area; the narrower the focus, the more precisely located and accurately conjoined the features in that location will be." (Treisman, 1988, p. 203). During normal veridical integration the aperture must match the size (and contours, according to Tsal, 1989a) of each object. However, due to task demands, the attentional spotlight is sometimes diffuse and therefore the features of several different objects are accessed at once. When this occurs there is no way for the system to determine which features belong together. Therefore, there is a back-up integration process in which features are integrated into objects at random. This random conjunction process will cause some illusory conjunctions.

Treisman (Treisman & Gelade, 1980; Treisman & Schmidt, 1982) suggests that there are other back-up methods of feature integration that come into play when normal attentional integration does not operate. She argues that even when attention is focused upon one object of a multiple-object scene we are often aware of other objects in the scene and these objects must have been integrated in the absence of focal attention. Treisman & Schmidt (1982) proposed two pre-attentive integration processes to account for this observation. In one of these processes, the features that fall outside the attentional spotlight are randomly conjoined to form object tokens. This process will cause illusory conjunctions (Treisman & Schmidt, 1982). The other process integrates features that are commonly associated together (e.g., *orange* and *carrot-shaped*). However, Treisman (1988) reported having found no evidence that feature associations affected the reporting of correct or illusory conjunctions.

The early accounts of FIT were vague about the nature of the object token representation. It was said that "focal attention provides the 'glue' which integrates the initially separable features into unitary objects" (Treisman & Gelade, 1980, p. 98). Treisman (1990) later replaced the concept of 'perceptual glue' with the object file metaphor (Kahneman & Treisman, 1984). An object file is a "temporary episodic representation within which successive states of an object are linked and integrated" (Kahneman et al., 1992, p. 175), i.e., it is the container or "collecting box in which an object token is formed" (Treisman, 1992, p. 863) and maintained over time. Object files are analogous to the files in which the police gather the evidence and information pertaining to a particular case (Kahneman & Treisman, 1984). The contents of an object file correspond to the current information that the perceptual system has about a particular object. When a new object is attended to, a file is opened to deal with the information about it. The object file's contents are updated when new information becomes available. Object files are maintained only for as long as the objects they encode are in sight.

Object tokens are said to be addressed by the location of the object they represent rather than by any particular attribute contained in the file (Kahneman et al., 1992). Also, they are said to contain two types of information about an object. First, they identify the set of features that an object consists of. Treisman (1990; Kahneman & Treisman, 1984) acknowledged that it is not sufficient to represent an object by a collection of feature identities, it is also necessary to describe the structural relations between these features. For example, the letters T and L differ not in the features they comprise (a vertical bar and a horizontal bar) but in the arrangement of those features. Therefore, object files also contain a structural description of the spatial relations between features. FIT does not describe how the structural analysis of objects takes place, but Treisman (1990) has said that "the role of attention is to select the features that belong together to permit the structural analysis of their relations" (p. 461); i.e., the attentional spotlight performs a structural analysis of the input. The second kind of information contained in an object file is the identity of the object, if visual system has already determined this.

An object reviewing process constantly updates the contents of object files[9]. Therefore, object files are supposed to account for the temporal continuity of objects. It has been said that the "allocation of attention to the target item evokes an automatic process of reviewing, which selects one of the current object files, resulting in facilitation when the target and retrieved item match, interference when they do not" (Kahneman et al., 1992, p. 209). It is unclear whether the same attentional spotlight mechanism is considered to be involved in both feature integration and reviewing.

[9] "When the sensory situation changes, the information in the files is updated, yielding the perceptual experience of changing or moving objects. A file is kept open so long as its object is in view, and may be discarded shortly thereafter. The system bridges over the discontinuities produced by temporary occlusion, or by saccades, assigning current information to pre-existing files whenever possible." (Kahneman et al., 1992, p. 178)

In summary, the existence of illusory conjunctions is central to feature integration theory (Treisman & Gelade, 1980). The theory predicts that "when attention is diverted or overloaded, simple features should be 'free-floating' with respect to one another and should therefore at times be wrongly recombined to form 'illusory conjunctions'" (Treisman & Paterson, 1984, p. 14). The current properties of a visual object are recorded in object-centred co-ordinates in object files (Kahneman & Treisman, 1984). The utility of FIT can be determined by investigating the conditions under which illusory conjunctions occur. This evidence is reviewed later, but first let us turn our attention to location uncertainty theory.

1.3.2 Location Uncertainty Theory

The location uncertainty theory (LUT) of William Prinzmetal and his colleagues (Ashby et al., 1996; Maddox et al., 1994; Prinzmetal, 1981; Prinzmetal & Keysar, 1989) is the main rival account of illusory conjunctions to feature integration theory (FIT). Its authors' aim has been "to develop a general theory of feature integration rather than one that applies to only a few limited conditions." (Prinzmetal et al., 1995, p. 1374). LUT also encompasses an explanation of the neon-colours illusion (Prinzmetal & Keysar, 1989).

The "central" idea of LUT is that illusory conjunctions are caused by "poor spatial resolution or location information for features under certain conditions such as brief exposure, diverted attention, or peripheral presentation" (Prinzmetal & Keysar, 1989, p. 185). In other words, illusory conjunctions are caused by *location uncertainty*. The probability that two features in different stimulus objects will be incorrectly conjoined is a function of the location uncertainty regarding those features. LUT predicts more conjunction errors when location uncertainty is high than when it is low (Ashby et al., 1996; Prinzmetal & Keysar, 1989; Maddox et al., 1994)

Prinzmetal & Keysar (1989) proposed a neural mechanism to account for location uncertainty. The detection and localization of features is thought to be mediated by neurons dedicated to signal whenever a particular visual property appears within its receptive field. The response of single neuron indicates that the feature is located within its receptive field but not whereabouts within the field; i.e., the presence of a feature is indicated but its location is uncertain. The exact location of a feature is coded by the combined activation of several neurons. LUT envisages that the set of detectors dedicated to a particular feature is assumed to have overlapping receptive fields (Hubel & Wiesel, 1962 & 1968). A stimulus attribute will activate only those detectors whose receptive fields encompass the location of the property. Therefore, the feature is known to be located where the receptive fields of the active detectors intersect. Under normal foveal viewing conditions this area of intersection is assumed to be negligible and therefore the exact location of the feature is indicated. However, under certain conditions the area of intersection will be large and the exact location of the feature within that area will be unknown. The larger the area of receptive field overlap, the more spatial ambiguity exists. Therefore, described at the neural level, the uncertainty regarding the location of a feature corresponds to the size of the area of intersection among the receptive fields of neurons activated by the feature.

LUT's authors have identified two means by which the area of receptive field intersection can be adjusted and consequently affect the frequency of illusory conjunctions. First, they assume that the area of intersection is a function of the number of neurons activated by a stimulus. The fewer active neurons there are, the larger the area of intersection will be. One factor thought to control the number of neurons activated by a stimulus is function of the exposure duration of that stimulus. A brief presentation may not provide sufficient information to permit the activation of all the relevant feature detectors. Therefore, LUT predicts that the frequency of illusory conjunctions is a function of stimulus exposure.

Second, the area of receptive field intersection is assumed to be a function of receptive field size. The larger the receptive fields, the larger the area of their intersection. It is widely acknowledged that receptive field size increases with retinal eccentricity (e.g., Hubel & Wiesel, 1962 & 1968). Therefore, LUT predicts that the frequency of illusory conjunctions is a function of retinal eccentricity of the stimulus. This prediction is supported by several studies (Klein & Levi, 1987; Levi & Klein, 1989; Wolford & Shum, 1980).

LUT, unlike FIT, does not envisage a special role for attention during feature integration. The theory holds that attention merely facilitates the processing of all visual information. However, attention manipulations are expected to affect the rate of illusory conjunctions indirectly by affecting location uncertainty (Prinzmetal & Keysar, 1989)[10]. Prinzmetal & Keysar proposed that focused attention can decrease location uncertainty either by causing more neurons to be activated or by modifying the size of their receptive fields (Moran & Desimone, 1985).

So how does location uncertainty cause illusory conjunctions? LUT holds that spatial ambiguity forces the perceptual system to make a "best guess" of a feature's location (Prinzmetal & Keysar, 1989, p. 811). These spatial guesses will often result in the perceived location of a feature being displaced from its actual location. The non-veridical localization of features will sometimes cause illusory conjunctions. Imagine a scene of two items, each comprised of a colour and a shape feature. Under certain extreme presentation conditions, location uncertainty will cause the four features to be located incorrectly. The theory assumes that the perceptual system adopts a decision rule by which displaced features are conjoined. It is proposed that the perceptual system selects the colour feature that appears closest to a given shape feature. Therefore, an illusory conjunction occurs when the shape feature of one item appears closer to the colour feature of the other item than to its own colour. Similarly, the displacement of form features can cause illusory conjunctions that result in non-veridical form perception (e.g., Maddox et al., 1994; Prinzmetal, 1981; Wolford & Shum, 1980).

10 "Diverting attention can increase the amount of illusory conjunctions by limiting location information (i.e. lowering spatial resolution).... However, the effect of attention is not specific to location information, but it should affect all aspects of stimulus information. Hence attention should affect the number of feature errors, as well as the number of conjunction errors." (Prinzmetal & Keysar, 1989, p.168)

LUT predicts that the probability that two features in different stimulus objects will form an illusory conjunction on a given stimulus presentation is a function of the distance between the two objects (Ashby et al., 1996). The closer two features are, the more likely that spatial ambiguity will cause them to appear at the same location. Therefore, LUT predicts more conjunction errors between closely located items than distantly located items. This prediction is supported by the finding that inter-item distance controls the probability of conjunction errors (e.g., Chastain, 1982; Cohen & Ivry, 1989; Gallant & Garner, 1988; Ivry & Prinzmetal, 1991; Keele et al., 1988; Prinzmetal & Keysar, 1989; Prinzmetal & Millis-Wright, 1984; Prinzmetal, Treiman & Rho, 1986; Snyder, 1972; Wolford & Shum, 1980). For example, Wolford & Shum (1980) found that tick marks in squares occasionally migrate to adjacent squares.

LUT also assumes that visual integration is affected by the perceptual organisation of the visual scene, because "features are not usually free floating in normal vision but are constrained by a rich assortment of organizational factors" (Prinzmetal & Keysar, 1989, p.168). Prinzmetal & Keysar (1989) proposed that perceptual grouping affects the perceived location of features (Coren & Girus, 1980) as coded by the spatiotopic feature maps; i.e., the dimensions of the psychological space in which features are mapped are distorted by the organization of the scene. Several studies have suggested that illusory conjunctions are more likely within a perceptual group than between perceptual groups (Ivry & Prinzmetal, 1991; Prinzmetal, 1981; Prinzmetal & Keysar, 1989).

It is not entirely clear what constitutes an object token in the LUT framework. There are two possible readings. One reading is that topographically organized feature maps are used to encode objects. If so, the activity of units in separate maps encodes features from the same object when the receptive fields of these units are the same. If this reading is correct then the spatial guessing process that causes illusory conjunctions must determine which units in the features maps become active. However, a second reading is that feature conjunctions are not encoded by topographic feature maps. If this is the correct interpretation then the nature of object tokens is not specified by LUT. It is assumed that the first reading is the intended one.

1.3.3 Green's (1991) Recurrent Architecture Network Model

Green (1991) proposed a recurrent architecture network (RAN) model of early visual processing. He pointed out that a common assumption within theories of low-level visual processing (e.g., Atkinson & Braddick, 1989; Sagi & Julesz, 1985), notably FIT (Treisman & Gelade, 1980), is that visual feature abstraction and visual integration are separate, serially applied operations. However, Green argued that it would be better for features to be abstracted and integrated by a single process because the "computations performed by different feature modules must be combined into a consistent global solution." (p. 391).

Green (op. cit.) proposed that connections between and within topographically arranged feature maps form a recurrent neural network. The abstraction and integration of features is performed by the relaxation of this network. During relaxation the activation of a unit is constrained by the activity of neighbouring units within the same feature module and in other feature modules. These constraints should mean that the different feature modules achieve a mutually consistent segmentation. A similar idea has also been suggested by Poggio, Gamble & Little (1988) on the grounds that "combining the evidence provided by multiple visual cues ... provide[s] a more reliable map of the objects in a visual scene than any single cue alone ..." (p. 436).

Green (op. cit.) proposed that illusory conjunctions are caused because "interruption early in processing, such as by a mask may cause the local segmentations to become partially completed but not firmly coupled together" (p. 393). He assumed that the connections between units in a feature map are shorter than the connections between units in different feature maps. Consequently, processing may reveal the identity of features before they are precisely located or a consistent segmentation is found. Therefore, Green predicts that illusory conjunctions can occur between proximal objects but not distant ones.

1.4 What Illusory Conjunctions Tell us About Feature Integration

FIT, LUT and the RAN model all aim to explain how visual feature integration takes place. It would be interesting, therefore, to compare their abilities to account for the empirical evidence. However, the three theories differ in their scope; i.e. the types of phenomena that a theory attempts to account for. FIT aims to account for the findings of the visual search, illusory conjunction and texture segregation paradigms. LUT aims to account for illusory conjunctions and the neon colour illusion (Prinzmetal & Keysar, 1989). The RAN model aims to account for illusory conjunctions and a variety of other findings (Green, 1991).

Perhaps, the comparison of FIT, LUT and the RAN model should first focus upon where their scopes overlap. This review will concentrate on comparing how well these theories account for the empirical evidence regarding illusory conjunctions[11]. The three theories propose that illusory conjunctions are caused by different mechanisms. Nevertheless, the predictions generated from these theories are frequently similar if not equivalent. Although a considerable number of experiments have studied effects upon illusory conjunctions there are few findings that favour one theory over the others. It appears that each of the theories is able to explain the data so long as one accepts certain plausible additional assumptions.

Three theoretically significant factors have been found to affect the production of illusory conjunctions; attention, inter-item distance and perceptual organization. The bodies of research concerned with each of these effects are discussed separately in the next three sub-sections.

[11] The following articles review the evidence from the other paradigms addressed by FIT and LUT, and the implications for these theories: visual search (Cave & Wolfe, 1990; Treisman & Gormican, 1988; Duncan & Humphreys, 1989, 1992), texture segregation (Treisman & Gelade, 1980) and the neon-colour illusion (Prinzmetal & Keysar, 1989).

1.4.1 Illusory Conjunctions and Attention

An attentional mechanism plays an important role within FIT, so is not surprising that many studies have investigated the effects of attentional manipulations upon the generation of illusory conjunctions. Two methods of manipulating visual attention have been employed in illusory conjunction experiments. One method involves participants reporting one or more digits presented in same display as the stimulus objects (Cohen & Ivry, 1989; Eglin, 1987; Ivry & Prinzmetal, 1991; Kleiss & Lane, 1986; Prinzmetal et al., 1995; Prinzmetal & Keysar, 1989; Treisman & Schmidt, 1982; Tsal et al., 1994). The participants' primary task is to report the digits. It is thought that the area in which the digits are found will receive high attentional priority and other areas of the display will receive low attentional priority (Treisman & Schmidt, 1982; Tsal et al., 1994).

Many experimenters have found that a concurrent digit task can interfere with performance of a secondary (visual) task causing illusory conjunctions (Cohen & Ivry, 1989; Eglin, 1987; Ivry & Prinzmetal, 1991; Kleiss & Lane, 1986; Prinzmetal et al., 1995; Prinzmetal & Keysar, 1989; Treisman & Schmidt, 1982; Tsal et al., 1994). These findings have been taken by supporters of FIT to concur with the theory's central idea that illusory conjunctions are caused by diverted or spread attention. However, the findings equally support LUT because it is thought that diverted attention from a region serves to increase perceptual uncertainty thereby increasing the likelihood of illusory conjunctions (Ashby et al., 1996; Prinzmetal & Keysar, 1989).

However, contrary to the predictions of both FIT and LUT, Houck & Hoffman (1986) found that performing an attention demanding digit task does not necessarily cause illusory conjunctions. They found that a contingent visual after-effect (McCullough, 1965) "dependent upon a conjunction of colour and orientation, can be established outside the focus of spatial attention" (Houck & Hoffman, 1986, p. 197). On no occasion did the observed after-effects suggest that an illusory conjunction of colour and orientation had occurred. Treisman (1990), in defence of FIT, suggested that the locus of the McCullough effect is before features are completely disambiguated, i.e., before feature abstraction is complete. This explanation can work for LUT too. Green (1991) argues that the RAN model can account for Houck & Hoffman's (1986) finding because the various feature modules are interconnected. Presumably, the contingent after-effect is supported by the modification of the connection strengths between the colour and orientation modules.

The digit task is a relatively weak attentional manipulation (Tsal, 1989a; Tsal et al., 1994). After all, it is not clear why Treisman & Schmidt (1982) consider the digit task requires attentional processing. If letter features can be determined pre-attentively then so too can digits. A stronger method of controlling attention involves the use of spatial cueing. Location pre-cueing is thought to cause the covert orientation of attentional mechanisms to the location indicated by the cue (Posner, 1980)[12]. This method has been used by experimenters to manipulate attention in several studies of illusory conjunctions (Briand & Klein 1987, Prinzmetal, Presti & Posner, 1986; Treisman & Schmidt, 1982; Tsal et al., 1994).

Prinzmetal, Presti & Posner (1986) were the first to investigate the effects of valid and invalid spatial cueing on illusory conjunctions. In their Experiment 2, the task was to report the presence or absence of a pre-designated target object (a coloured letter *X*) presented in a square array with three distractors (coloured letter *O*s). On different trials three types of stimulus array were presented. Target displays contained the target object. In conjunction displays the target colour and the target letter were present in separate objects. Feature displays did not contain the target colour at all. A peripheral cue identified the location of the array on two thirds of the trials and was invalid on the rest. The exposure duration of the stimulus displays was adjusted separately for the valid and invalid cueing conditions to ensure that feature displays caused equal numbers of false alarms. This was to ensure that any effect of spatial cueing upon conjunction display false alarms could not be attributable to differences in illusory features and guessing between conditions. The experimenters

[12] Although it is possible for participants to adopt a *probability matching strategy* (Jonides, 1983; Eriksen & Yeh, 1985) so that non-cued locations are attended to on occasion.

found that conjunction display false alarms were less likely with valid cues than with invalid cues. They concluded that this demonstrated an effect of spatial cueing on the formation of illusory conjunctions.

However, Prinzmetal, Presti & Posner's interpretation of their findings does not square with another of their results (Tsal, 1989a). They also found that the number of misses on target display trials was not different in the valid and invalid cue conditions. Had invalid spatial cues caused more illusory conjunctions than valid spatial cues then it should be expected that more misses would occur under this condition, because on target display trials illusory conjunctions would have caused misses.

Nevertheless, Prinzmetal, Presti & Posner (1986; Experiment 3) also found that in a partial report task experiment, conjunction errors were more likely under invalid spatial cueing than valid spatial cueing, while there was no corresponding change in feature errors. The experimenters concluded that this provides converging evidence of the effect of peripheral spatial cueing on illusory conjunctions. Briand & Klein (1987; Experiment 4) have also found evidence of peripheral spatial cueing upon illusory conjunctions. However, contrary to Prinzmetal, Presti & Posner's (1986) and Briand & Klein's (1987) findings, Tsal *et al.* (1994) found no evidence of peripheral pre-cueing on rates of conjunction errors in their Experiment 3.

Briand & Klein (1987) hypothesized the existence of two attentional mechanisms; the endogenous orienting system is under the control of central spatial cueing and the exogenous orienting system is under the control of peripheral spatial cueing. They found that attentional processing under the control of a central spatial cue does not appear to affect illusory conjunctions and therefore concluded that only the automatic exogenous orienting system is involved with feature integration.

To determine whether the (exogenous) attentional system mediates veridical integration it is not sufficient to show that the misdirection of attention manipulation causes more illusory conjunctions. The findings of experiments that incorporated a digit task to control attention support the predictions of FIT, LUT and the RAN model. All that these experiments have demonstrated is that attention can facilitate visual integration. Attention can facilitate many visual tasks but that does not necessarily mean that these tasks are performed by an attentional mechanism. Consequently, the effects of attention on illusory conjunctions have not demonstrated that integration is mediated by attention as FIT claims (Tsal, 1989a, b; Green, 1991). One must demonstrate that attention is necessary and sufficient for veridical integration. Only a few studies have addressed this (Prinzmetal et al., 1995; Treisman & Schmidt, 1982).

Treisman & Schmidt's (1982) Experiment 5 tested their claim that illusory conjunctions do not occur when attention is directed and focused upon a single target object. Attention was controlled by means of a peripheral cue that identified the target object. The observed number of conjunction errors was below the baseline level. The experimenters concluded that the normal veridical feature integration mechanism proposed by FIT was operating under these conditions. This contrasted with their finding of many conjunction errors in Experiment 4 when location cues were given after the target presentation and a concurrent digit task was performed. Treisman & Schmidt analysed the results of the two experiments together and concluded that directed and focused attention was necessary for veridical integration.

However, Prinzmetal Presti & Posner (1986) identified a problem with Treisman & Schmidt's study. In Experiments 4 & 5, exposure duration was individually determined so that each participant would produce an equal number of correct reports. But this meant that feature errors and conjunction errors were constrained to be inversely proportional. Therefore any effect upon feature errors would cause a reciprocal effect in conjunction errors. Exposure duration in Experiment 5 (mean 89 msecs) was much shorter than exposure duration in Experiment 4 (mean 199 msecs) because of the differing attention manipulations. According to feature integration theory this would have caused many more feature errors in Experiment 5 than in Experiment 4. Prinzmetal Presti & Posner concluded that this effect caused the lack of conjunction errors in Experiment 5.

Many investigators have found evidence of illusory conjunctions without a digit task or spatial cueing being used to divert attentional processing away from the stimuli (Ashby et al., 1996; Gallant & Garner, 1988; Prinzmetal, 1981; Lasaga & Hecht, 1991; Maddox et al., 1994; Snyder, 1972; Prinzmetal et al., 1995; Prinzmetal et al., 1991; Wolford & Shum, 1980). The stimulus exposure duration was less than 200 msecs in all of these studies. However, it is not unreasonable to assume that brief exposure will affect the spread and location of attention. Prinzmetal *et al.* (1995) undertook a series of experiments to determine whether illusory conjunctions could occur when the stimuli are exposed for 1.5 secs. Experiment 2 is of particular interest because its results suggest, contrary to FIT, that illusory conjunctions can occur under conditions where it would be expected that attention is directed and focused upon a single object. In one condition, participants were instructed to fixate on a central point and their eye movements were monitored as a manipulation check. The retinal eccentricity (i.e., the radial distance from the fixation point) of stimulus objects was determined for each individual to achieve 80% correct responses. Because the exposure duration was much longer than most other illusory conjunction experiments the stimulus eccentricity was high (mean 6.7 degrees of visual angle). FIT maintains that 1.5 secs would be ample time to focus attention on the target stimulus, so illusory conjunctions should not occur. Remarkably, conjunction errors were significantly higher than the baseline level. The pattern of error responses under these conditions was very similar to the patterns observed with comparable traditional illusory conjunction methods (i.e., a central digit task and 150 msec exposure duration). It appears that high eccentricity alone is sufficient to cause illusory conjunctions. This finding is compatible with LUT, but at face value is contrary to FIT.

It may be possible for FIT to account for Prinzmetal *et al.*'s (1995) findings if it can be shown that there are limitations upon the location and spread of the attentional spotlight within the periphery. Two possibilities may enable FIT to account for these findings. First, the deployment of the attentional spotlight may be restricted to a central region. Second, attentional spotlight may be incapable of focusing upon a single item when outside of the central region.

One of Prinzmetal *et al.*'s (1995) other findings favours the second of these alternatives over the first. If explicable in terms of FIT at all, then the illusory conjunctions must have been caused by "intra-spotlight" illusory conjunctions rather than extra-spotlight illusory conjunctions. This is because on 75% of trials a correct report was made. FIT predicts that if the number of correct reports exceeds the number of conjunction errors then veridical integration (i.e., integration involving focused attention) occurred on some trials. If veridical integration was possible on some trials then the spotlight can be deployed in the periphery.

Tsal *et al.* (1994) investigated whether it is possible for an illusory conjunction to be composed of a feature that FIT claims to be inside the attentional spotlight and a feature that FIT claims to be outside the spotlight. They refer to errors of this type as mixed illusory conjunctions. FIT offers no explanation of mixed illusory conjunctions, "the theory predicts that when attention is focused on a subset of presented items, illusory conjunctions should be formed either within the attended subset or outside it, but not between the attended and unattended items" (Treisman & Schmidt, 1982, p. 118). In the terms of LUT, mixed illusory conjunctions are like any other illusory conjunction. This is because the theory posits the existence of a single mechanism causing illusory conjunctions irrespective of the attentional processing the component features receive. Tsal *et al.* (1994) found evidence of mixed illusory conjunctions using a variety of attention manipulations. However, they assume that FIT's attentional spotlight should encompass all high attentional priority items and no low attentional priority items, particularly if a strong attentional manipulation is used. This assumption would be false if more than one attentional fixation were to occur during each stimulus presentation.

1.4.2 Illusory Conjunctions and Inter-Item Distance

One important idea proposed by FIT is that the locations of pre-attentively registered features are not available to subsequent processing in the absence of focused and appropriately directed attention (Treisman & Gelade, 1980; Treisman & Schmidt, 1982). These features are therefore "free-floating", i.e., they are equally likely to recombine to form illusory conjunctions irrespective of the distances between them. In support of this prediction, Treisman & Schmidt (1982; Experiment 1) found that the probability of an illusory conjunction occurring between the features of two objects was not affected by the distance between the objects. This finding was replicated by Cohen & Ivry (1989; Experiments 3 & 4).

However, contrary to Treisman & Schmidt's (1982) and Cohen & Ivry's (1989) findings, many studies have found that illusory conjunctions are more frequent the smaller the distance between objects. Both LUT and the RAN model predict this effect. The inter-item distance effect has been found both with stimuli composed only of shape features (Chastain, 1982; Gallant & Garner, 1988; Lasaga & Hecht, 1991; Maddox et al., 1994; Wolford & Shum, 1980) and colour-shape objects (Ashby et al., 1996; Cohen & Ivry, 1989, Experiment 1; Ivry & Prinzmetal, 1991; Keele et al., 1988; Prinzmetal & Keysar, 1989; Prinzmetal & Millis-Wright, 1984; Prinzmetal, Treiman & Rho, 1986; Snyder, 1972). Ashby et al. (1996), for example, used sophisticated models to estimate the true levels of illusory conjunctions in an experiment having four levels of inter-item distance. They found decreasing probabilities of illusory conjunctions with increasing inter-item distance.

Nevertheless, feature integration theory can account for the inter-item distance effect in two ways. First, Treisman & Schmidt (1982) argued that the inter-item distance effect "could be explained by partial but imperfect narrowing of attention, so that the focus included not only the cued item but its immediate neighbours" (p. 118). In other words, on occasion the attentional spotlight is not focused on a single object but spread over two or more objects. When this happens illusory conjunctions occur between the features of items within the spotlight. These "intra-spotlight" illusory conjunctions, are composed of features from closely located items and therefore their occurrence will cause the inter-item distance effect. Second, Cohen & Ivry (1989) suggested that "features outside the focus of attention may be registered with coarse location information" (p. 650). This allows for distance effects to occur outside the focus of attention, whereas, following FIT, none would occur within the focus of attention.

FIT appears to account for the inter-item distance effects found by Snyder (1972) and others but can LUT account for the absence of the inter-item distance effect found by Treisman & Schmidt (1982) and Cohen & Ivry (1989)? One defence has been to suggest that the findings of Treisman & Schmidt (1982) and Cohen & Ivry (1989) are artefactual. Ashby et al. (1996) suggested that the model that Cohen & Ivry (1989) used to calculate baseline conjunction errors ignored important information contained in the data. Ashby et al. (1996) found that Cohen & Ivry's data better fitted a model derived from location uncertainty theory, predicting the distance effect, than a model derived from feature integration theory in which all illusory conjunctions were equally likely irrespective of inter-item distance. They concluded that Cohen & Ivry's (1989) data supported the existence of the inter-item distance upon illusory conjunctions. However, it seems unlikely that a similar re-analysis of Treisman & Schmidt's (1982) data would lead to the same conclusions as they had found that the conjunction of distant features was more likely than adjacent features (although the difference was not significant).

Another possible explanation of Treisman & Schmidt's (1982) and Cohen & Ivry's (1989) findings is that the inter-item distance effect was greatly attenuated in these studies. Prinzmetal & Keysar (1989) noted that the stimuli in both Treisman & Schmidt's and Cohen & Ivry's studies were flanked by to-be-reported digits, whereas this manipulation was not used in similar studies that did reveal the inter-item distance effect (e.g., Ashby et al., 1996; Cohen & Ivry, 1989, Experiments 1 & 2; Prinzmetal & Millis-Wright, 1984; Snyder, 1972). Prinzmetal & Keysar suggested that "reporting the digits induces spatially selective filtering that reduces the effect of distance ... [and as] a result, all the items between the digits become more similar in color" (Prinzmetal & Keysar, 1989, p. 175). However, it is unclear what they mean by this.

1.4.3 Illusory Conjunctions and Perceptual Organization

Several studies have suggested that perceptual organization (Rock & Palmer, 1990; Wertheimer, 1912) can affect the production of illusory conjunctions (Gallant & Garner, 1988; Ivry & Prinzmetal, 1991; Lasaga & Hecht, 1991; Prinzmetal & Keysar, 1989). It appears that features from items grouped by Gestalt factors are more likely to form illusory conjunctions than features in separate groups. This effect has been found with stimulus objects grouped by colour similarity (Ivry & Prinzmetal, 1991), letter feature similarity (Ivry & Prinzmetal, 1991), good continuation (Ivry & Prinzmetal, 1991), and proximity (Prinzmetal & Keysar, 1989). It also appears that illusory conjunctions are more frequent when the resulting objects have either figural goodness (Gallant & Garner, 1988) or global goodness (Lasaga & Hecht, 1991). Furthermore, Prinzmetal & Keysar (1989) found that illusory conjunctions were more likely within groups defined by subjective organization (Attneave, 1971) than between such groups.

According to FIT, perceptual organization effects are "an indirect result of attention being allocated to perceptual groups of elements" (Treisman, 1995, p. 173). However, it does seem strange that the attentional spotlight can be allocated to an integrated group when it is the spotlight that is said to do the integrating. LUT suggests that perceptual organization effects occur because global stimulus properties distort the locations of features (Prinzmetal & Keysar, 1989). Green (1991) offers no explanation of these effects in describing the RAN model. However, they may be explicable in terms of the network achieving a globally consistent segmentation for each feature module. Recurrent network models of perceptual organization effects have been proposed previously (e.g., von der Malsburg & Buhmann, 1992).

1.5 Visual Previewing and Illusory Conjunctions

The above review suggests that FIT, LUT and the RAN model are equally favoured by the illusory conjunction literature. This is an unsatisfactory situation to which two approaches are possible. One approach is to extend the work on the effects of attention, inter-item distance and perceptual organization to test "finer grain" hypotheses capable of separating the theories. Another approach is to search for other factors that affect illusory conjunctions. This second approach has the advantage of forcing the theories to be more general and avoids the "temptation to derive theoretical constructs on the basis of only a small sample of experimental manipulations" (Prinzmetal et al., 1995, p. 1363). The experimental work documented in this thesis was motivated by the second of these approaches. The following section explores the possibility that *visual previewing*[13] might affect the formation of illusory conjunctions.

Before discussing how this experimental work might be undertaken, it will first be necessary to introduce the foundations of this work. Subsequent sub-sections review the visual previewing paradigm (Beller, 1971; Jonides & Mack, 1984; Posner & Snyder, 1975a, b), the dual-process model of visual previewing (Neely, 1977; Posner, 1978; Posner & Snyder, 1975a, b) and the previous work in which the previewing method has been applied to the study of visual representation (e.g., Di Pace, Marangolo, Pizzamiglio, 1997; Marangolo, Di Pace & Pizzamiglio, 1993; Humphreys & Quinlan, 1988; Simon, 1988; Taylor, 1977).

[13] In the literature the terms *previewing* and *priming* are often interchangeable (however, see Kahneman et al., 1992). So too are the terms *preview* and *prime*. These terms are used to refer to a variety of concepts; e.g., the experimental method, the observed effect of the method on behaviour and various hypothetical processes that are thought to mediate the effect. However, in this thesis, to aid clarity, these terms are given specific meanings. *Previewing* is used to refer to the experimental methodology that is elsewhere known as priming, i.e., the presentation of a preview or pre-target stimulus before the to-be-reported probe or target stimulus. The term *preview effect* refers to an observed effect of previewing upon participants' responses. *Priming* denotes Posner & Snyder's (1975a, b) hypothesized automatic and strategic processes that are thought to cause preview effects. In other words, *previewing*, the method, can cause *priming*, an internal process, which in turn causes a *preview effect*, a behavioural outcome.

1.5.1 Visual Previewing Paradigm

The priming or previewing paradigm is a variant of the preparation paradigm (Jonides & Mack, 1984). The paradigm is used to study the effects that a preview stimulus has on the processing of subsequent stimuli. The basic method involves the successive presentation of two stimulus displays. The first stimulus is the known as the *prime* (Beller, 1971) or *preview* display, the second stimulus is known as the *probe* (Beller, op. cit.) or *target* display. The participants' task is to report certain information conveyed by the probe display. The previewing method can be adapted for use with many different visual tasks; e.g., simultaneous matching (e.g., Posner & Snyder, 1975a), detection of luminance changes (e.g., Posner, Snyder & Davidson, 1980), visual search (e.g., Posner & Snyder, 1975a) and tachistoscopic identification (e.g., Di Pace et al., 1997; Humphreys & Quinlan, 1988; Taylor, 1977).

A distinction can be made between two types of preparation; spatial cueing and non-spatial previewing. In spatial cueing the location or direction of a spatial cue is varied whilst its colour, shape and other attributes are constant (e.g., Müller & Rabbitt, 1989; Posner, 1980; Posner et al., 1980). The effects of spatial cueing upon illusory conjunctions has already been studied (Briand & Klein 1987; Treisman & Schmidt, 1982; Prinzmetal, Presti & Posner, 1986; Tsal et al., 1994), as discussed earlier. In non-spatial previewing, the spatial characteristics of the preview are held constant and its non-spatial features are varied (e.g., Di Pace et al., 1997; Humphreys & Quinlan, 1988; Marangolo et al., 1993; Posner & Snyder, 1975a; Taylor, 1977; Simon, 1988). Non-spatial visual previewing can have powerful facilitatory and inhibitory effects on the speed and accuracy of reporting in many different visual tasks; for instance visual search (e.g., Maljkovic & Nakayama, 1994; Posner & Snyder, 1975a), visual matching (e.g., D'Agostino, 1982; Neumann & D'Agostino, 1981; Posner & Snyder, 1975a), the global or local structural interpretation of stimuli (Sanocki, 1993) and visual word recognition (e.g., Lesch & Pollatsek, 1993; Meyer & Schvaneveldt, 1971). The experimental work reported in this thesis is concerned with the possibility that non-spatial previewing can affect the production of illusory conjunctions. This possibility has not been investigated previously. If the effect does occur then visual previewing could be used to gain a better understanding of how the visual system performs feature integration and encodes object tokens.

An important independent variable, used in all previewing experiments, is preview-probe congruence. This variable quantifies the similarity or dissimilarity of the preview and probe stimuli. A congruent preview is similar or related to the probe, in some way. Incongruent previews are dissimilar or unrelated to their probes. For example, if the dimension of congruence is the colour of the stimuli then the congruent preview will be the same colour as the probe whereas the incongruent preview will be a different colour.

A (cost-plus-benefit) *preview effect* or *selective preparation effect* (Jonides & Mack, 1984) is said to occur when the latency or accuracy of participants' reports of a subsequently presented target stimulus is different with congruent previews than with incongruent previews. It is usual for congruent previews to cause faster or more accurate reporting of target stimuli than incongruent previews do (e.g., Beller, 1971; Di Pace et al., 1997; Marangolo et al., 1993; Humphreys & Quinlan, 1988; Posner & Snyder, 1975a; Taylor, 1977). Often experimenters are interested in the effect that various types of preview have on participants' reaction times, however preview effects on the frequencies of correct responses and various error responses are also possible.

However, congruent and incongruent previews are thought to cause general warning effects as well as selective preparation effects. General warning effects (e.g., Posner & Boies, 1971; Taylor, 1977) "heighten the subject's general alertness by whatever means, and thereby increase overall attentiveness to all ... [stimuli] in the task." (Jonides & Mack, 1984, p. 30). Cost-benefit analysis (Posner & Snyder, 1975a, b; Jonides & Mack, 1984) is a method for separating general warning and selective effects. In order to perform this analysis, a previewing experiment must have at least three preview conditions; the congruent and incongruent selective preview conditions and a neutral preview control condition. A neutral preview is one that has the same general warning effect as the selective previews, but has no selective previewing effect. For instance, in an experiment where the dimension of congruence is the colour of the stimuli, a neutral preview might be an item in a colour that does not appear in the probe display at any time during the experiment. Cost-benefit analysis involves the calculation of the selective benefit or facilitation of congruent preparation and the selective cost or inhibition of incongruent preparation. The congruent preview benefit is determined by subtracting the scores in the neutral preview condition from the scores in the congruent preview condition. Responses are expected to be faster and more accurate following a congruent preview than following a neutral preview. The incongruent preview cost is determined by subtracting the scores in the neutral preview condition from the scores in the incongruent preview condition. Responses are expected to be slower and less accurate following an incongruent preview than following a neutral preview.

However, Jonides & Mack (1984) suggest that cost-benefit analysis is not appropriate if the neutral preview does not have the same general warning effect as the selective previews or has selective previewing effects of its own. Under these circumstances the magnitudes of costs and benefits are rendered meaningless. Jonides & Mack identified many reasons why previews considered to be neutral at face value, in fact turn out not to be. They advised two courses of action with regard to cost-benefit analysis. First, try to match as closely as possible, the physical appearance, alerting salience and ease of encoding of the neutral and selective previews. Second, do not undertake cost-benefit analysis if there is doubt about the validity of the neutral preview. When in doubt, the only appropriate comparison is between the congruent and incongruent previews.

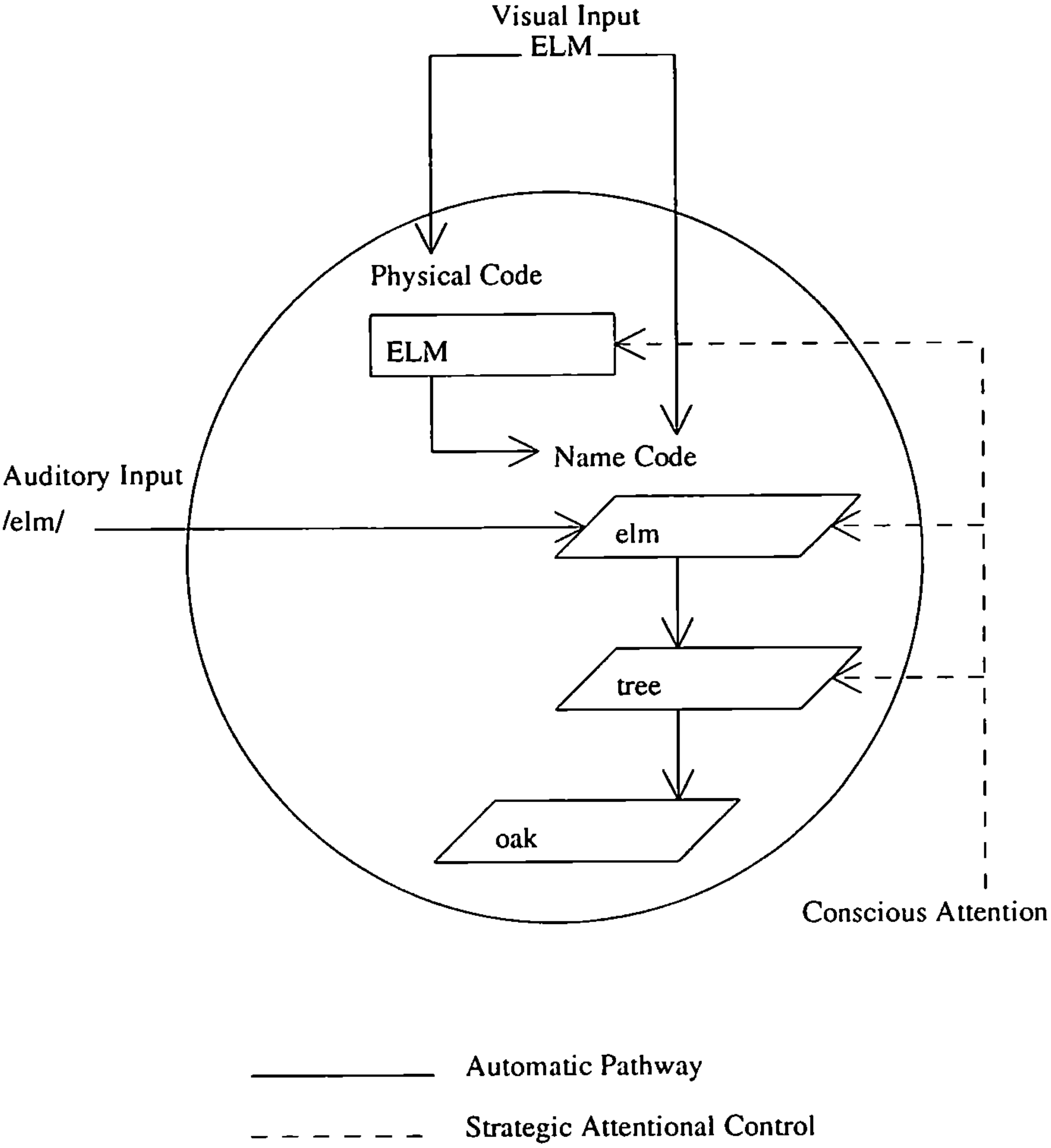

Figure 1.3. The Two Factor Theory of Priming (Posner & Snyder, 1975a, b).

1.5.2 The Two-Factor Model of Visual Previewing

A two-factor model has been proposed to account for the existence of two distinctive patterns of selective preparatory effects (Neely, 1977; Posner, 1978; Posner & Snyder, 1975a, b; Taylor, 1977). If preview-probe stimulus onset asynchrony (SOA; i.e., the time delay between the onset of the preview and the onset of the target) is 250 msecs or less and the number of congruent trials does not exceed the number on incongruent trials then previewing can cause a cost but no benefit (Posner & Snyder, 1975a, b; Taylor, 1977). If the preview-probe SOA is more than 250 msecs and there are more congruent trials than incongruent trials then previewing causes both a benefit and a cost (Posner & Snyder, 1975a, b; Taylor, 1977). The two-factor model attributes the two patterns of preview effects to two priming processes (see Figure 1.3).

One of the processes thought to cause selective preparation is known as automatic pathway activation (Keele, 1973; Posner & Snyder, 1975b; Warren, 1972) or bottom-up priming. This process is thought to cause preview effects when the preview-probe SOA is 250 msecs or less and the number of congruent trials does not exceed the number of incongruent trials. This process is influenced only by the immediate properties of stimulus and not by a participant's expectations or knowledge of task demands. According to the dual-process model, information about a visual stimulus is encoded during normal perception by the activation of certain representational structures or processors that act as an internal description of the visual scene (Hebb, 1949; Rumelhart & McClelland, 1986; Morton, 1969; Selfridge, 1959). In other words, stimuli, such as preview and probe displays, are encoded as patterns of activation over parallel processing resources. This concept is now a cornerstone of connectionist thinking, the activation of a processor or unit is considered to encode the degree of confidence the system has that a certain feature or microfeature is present (Rumelhart & McClelland, 1986).

Furthermore, stimuli are thought to be encoded by several different representational domains each of which makes explicit certain information (Posner & Snyder, 1975b). For instance, the physical domain encodes the physical attributes of the stimulus, and the name domain encodes the identities of stimulus objects. Many different forms of physical codes have been postulated (see Feldman, 1985; Marr, 1982); for example, topographic feature maps (Treisman & Gelade, 1980) and object files (Kahneman & Treisman, 1984). A stimulus will cause a pathway of activation throughout the brain. Activation of the physical code of a stimulus (i.e., the internal representation of the stimulus' physical characteristics) is thought to spread in a bottom-up fashion to activate its name code (i.e., the representation of the name of the stimulus).

Selective preparation is thought to occur because the preview stimulus affects processing in the pathway that it activates, for a short period after preview offset. As a result, the target may easily reactivate the representational resources previously activated by the preview. This could happen in at least two different ways. First, the activity of a unit may not cease instantaneously when the stimulus causing its activation is removed. Instead the activity may slowly decay back to the resting state, during several hundred milliseconds. The immediate activation caused by the target and the residual activation caused by the preview will be summed. Second, the evidence threshold at which a unit becomes active may be lowered temporarily in a unit has been activated recently (Keele, 1973). Again this state of threshold suppression may persist for several hundred milliseconds. Either way, when two stimuli are presented in quick succession the processing of the first stimulus will affect the processing of the second stimulus. The residual activation or threshold suppression of units activated by a preview stimulus will help these units to reach a given level of activation in response to the probe stimulus. Under tachistoscopic presentation, the facilitation effect will increase the probability that the units will achieve a level of activation sufficient to trigger a response before the offset of the stimulus.

Posner & Snyder (1975b) have suggested that a preview will affect the processing of a probe stimulus by automatic pathway activation only when the two stimuli activate the same processing resources; i.e., in connectionist terms, when the activation patterns corresponding to the stimuli at various representational domains overlap to some degree. A congruent preview and probe are similar in some regard. Therefore, in whatever representational schemes that make this similarity explicit, the activation patterns that stand for these stimuli will be overlapping. Consequently, the processing of the probe stimulus will be facilitated in the manner described above. However, the dissimilarity of an incongruent preview and probe will ensure that the activation patterns corresponding to these stimuli will not overlap at the level of representation that makes this dissimilarity explicit. Therefore, processing the probe stimulus will not be facilitated. Hence, automatic pathway activation is thought to cause a congruent preview benefit but not an incongruent preview cost (Posner & Snyder, 1975b).

The other process thought to cause selective preparation is known as strategic attentional control (Posner & Snyder, 1975a) or top-down priming. This process is thought to cause preview effects when the preview-probe SOA is greater than 250 msecs and the number of congruent trials exceeds the number on incongruent trials. A participant's expectations and knowledge of task demands will influence this process. According to the dual-process account, participants become aware of the relationship between the preview and probe stimuli. Consequently, they come to expect that particular previews are likely to precede particular probes. Posner & Snyder (1975b) suggested that this expectation causes a general-purpose limited-capacity attentional mechanism to have a top-down effect upon visual processing. They argued that the attentional mechanism is under the strategic control of participants;

> ... subjects can program their conscious attention to (1) receive information from a particular input channel or area of memory and (2) perform particular operations upon received information. These programs, which are under the conscious control of the subject, we have been calling strategies. Strategies cannot prevent ... automatic activation processes. (Posner & Snyder, 1975b, p. 73)

Furthermore, they argued that;

> Once a subject invests his conscious attention in the processing of a stimulus, the benefit obtained from pathway activation is increased, and this benefit is

accompanied by a widespread cost or inhibition in the ability of *any* other signals to rise to active attention. This position follows from the limited-capacity nature of the conscious processor." (p. 66)

Therefore, the attentional mechanism will facilitate the processing of the expected stimulus but have inhibitory consequences for processing unexpected stimuli (Posner & Snyder, 1975). However, Posner & Snyder's (1975b) account of selective attention is open to the objection that it appears to involve an homunculus (Styles, 1997). Recently, Duncan, Humphreys & Ward, (1997) have proposed an account of selective attention that is not homuncular. They suggest that attention is caused by integrated competition within multiple sub-systems that encode different properties of an object. Furthermore, they suggest that selective control is mediated by high-level cognitive processes causing the top-down activation of these sub-systems in response to task demands. This modern account of attention offers a new way of describing Posner & Snyder's (1975b) strategic attentional control priming mechanism as a form of top-down priming.

1.5.3 Preview Effects Involving the Activation of Object Tokens

It is possible that some preview effects may involve the activation of object tokens. This possibility is a logical consequence of bringing together Posner & Snyder's (1975b) proposal that preview effects are caused by the activation of various representations of the stimuli and Kahneman & Treisman's (1984) suggestion that the integrity of visual objects is made explicit by an object token domain. As described earlier, the object token domain is a type of physical code that explicitly describes which features belong to which objects. Together, the two ideas suggest that it may be possible for previewing to affect the activation of representations within object token domain.

The preview effects found in three strands of research, colour previewing of colour identification experiments (e.g., Di Pace et al., 1997; Marangolo et al., 1993; Simon, 1988), shape previewing of shape identification experiments (e.g., Arguin & Bub, 1995; Carr, McCauley, Sperber & Parmelee, 1982; Humphreys & Quinlan, 1988; Jacobs &

Grainger, 1991; Taylor, 1977) and the object-reviewing paradigm (Gordon & Irwin, 1996; Henderson, 1994; Henderson & Anes, 1994; Kahneman et al., 1992), may involve the priming of visual object tokens. These strands of research are reviewed below.

Colour Previewing of Colour Identification

Several researchers have investigated whether colour previewing can affect colour identification (Di Pace et al., 1997; Marangolo et al., 1993; Simon, 1988). Initially, Simon (1988) failed to find evidence for this effect. However, in contrast, Neumann & D'Agostino (1981) and D'Agostino (1982) had previously found colour preview effects upon a colour-matching task. Marangolo et al. (1993) argued that the absence of a preview effect in Simon's (1988) study was due to the unusually long preview-probe SOA (2.5 secs).

Marangolo et al. (1993) found evidence of a colour priming effect upon colour identification. In two experiments they presented red, green or black (neutral) circular previews with red or green annular probes. In one experiment the predictive validity of the preview (i.e., the ratio of congruent preview trials to incongruent preview trials) was manipulated (4:1, 1:1 or 1:4) and the preview-probe SOA was held constant at 350 msecs (150 msecs preview exposure duration and 200 msecs inter-stimulus interval). Significant costs and benefits were found at all levels of predictive validity[14]. In the other experiment preview-probe SOA was manipulated (150 msecs, 350 msecs or 2100 msecs with a preview exposure duration of 100 msecs) and there were equal numbers of congruent and incongruent trials. Significant costs and benefits were found with the shortest SOA. With the medium SOA only a significant benefit was found. In the equivalent condition in the other experiment a significant cost was found.

Marangolo et al. (1993) did not conjecture what type of representation of the stimuli was activated to bring about the colour priming effect. However, one fact is suggestive

[14] However, it should be noted that because predictive validity was varied within-subjects, the high expectancy conditions may have caused a carry-over effect (see La Berge, Van Gelder & Yellott, 1970).

regarding this question; the physical boundaries of the preview and probe objects did not overlap in their experiments. The two-factor theory of selective preparation holds that the degree to which previewing facilitates a visual task is a function of the overlap between the representation of the preview object and the representation of the target object; i.e., the preview and probe stimuli are encoded by same resources. (Posner & Snyder, 1975a). In other words, the activation patterns corresponding to the congruent preview and the target must be co-extensive in the domain that mediates the selective preparation effect.

The descriptions of the two identical objects at different locations will not overlap in any representational domain in which features have viewer-centred or world-centred co-ordinates. Therefore, these types of domain could not be involved in the observed preview effect. Notably, this rules out the possibility that the preview effects involve the priming of a topographic feature map representation of the stimuli. In a topographic featural representation, two stimuli will be encoded by the same resources if and only if the stimuli share a common feature and a common location. For example, different detectors within the red feature map would encode a red preview object and a red probe object if the objects appeared at different locations. Therefore, the preview would not affect the speed or accuracy of processing the probe. However, in Marangolo et al.'s (1993) experiments the inner contours of the probes corresponded with the outer contours of the previews. Therefore, it may have been possible for a spatially coarse-coded topographic representation of adjacent or proximally located objects may overlap sufficiently to cause priming effects.

The colour preview effect found by Marangolo et al. (1997) appears to be mediated by the activation of a representational domain that explicitly encodes the similarity of two objects possessing the same attributes but having different locations; i.e., there is overlap between the descriptions of the objects. It is possible that the object properties are encoded in object-centred co-ordinates (Feldman, 1985; Marr, 1982; Quinlan, 1991). It has been suggested that object tokens are encoded in object-centred co-ordinates (Kahneman &

Treisman, 1984). It is also possible that the domain that mediates the preview effect does not encode location explicitly.

There are three domains that may be involved in causing the preview effect. One possibility is that the object type representation of the stimuli is involved (Kahneman & Treisman, 1984). Object types are the outcome of the process of identifying a stimulus as belonging to a particular category. It has been suggested that priming of object types can cause object-specific preview effects (Henderson, 1994; Henderson & Anes, 1994). A second possibility is that the name code of stimuli is involved in the preview effect (Posner & Snyder, 1975b). The name code is a representation of the lexical entry that corresponds to the object type classification. However, Kahneman & Treisman (1984) argued that an objects' name, being a property of the object, is contained within an object token. Even so it may be possible to prime the object name independently of the other object attributes. A third possibility is the representation of the response appropriate to the task and stimuli, sometimes known as a motor plan, is involved in the preview effect. Some authors have considered the possibility that the locus of preview effects may be at the response end of the processing pathway (e.g., Di Pace et al., 1997; La Berge et al., 1970; Simon, 1988). However, Di Pace et al. (1997) undertook a series of experiments which suggested that Marangolo et al.'s (1993) preview effects were mediated by the priming of a representation of the stimuli rather than a representation of the responses.

Shape Previewing of Shape Identification

The effects of shape feature previewing upon the identification and classification have been studied using a variety of shape stimuli; alphanumeric characters (Arguin & Bub, 1995; Jacobs & Grainger, 1991; Taylor, 1977), line drawings of common objects (Carr et al., 1982; McCauley et al., 1980) and outline geometric shapes (Humphreys & Quinlan, 1988). The results of two of these studies suggest that object tokens can be primed.

Taylor (1977) in several experiments presented participants with a centrally located probe letter (either a *K* or a *T*) and two flanking preview letters (either a *K* or a *T* in the congruent and incongruent conditions or an *O* in the neutral condition). The probe letter was presented for 500 msecs and the preview was presented for 250 msecs. The task was to identify the target letter by pressing one of two keys. Choice reaction time (RT) and errors data were recorded. In one experiment the preview-probe SOA was varied within-subjects (0, 100, 200, 300, 400 or 500 msecs) and predictive validity was varied between-subjects (the ratio of congruent to incongruent trials was 4:1 or 1:1). The magnitudes of the benefit effect and the cost effect were greater when predictive validity was high (4:1) than when it was low (1:1). When there were equal numbers of congruent and incongruent trials facilitation and inhibition decreased with increasing SOA and was roughly zero when SOA was 400 msecs or more. When there were more congruent trials than incongruent trials, inhibition decreased with increasing SOA but facilitation increased between 0 and 200 msecs then levelled off. The different patterns of results in the two predictive validity conditions were taken to indicate the existence of two priming mechanisms. Like Marangolo et al.'s (1993) study the preview effect occurred despite the target and preview objects having different locations. This suggests that the effect was not mediated by the priming of topographic feature maps.

Humphreys & Quinlan (1988) investigated whether it is possible to prime a representation of visual form that is invariant to simple transformations such as rotation in three dimensions. In one experiment the stimuli were outlines of three-sided or four-sided geometric forms. The task was to report as quickly as possible, by means of a key press, whether a target had three or four sides. In different conditions the preview objects were identical to the target in shape and orientation, the same shape but a different orientation in three dimensions, or a different shape. Benefit effects upon reaction time were found when the prime and target were identical and when the target was a transformation of the preview.

It was concluded that the preview effects were "determined by the similarity of the frame-based descriptions of primes and targets" (Humphreys & Quinlan, 1988, p. 203). Although, it was not stated explicitly, these frame-based descriptions may have been object tokens for the stimuli. Humphreys & Quinlan (1988) suggested that the representation primed in their study permitted object identification. Also they suggested that the locations of an object's features are coded relative to principal axis of elongation in this representation (Marr, 1982; Marr & Nishihara, 1978). Kahneman & Treisman (1984) ascribed the same properties to visual object tokens.

The Object Reviewing Paradigm

Object reviewing theory (Kahneman et al., 1992) was proposed to answer the question; "How does the visual system retain and combine information about an object over time and space?" (Henderson, 1994, p. 410). In other words, the theory describes how the information derived from a previous glimpse of an object may help process information derived from a subsequent glimpse of the same object. The theory maintains that certain preview effects are mediated by a bottom-up mechanism, known as object reviewing, that involves object tokens. This bottom-up mechanism is unlike the one proposed by Posner & Snyder (1975b).

Object reviewing theory is related to FIT by their common use of the notion that information about objects is stored within object files (Kahneman & Treisman, 1984; Treisman, 1990). As described earlier, an object file is a representational structure that registers the current attributes of a single visual object (Kahneman & Treisman, 1984). An object file is present for as long as its corresponding object is visible thereby making the temporal continuity of the object explicit. If an object disappears its object file will remain for a short time, which "bridges over the discontinuities produced by temporary occlusion, or by saccades, assigning current information to pre-existing files whenever possible." (Kahneman et al., 1992, p. 178).

Object reviewing theory holds that when the visual properties of an object change, the contents of the object file that encodes the object must also be changed. Kahneman et al. (1992) proposed that object previewing, the process of updating object files, occurs in three stages. First, the visual system detects a change in the input stream. Second, correspondence between the objects that were originally present and the objects that are currently present is determined. Kahneman et al. (1992) claim that correspondence (or addressing) is determined by the spatiotemporal characteristics of the stimuli (i.e., proximity in space and time) but not by content (e.g., the colour or shape of the objects)[15].

If there is only one object present in successive glimpses then the correspondence is obvious. Therefore, object reviewing theory may explain the effects found in previewing studies where the preview and target objects had different locations (e.g., Di Pace et al., 1997; Humphreys & Quinlan, 1988; Marangolo et al., 1993; Taylor, 1977). Object reviewing theory claims that the preview and target objects will be linked by default. This will affect processing of the latter object as explained later.

When there are many objects present in successive glimpses the correspondence process must link the successive states of each object in the scene (Ullman, 1979). Correspondence is determined by a best-fit calculation; "a one-to-one mapping is preferred, and an object is not necessarily assigned to its nearest neighbour in the previous scene." (Kahneman et al., 1992, p. 180). If there are two competing sets of object correspondences, as can occur in the Ternus (1938) apparent motion display, then one mapping is randomly selected[16]. If the correspondence operation fails to match an object to an object in a previous state of the visual scene then a new object file is set up.

When the correspondence operation links two successive states of a visual object then the object file that encoded the original state of the object is used to encode its subsequent state. It is said that reviewing "facilitates recognition when the current and previous states

[15] Kahneman et al. (1992) claim that "object files are addressed primarily by spatiotemporal characteristics rather than by properties or labels." (p. 180).

[16] "In the absence of selective perceptual factors a random item will be reviewed" (Kahneman et al., 1992, p. 209)

of the object match, [and] hampers it otherwise." (Kahneman et al., 1992, p. 176). In other words correspondence permits a short-cut to object identification. Of course, naming latency will be reduced only if correspondence can be computed faster than feature abstraction and identification.

Finally, a process known as impletion uses the information from the previous and current states of the object file to produce the perception of change. This change may be due to real movement, apparent motion, colour change, shape change, or rotation. The continuity of an object file makes explicit the continuity of an object even though its properties may change. The contents of the object file make explicit the properties of the object at any given time. The visual system uses the "current and reviewed information to produce a percept of change or motion that links the two views" (Kahneman et al., 1992, p. 179).

Kahneman et al. (1992) take pains to distinguish the object reviewing process from Posner & Snyder's (1975a) priming processes: "the facilitation or interference are not necessarily produced by an activation process that is instigated by the "prime" and continues during the ISI between this stimulus and the subsequent target." (Kahneman et al., 1992, p. 183). They suggest that object-specific preview effects can be caused by "a retrieval process triggered by the target which picks out the trace of a particular past episode" (p. 183).

Support for object reviewing theory comes from object reviewing paradigm experiments (Gordon & Irwin, 1996; Henderson, 1994; Henderson & Anes, 1994; Kahneman et al., 1992). Essentially the method used in these experiments is similar to that used in the previewing paradigm. However, in the object reviewing paradigm there are two or more preview objects, one of which is linked to a target object. Kahneman et al. (1992) used two methods to link the successive states of an object. One method involved the preview and probe objects being surrounded by a frame. During the inter-stimulus interval the frame moved from the location of the preview object to the location of the probe object. The other method for establishing linking involved controlling the exposure duration of the prime and probe displays, the inter-stimulus interval and the spatial separation between the prime and probe objects so that apparent motion was seen between the linked objects.

The consistent finding in these studies was that an object-specific preview effect on response latency occurred; i.e., the effect is related to the similarity between the linked preview object and the target object. Object reviewing theory holds that an object-specific preview effect will occur only when the same object file handles the prime object and the target object. Therefore, the reviewing process "appears to involve the retrieval by a current stimulus of a plausible prior instantiation, which speeds up or impedes the identification of the current stimulus and the response to it." (Kahneman et al., 1992; pp. 183-184).

In one of Kahneman et al.'s (1992) experiments there were two preview items and two target objects, all of which were letters. The preview items appeared either side of the vertical midline. The probe items were the same distance apart as the preview items. One target item appeared centrally and the other appeared peripherally either on the left or the right. The timing of presenting the stimuli ensured that global apparent motion was seen between the preview objects and the probe objects (Ternus, 1938). The direction of the apparent movement was determined by the location of the peripheral probe item.

Participants reported the target object, which was central probe item. One of the preview objects was the same as the target object. In one condition this preview object and the target object were linked by the apparent motion, in the other condition the other preview object was linked to the target object. Reaction times were found to be significantly faster in the first of these conditions than in the second. Kahneman et al. (1992) referred to this as an object-specific preview effect upon object identification, "because the effect of a preview depends on whether the target and the prime are both seen as states of the same perceived object." (Kahneman et al., 1992, p. 176).

1.5.4 The Priming of Feature Integration Hypothesis

The studies discussed in the last section suggest that the priming of visual object tokens causes several preview effects. Object tokens are considered to be the output of the visual integration process (Kahneman & Treisman, 1984). It follows, that the priming of object tokens may affect the integration of features in subsequent displays. If so, we should expect previewing that activates object tokens to affect the accuracy (and latency) of reporting conjunctions of target features. One effect may be to vary the number of illusory conjunctions that viewers experience. Illusory conjunctions are object tokens that stand for non-existent objects comprised of features that actually belong to two or more objects. They are thought to occur when the normal process of feature integration is interrupted or interfered with (Ashby et al., 1996; Green, 1991; Treisman & Schmidt, 1982). The *priming of feature integration hypothesis* is the suggestion that non-spatial visual previewing can facilitate or inhibit the activation of object tokens and that this will affect the integration of features thereby varying the numbers of illusory conjunctions produced.

Given the ubiquity of preview effects upon other visual processes it is quite plausible that similar effects upon visual integration may also occur. Furthermore, spatial previewing has already been found to influence the production of illusory conjunctions (Briand & Klein, 1987; Prinzmetal et al., 1986; Tsal et al., 1994). The possibility that non-spatial previewing may affect visual feature integration and the production of illusory conjunctions has not been investigated previously. The experiments that are described in the subsequent chapters of this thesis investigated whether the priming of feature integration hypothesis is true.

It is widely believed (e.g., Neely, 1977; Posner & Snyder, 1975b) that preview effects are caused by two priming processes; top-down and bottom-up priming. Therefore, it is to be expected that there are top-down and bottom-up priming effects upon the integration of visual features. A variety of top-down effects upon illusory conjunction formation have been documented (see Prinzmetal, 1995, for a review). The priming of feature integration hypothesis would be supported by evidence of top-down priming, bottom-up priming or both.

Two different forms of non-spatial previewing may affect the integration of visual features. One form involves the previewing of an object composed of a task-relevant feature and a task-neutral feature; i.e., feature previewing. This form of previewing is widely-used (e.g., Beller, 1971; Marangolo et al., 1993; Humphreys & Quinlan, 1988; Posner & Snyder, 1975a; Taylor, 1977). For example, in Marangolo et al.'s (1993) study the colour of the preview was relevant to the task but its shape was not. Feature previewing has been found to cause effects that may have been mediated by the priming of object tokens (e.g., Marangolo et al., 1993; Humphreys & Quinlan, 1988). The suggestion was made earlier that the priming of object tokens may affect visual integration. Perhaps previewing a (task-relevant) feature prepares it for conjoining with other features irrespective of what these other features may be. If so congruent feature previewing would facilitate the integration of the target display and thereby cause fewer illusory conjunctions than incongruent previews. The effect of feature previewing upon visual integration was studied by the experiments reported in Chapter 2.

However, it is also possible that feature previews do not affect integration because they do not convey any information about what features are conjoined together in the target. Another form of previewing, conjunction previewing, does convey this information and consequently may affect the integration of visual features even if feature previewing does not. In conjunction previewing the preview objects consist of a combination of features, both of which are relevant to the task. In the congruent conjunction preview condition the same feature combination is present in the preview and the target. In the incongruent conjunction preview condition the same features are present in the preview and the target but in a different combination.

For conjunction previewing to affect the integration of features, the congruent conjunction preview and target objects must be encoded by the same resources, whereas the incongruent preview and target objects must be encoded by different resources. If this is so, when a congruent conjunction preview precedes the target display the correct object token will be more easily re-activated and fewer illusory conjunctions will occur. Also, when an incongruent conjunction preview precedes the target display then an object token of an illusory conjunction will be less easily activated when the target display appears. Consequently the integration of a subsequently presented target display will be faster and more accurate (i.e., fewer illusory conjunctions will occur) when the preview and target items are congruent than when they are incongruent. The effects of conjunction previewing upon visual integration were studied in the experiments described in Chapters 3, 4 and 5.

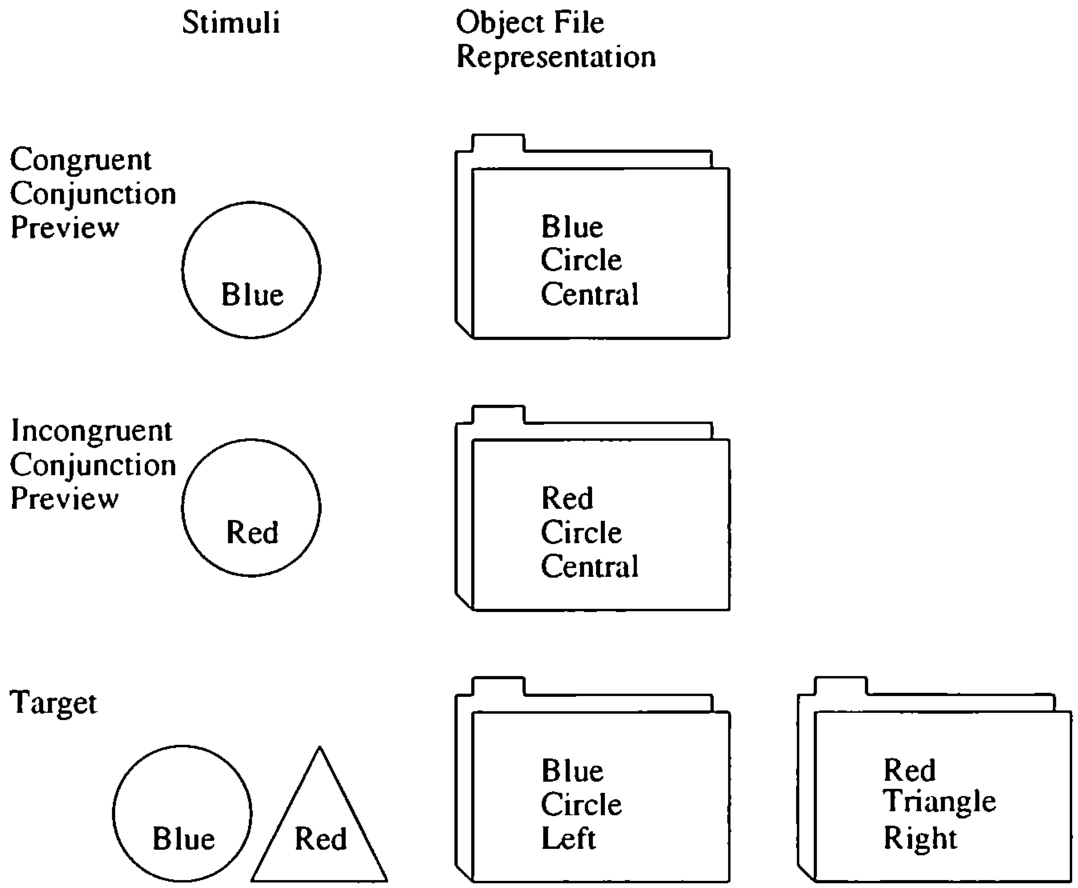

Figure 1.4. Object file representation of congruent and incongruent conjunction preview stimuli and target stimuli.

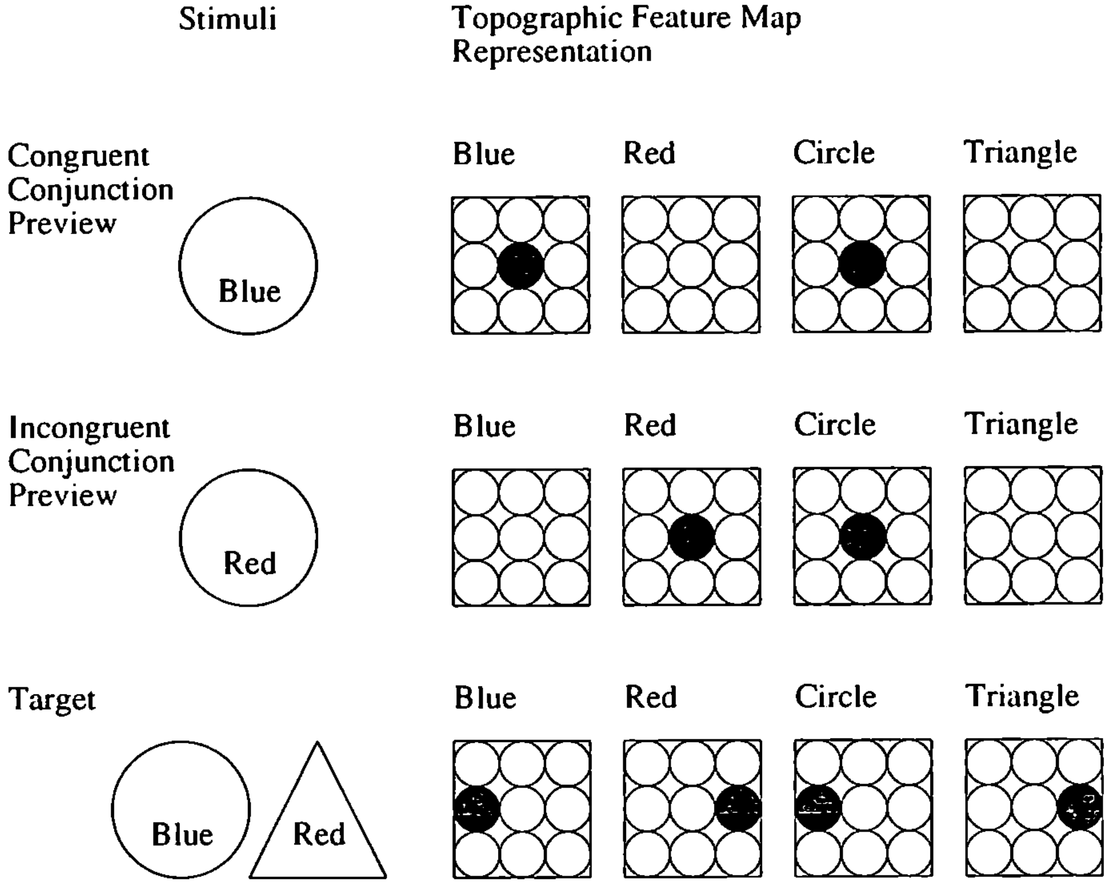

Figure 1.5. Topographic feature map representation of congruent and incongruent conjunction preview and target stimuli. For simplicity each feature map encodes only nine feature locations. White circles indicate inactive units and black circles indicate active units.

It may be possible to explain the effects of feature previewing and conjunction previewing upon the generation of illusory conjunctions in terms of the three accounts of visual integration discussed earlier; i.e., feature integration theory (FIT; Treisman, 1990; Treisman & Gelade, 1980), location uncertainty theory (LUT; Ashby et al., 1996; Prinzmetal & Keysar, 1989), and Green's (1991) recurrent architecture network (RAN) model. These three theories agree that illusory conjunctions are caused during the process of visual integration and are encoded by object tokens. The theories disagree on what kind of process visual integration is, how these processes cause illusory conjunctions and how object tokens are encoded. Consequently, the theories make different predictions about the impact of conjunction previewing upon feature integration.

According to FIT, normal veridical feature integration is a serial process involving the deployment of an attentional spotlight (Treisman, 1990; Treisman & Gelade, 1980). The features illuminated by the spotlight at any given moment are transferred to an object file. Each object file encodes the properties of a single visual object; i.e., it maintains an object token. Object files contain an object-centred structural description of objects (Kahneman & Treisman, 1984). For previewing to affect the integration of target objects the object files for the preview must be involved in the representation of the target objects. Figure 1.4 depicts the object token representation of a congruent and an incongruent conjunction preview object and their associated target objects. The preview object appears centrally and the target objects appear off-centre; to the left and to the right. Posner & Snyder (1975b) hold that the representations of the previews and targets must overlap for priming to occur. Therefore, the same object file must register the preview object and one of the target objects, as shown in the figure.

LUT posits that objects are encoded by a set of topographically organized feature maps (Ashby et al., 1996; Prinzmetal & Keysar, 1989). The activity of a given unit in a map codes the conjunction of a particular attribute and its location. An object will activate units that encode the same location in different feature maps. Within the framework of LUT, visual integration is considered to involve the parallel propagation of activation to a set of topographically organized feature maps. Posner & Snyder's (1975a) priming mechanisms are compatible with network-based theories like LUT.

According to the RAN model, both feature detection and feature integration are performed by a multiple soft-constraint satisfaction process (Green, 1991). Upon normal relaxation the output of the network will encode a veridical representation of the objects contained in the visual scene. However, if the input scene ceases to be displayed before the relaxation process is completed then errors of feature detection and integration will occur. The network may be constrained to return a best-fit response under these circumstances. Under certain conditions feature detection may be reasonably accurate but integration may be incomplete in which case the best-fit response may result in an illusory conjunction. It is not difficult to imagine how Posner & Snyder's (1975a, b) priming mechanisms might be incorporated into the RAN approach.

LUT and the RAN model appear to offer the same explanation of how object tokens are encoded. In LUT, and potentially in the RAN model too, the object token for a blue circle is encoded by a set of topographic maps by the activation of a unit (or units) in the *blue* feature map and a unit in the *circle* feature map. Both of these features must have the same location for them to be considered conjoined. In describing the RAN model, Green (1991) paid little attention to how objects are represented as he was primarily concerned with what he termed the architecture of visual integration. However, Green did offer the following quote;

> "If as we believe, color and form are processed in separate parts of the nervous system, why does one not simply perceive circle, triangle, blue, green without knowing which form has which color? the simple answer, I think, is that blue and circle are tagged to the same spatial location." (Attneave, 1974, p. 109)

For Attneave, and perhaps Green, to encode an object token the features of an object must be "tagged to the same spatial location". This location would need to be in viewer-centred or world-centred co-ordinates. Green discusses feature modules extensively and it might be thought that these modules encode object tokens, as is the case in LUT.

However, if object tokens are encoded by topographic feature maps, as LUT and the RAN model suggest, then preview effects upon visual feature integration could only occur if the preview and target objects share the same location. If the preview and target objects have different locations then there will not be an overlap between the their representations. Figure 1.5 depicts the topographic representation of a congruent and an incongruent conjunction preview object and their associated target objects. For simplicity, each feature map encodes only nine locations. The preview object appears centrally and the target objects appear off-centre; to the left and to the right. The figure shows that both the congruent and incongruent preview stimuli activate different feature detectors to the target stimuli; i.e., the representations for the previews and the targets do not overlap. But Posner & Snyder (1975b) hold that the representations of the previews and targets must overlap for priming to occur.

The priming of feature integration hypothesis leads to several empirical questions. First, can either or both feature previewing and conjunction previewing vary the numbers of conjunction errors that occur during an integration task? Second, if such preview effects occur do top-down priming processes, bottom-up priming processes or both mediated them. Third, are there plausible accounts of these preview effects that do not involve the priming of object tokens and if so can they be rejected. The experiments that are reported in Chapters 2 to 5 were undertaken in to find answers these questions.

1.6 Summary of Chapter

Visual feature integration is the process that isolates the information regarding each object in a scene. This information about the physical properties of an object is encoded as an object token. Illusory conjunctions can occur; i.e., object tokens can be generated that contain incorrect combinations of features from different objects. Feature integration theory (Treisman, 1990; Treisman & Gelade, 1980), location uncertainty theory (Ashby et al., 1996: Prinzmetal & Keysar, 1989) and the recurrent architecture network model (Green, 1991) are theories of feature integration and the generation of illusory conjunctions. The illusory conjunction literature does not strongly favour any one of these theories.

It was conjectured that non-spatial visual previewing may affect the production of illusory conjunctions. Visual previewing involves the presentation of a preview stimulus prior to the to-be-reported target stimulus. Previewing can have powerful effects upon the latency and accuracy of the report of the target. Bottom-up and top-down priming mechanisms have been proposed to account for these effects (Posner & Snyder, 1975b). It is possible that these processes may interact with the process of integrating visual stimuli and thereby affect the generation of illusory conjunctions; i.e., the priming of feature integration hypothesis. The experiments that are reported in this thesis investigated this possibility. The circumstances surrounding the preview effect upon illusory conjunctions may favour one of the three theories of visual integration.

CHAPTER 2: THE EFFECT OF FEATURE PREVIEWING UPON VISUAL FEATURE INTEGRATION

2.1 Outline of Chapter

In the previous chapter it was conjectured that *visual previewing*[17] (e.g., Beller, 1971; Posner & Snyder, 1975a, b; Jonides & Mack, 1984) may influence the integration of visual stimuli and consequently may vary the numbers of illusory conjunctions occurring; i.e., the priming of feature integration hypothesis. However, the possibility that (non-spatial) previewing can have this effect has not been investigated before. This chapter describes three experiments that were undertaken to determine whether *feature previewing* can influence the number of illusory conjunctions that occur. Feature previewing is a type of visual previewing in which the preview stimulus is either congruent or incongruent with the target stimulus on a single stimulus dimension.

Experiment 1, which is described in Section 2.3, investigated the effect of *colour* feature previews upon the partial report of the *colour* identities and conjunctions of two probe objects. The congruent preview stimulus was the same colour as one of the target objects and the incongruent preview stimulus was a different colour to both of the target objects. A *negative* cost-plus-benefit preview effect on conjunction error scores was observed. This was in the opposite direction to the effect that was expected. The preview effect upon conjunction errors was not attributable to those processes that cause feature errors (Prinzmetal, 1981; Treisman & Schmidt, 1982) because feature error scores did not exhibit the same effect.

Experiment 2, which is described in Section 2.4, investigated the effect of *colour* feature previews upon the partial report of the *shape* identities and conjunctions of two probe objects. However, unlike Experiment 1, there was no evidence of a cost-plus-benefit preview effect upon either conjunction error or feature error scores.

[17] This is more commonly known as visual priming. However, in this thesis to aid clarity, *previewing* is used to refer to the experimental methodology, i.e., the presentation of a preview or pre-target stimulus before the to-be-reported probe or target stimulus; the term *preview effect* refers to an observed effect of previewing upon participants' responses; and *priming* denotes Posner & Snyder's (1975a, b) hypothesized automatic and strategic processes by which preview effects are thought to occur.

Experiment 3, which is described in Section 2.5, investigated the effect of *shape* feature previews upon the partial report of the probe *colour* identities and conjunctions of two probe objects. The congruent preview stimulus was the same shape as one of the target objects and the incongruent preview stimulus was a different shape to both of the target objects. Like Experiment 2, there was no evidence of a cost-plus-benefit preview effect upon either conjunction error or feature error scores.

Section 2.6 discusses the results of the three experiments together. It was concluded that there was no evidence to suggest that either colour or shape feature previewing can affect the production of illusory conjunctions. Instead it is suggested that the effect found in Experiment 1 was due to the participants using a *preview-report strategy.*

2.2 Introduction

In Chapter 1 it was suggested that visual previewing may interact with visual feature integration thereby affecting the production of illusory conjunctions. This chapter reports several experiments that investigated the effects of *feature previewing* upon visual feature integration.

Feature previewing is a form of previewing in which the preview display contains a *task-relevant feature* (i.e., a feature that appears in the target display and is reported by participants on some of the experimental trials). There are two feature preview conditions. On a *congruent* feature preview trial, the preview display contains a feature that is also present in the target display on that trial. On an *incongruent* feature preview trial, the preview display contains a feature that is not present in the target display on that trial. For example, on a trial where the probe objects are a blue circle and a red triangle a congruent feature preview display might contain a blue or a circular object and an incongruent feature preview display might contain a green or a diamond-shaped object. A *feature preview effect* would be said to occur if the accuracy of participants' reports of target displays are different in the congruent and the incongruent feature preview conditions.

In the experiments reported in this chapter, the effect of previewing upon visual integration was quantified by the numbers of *conjunction errors* made. A conjunction error is a report of a non-existent object whose features actually appear in separate objects in the target display. It was expected that congruent feature previews would cause fewer conjunction errors than incongruent feature previews would. This preview effect was a prediction of the priming of visual integration hypothesis (see Chapter 1). The hypothesis states that automatic or strategic priming of the process of visual integration will affect the production of illusory conjunctions. Typically a visual task will be facilitated by congruent previews and interfere with by incongruent previews (e.g., Humphreys & Quinlan, 1988; Posner & Snyder, 1975a; Marangolo et al., 1993; Taylor, 1977). Therefore, congruent feature previews will be expected to *facilitate* veridical integration and will *reduce* the number of illusory conjunctions that occur. Furthermore, incongruent feature previews will be expected to *interfere* with veridical integration and *increase* the number of illusory conjunctions that occur.

However, conjunction errors need not be always caused by illusory conjunctions, they may also be caused by the same mechanisms that cause feature errors (Treisman & Schmidt, 1982). A *feature error* is a report of a feature that is not present in the target display. Two processes have been proposed to account for the existence of feature errors.

Treisman & Schmidt (op. cit.) have suggested that feature errors are caused by the visual properties of objects being incorrectly registered during feature abstraction. For instance, under certain viewing conditions a red item might cause the activation of a detector that normally responds to orange. However, the same mechanism can also produce conjunction errors. A conjunction error would occur when non-veridical feature abstraction results in the incorrect registration of a feature that, coincidentally, is the same as another feature in the target display. For example, imagine a target display that contains a blue circle and a red triangle. If the *red* feature is registered as *blue* then the viewer may report having seen a red circle. This report would be classified as a conjunction error.

Prinzmetal (1981) proposed another mechanism that may cause feature errors. He suggested that feature errors occur when a viewer does not have access to a particular feature and he or she is consequently forced to guess the feature's identity. This mechanism also can produce conjunction errors. A conjunction error would occur when a viewer incorrectly guesses the colour of one target object and thereby reports the colour of another target object. For example, imagine again a target display that contains a blue circle and a red triangle. If the viewer guessed the colour of the circle to be red then they may report a red circle; i.e., they would make a conjunction error.

It is possible that feature previewing can affect the numbers of *feature errors* that are made. This idea is supported by studies in which feature previewing has been found to affect the latency of feature recognition (e.g., Di Pace et al., 1997; Taylor, 1977). Perhaps a congruent feature preview lowers the threshold for the detection of an identical feature in the probe display. This would result in faster responses in reaction time studies. However, if the target exposure duration is fixed, a change in detection threshold may vary the number of feature errors that occur. The change in threshold may reduce the probability that a viewer is forced to guess the identity of the target feature or it may reduce the probability that a non-veridical feature is registered instead of the target feature. Either of these outcomes would result in fewer feature errors.

Given the possibility that conjunction errors can be caused by the same mechanisms that cause feature errors, it is also possible that these mechanisms might mediate a preview effect upon conjunction errors. However, there are several methods by which this alternative explanation of any preview effect on conjunction error scores could been evaluated. One method is to perform a simple baseline analysis of conjunction error and feature error scores (e.g., Treisman & Schmidt, 1982; Cohen & Ivry, 1989). This method determines the expected number of conjunction errors for a given number of feature errors observed in an experiment or condition of an experiment. Another method is to analyse the data using a multinomial model (e.g., Ashby et al., 1996). This method can be used to determine expected number of conjunction errors given the numbers of various types of report (e.g., feature errors and correct reports).

A third method is to compare the effects of the feature previewing upon conjunction error scores with its effects on feature error scores. This method had not been used before to the present study. If the same pattern of preview effects is found with conjunction errors and feature errors then they may have been caused by the same processes. For example, this would be the conclusion if the congruent preview causes significantly more conjunction errors and feature errors than the incongruent preview. The implication is that the effect upon conjunction errors was mediated by the processes that cause feature errors rather than by processes involved in the generation of illusory conjunctions. If different patterns of means are found then the preview effect on conjunction errors would appear not to have been mediated by the same processes that cause feature errors. For example, this would be the conclusion if the congruent preview causes significantly more conjunction errors than the incongruent preview but there is no significant difference in the numbers of feature errors. In this case it would be possible for the effect of previewing on conjunction errors to be mediated by the production of illusory conjunctions. This was the method employed to analyse the data from the experiments reported in this thesis.

Three experiments were undertaken. The first investigated the effect of *colour* feature previews upon conjunction error and feature error scores. This experiment is reported in the next section.

2.3 Experiment 1: Colour Previewing and Illusory Conjunctions

2.3.1 Introduction

The main goal of Experiment 1 was to determine whether the colour feature previewing can influence visual feature integration as evidenced by effects on the production of conjunction errors and feature errors. On each experimental trial, a target display containing two colour-filled geometric shapes was presented. The participants used a mouse-controlled pointer to press on-screen buttons to report of the colour identities and conjunctions of the two objects. A conjunction error occurred when a participant reported that a target object was the colour of the other target object; for example, if the target objects were a blue circle and a red triangle and the participant reported a red circle or a blue triangle. A feature error occurred when a participant reported that a target object was a colour that did not appear in the target display at all; for example, if the target objects were a blue circle and a red triangle and the participant reported a green circle or a purple triangle.

A preview or pre-target display was presented before the probe or target display. There were three different previewing conditions. In the *congruent colour preview* condition the object in the preview display (i.e., the preview object) was the same colour as one of the object in the probe display (i.e., a probe or target object). In the *incongruent colour preview* condition the preview object was a different colour to either of the probe objects. In the *no preview object* condition there was no object in the preview display. This control condition was included so that cost-benefit analysis (Jonides & Mack, 1984; Posner & Snyder, 1975b) could be performed.

The priming of feature integration hypothesis holds that congruent previews facilitate visual feature integration whereas incongruent previews inhibit visual feature integration. In the present experiment, congruent colour previews were expected to cause fewer illusory conjunctions than incongruent colour previews. This was expected to cause a significant difference in conjunction error scores between the congruent and incongruent preview conditions. Analysis of the feature error data was undertaken to determine whether the preview effect on conjunction error scores was attributable to illusory conjunctions.

2.3.2 Method

Participants

Fourteen psychology undergraduates at the University of Plymouth participated as part of the course requirements. They had either normal or corrected-to-normal vision and reported having no major visual deficits. Each person participated in a single experimental session lasting about 30 minutes.

Design

The experiment consisted of 300 trials in which the participants were presented with preview and probe displays containing coloured geometric shapes. The experiment had a two-way repeated-measures design. The independent variables were the type of preview display and trial block. There were three levels of preview display. In the congruent colour preview condition, the preview object had the same colour as one of the probe objects. In the incongruent colour preview condition, the preview object had a different colour to both the probe objects. In the no preview object condition the preview display did not contain an object. The no object preview condition was a control condition that was included to enable cost-benefit analysis (Jonides & Mack, 1984; Posner & Snyder, 1975a) of a preview effect if found. There were two levels of trial block; the experiment was split into two consecutive blocks of 150 trials.

Apparatus and Stimuli

The experiment was mediated by an Acorn Archimedes A410/1 computer. The stimuli were displayed on an Acorn AKF18 60 Hz colour monitor from a distance of approximately 75 cm under dim lighting conditions. On the Acorn computer the colours used had the following RGB values; 255, 0, 0 (red); 0, 0, 255 (blue); 0, 255, 0 (green); 255, 127, 0 (orange); 255, 0, 255 (purple); 63, 63, 63 (grey); 0, 0, 0 (black); 255, 255, 255 (white). These colour values were used in all the experiments reported in this thesis. The stimuli consisted of three displays; a preview or pre-target display, a probe or target display and a masking or post-target display. All the stimulus displays had a black background.

There were six different preview displays. In the *no preview object* condition the preview display contained only a centrally located diamond-shaped fixation point rendered in white. The other five preview displays contained a centrally located colour-filled object rendered in one of five colours: blue, green, magenta, orange and red. The preview object was a coloured square of approximately 1.68° of visual angle in height and width. Square was considered a task-neutral shape in this experiment because probe objects were never square. The displays that contained a preview object also contained a diamond-shaped fixation point that was rendered in black and superimposed on the preview object. The height and width of the fixation point was approximately 0.38° of visual angle in all preview displays.

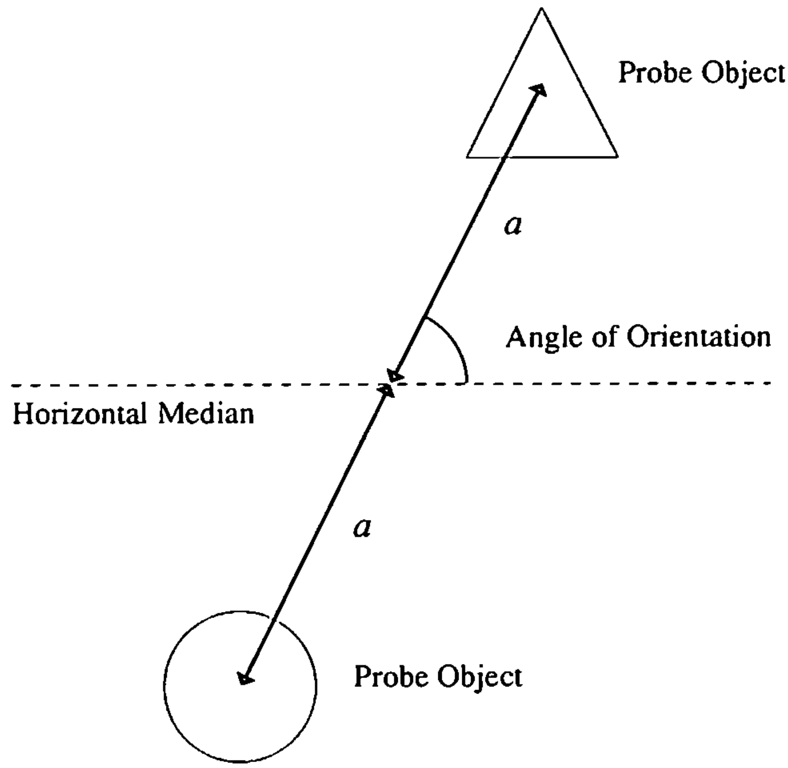

Figure 2.1. Layout and approximate dimensions of the probe displays in Experiment 1 (and Experiments 2 and 3). The retinal eccentricities (i.e., the distance from the point of fixation) of the two probe objects (distance *a*) were approximately 2.1° of visual angle.

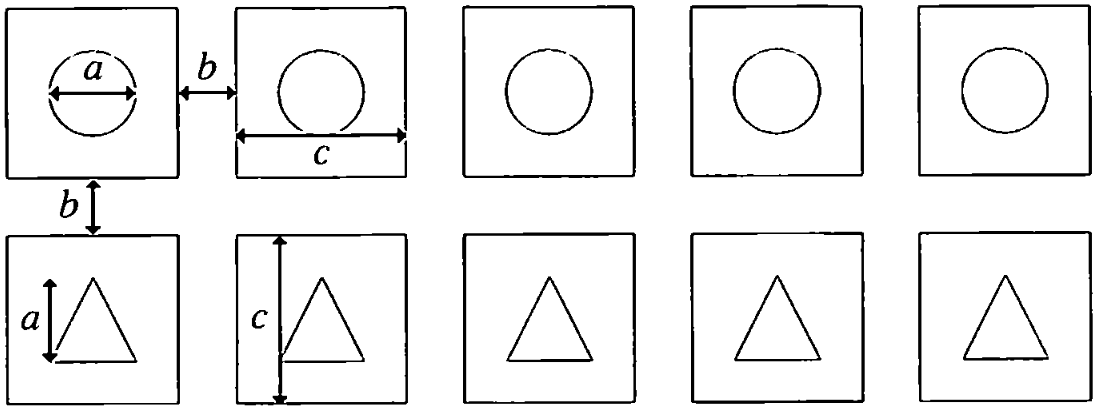

Figure 2.2. Layout and approximate dimensions, in degrees of visual angle, of the response displays in Experiment 1 (and Experiment 3). The height and width of icons (distance *a*) was 0.76°; the vertical and horizontal spacing between buttons (distance *b*) was 0.38°; and the height and width of buttons (distance *c*) was 1.99°. This particular response display would have been used on a trial when the probe objects were a circle and a triangle.

The probe display contained two probe objects (see Figure 2.1). The probe objects were colour-filled geometric shapes. The two probe colours were selected from the same set of five colours as was used to render the prime objects: blue, green, magenta, orange and red. Consequently, there were 25 possible permutations of the two colours in probe display. In 20 of these permutations the colours of the two probe objects were different. In the other five permutations the colours of the two probe objects were the same. The trials upon which these displays were presented were dummy trials where no data was collected.

The two probe shapes were randomly selected without replacement from a pool of four shapes: circle, cross, five-pointed star and triangle. The height and width of each probe item was approximately 1.68° of visual angle. The two probe objects were located so that their centres were at the ends of an unseen line approximately 4.20° in length. The midpoint of this line coincided with the centre of the display. The angle between the unseen line and the horizontal meridian was randomly determined on each trial. This ensured that the participants could not predict where the target items would be located. Consequently, the participants attended equally to the two probe objects. If they had been able to determine in advance where the probe objects would appear then one of the probe objects may have received a higher attentional priority than the object. This could have limited the number of illusory conjunctions occurring (Cohen & Ivry, 1989; Treisman & Schmidt, 1982).

The masking display consisted of two feature masks at the same locations as the probe items. Each mask was a 10 by 10 block of feature chunks randomly selected from the possible shapes and colours. Each feature chunk was approximately 0.05° of visual angle in size and the whole mask had the same height and width as the probe items.

The response display contained two rows of five on-screen buttons (see Figure 2.2). The buttons were black squares set against a mid-grey background. A coloured icon representing the possible identity of a probe object was displayed at the centre of each button. The button icons in the top row had the same shape as one of the probe objects in each of the five colour alternatives, presented in a random order across the buttons. The icons in the bottom row had the same shape as the other probe object in each of the five colour alternatives in a different random order across the buttons. For example, a probe display comprised of a red triangle and a blue circle would be followed by a response display with one row of buttons containing triangles in the five colours and the other row of buttons containing circles in the five colours.

Procedure

Each participant was given written and verbal instructions before undertaking a practise session of 30 trials, randomly selected from the full experiment. The practise session was to familiarise the participants with the stimuli and the task. The full experiment was then commenced after a brief delay and lasted about half an hour. The stimuli were viewed under dim lighting conditions from a distance of approximately 75 cm.

On each of the 300 experimental trials three stimulus displays were presented successively; a preview display, a probe display and a masking display. Finally a response display was presented and the participant reported the colours of the target objects.

The preview display was presented for 500 msecs. A tone was sounded at the onset of the display to alert the participants. The participants had been instructed to direct their gaze towards the fixation point but to ignore the preview object that was referred to in written and verbal instructions as a *distractor object* (see Taylor, 1977). There were six different preview displays. One display did not contain a preview object. This was presented in the "no preview object" condition. The other five displays contained preview objects in each of the five colours. These displays were presented on congruent and incongruent preview trials. On a congruent colour preview trial the preview colour was the same as one of the target colours. On an incongruent colour preview trial the preview colour was different to either of the target colours. Each preview display was paired with each of the 25 permutations of preview colours once in each block of trials. Therefore, there were two congruent colour preview trials to every three incongruent colour preview trials.

At the offset of the preview display, a probe display was presented for 80 msecs. This exposure duration had been found to yield above baseline conjunction errors with similar stimuli in a pilot study and in studies by other researchers (e.g., Treisman & Schmidt, 1982; Tsal et al., 1994).

Immediately after the probe display, a masking display was presented for 500 msecs. This served to limit the participants' access to the target stimuli (Breitmeyer, 1984; Kahneman, 1968). Several researchers have used masking displays in illusory conjunction experiments before (Cohen & Ivry, 1989; Treisman & Schmidt, 1982; Virzi & Egeth, 1984; Tsal et al., 1994).

Finally the response display was presented until the identities of the probe objects were reported. The participants made a forced-choice partial report of the two probe objects. They controlled an on-screen pointer, using the computer mouse, to select two on-screen buttons. The task was to select those buttons that contained icons of the probe objects that they believed they had seen in the probe display[18]. A click sound was generated to confirm button presses to the participants. This was a partial-report task because the participants were not required to recall the shapes of the target objects. These shapes were indicated to the participant by the response display. The response display provided a choice of colours but the shapes were always those that had appeared in the probe display. Therefore, the participants reported the colours that were conjoined with the given shapes. The response for a given trial was complete when two button presses had been made. No performance feedback was given during the experiment.

At the offset of the response display a plain dark field was displayed until the next trial

[18] Botella, Garcia & Barriopedro (1992) used a menu driven report system to study temporal illusory conjunctions in the rapid serial visual presentation paradigm.

commenced. The participant initiated the next trial, which started after a one second delay.

Sixty of the 300 trials were dummy trials, the responses to which were not analysed. The dummy trials were included in an attempt to make the participants' reports of the colours of the two probe objects independent of each other. The colours of the probe items were selected from a pool of five probe colours. Consequently, there were 25 possible permutations of the two colours in probe display. On 20 of these permutations the colours of the two probe objects were different. It was possible for conjunction errors to occur during the trials upon which these probe displays appeared. The responses on these trials were classified and analysed. On the other five permutations the colours of the two probe objects were the same and illusory conjunctions could not occur. It was *not* possible for conjunction errors to occur on trials when these probe displays appeared. The responses on these trials were *not* classified or analysed. These dummy trials were included in the experiment so that the participants could not use knowledge of the colour of one probe object to help determine the colour of the other. Otherwise, a participant who knew the colour of one object would also have known that other probe object was not that colour.

Table 2.1. *Mean proportions of conjunction errors and feature errors by condition in Experiment 1*

	Preview display		
		Colour preview	
	No object	Congruent	Incongruent
Conjunction errors	0.107	0.128	0.097
Colour feature errors	0.177	0.117	0.231

2.3.3 Results

The responses to each of the two probe objects on a each trial were classified as one of three types; correct reports, conjunction errors and (colour) feature errors. A correct report occurred when a participant correctly identified the colour of a probe object. A conjunction error occurred when a participant reported the colour of one probe object conjoined with the shape of the other probe object. A (colour) feature error occurred when a participant reported a colour that was not present in the probe array. The raw frequencies (per participant per condition) of conjunction errors and feature errors were transformed to proportions of the total number of object responses[19]. Table 2.1 displays the mean proportions of conjunction errors and colour feature errors in the three conditions. No statistical analyses were performed on the correct report data.

It was predicted that incongruent feature previews would cause more illusory conjunctions than congruent feature previews. There were two stages to finding evidence of such an effect. The first stage was to determine whether incongruent feature previews caused more conjunction errors than congruent feature previews. The second stage was to determine whether incongruent feature previews caused more feature errors than congruent feature previews. If this was the case then the preview effect upon conjunction error scores could be attributed to the mechanisms that cause feature errors (e.g., Prinzmetal, 1981; Treisman & Schmidt, 1982).

Conjunction errors

It was predicted that fewer conjunction errors would occur under congruent feature previewing than under incongruent feature previewing. However, exactly the reverse was found. The mean proportion of object responses classified as conjunction errors was highest in the congruent colour preview condition, next highest in the no preview object condition and lowest in the incongruent colour preview condition (see Table 2.1).

19 There were two objects to be reported on each trial, therefore the number of object reports is twice the number of trials.

A two-way repeated-measures ANOVA was performed on the conjunction error data. The mean scores in the three preview conditions were significantly different, F (2,26) = 3.74, $p < 0.05$. Follow-up analyses using Tukey's honestly significant difference test ($MS_e = 1.858 \times 10^{-3}$) identified a significant negative cost-plus-benefit preview effect (i.e., the mean conjunction error score was significantly higher in the congruent colour preview condition than in the incongruent colour preview condition), Q_{HSD} (2,24) = 3.80, $p < 0.05$. However, the benefit effect (i.e., the difference between the congruent colour preview and no preview object conditions) was not significant, Q_{HSD} (2,24) = 2.52, $p > 0.05$, and the cost effect (i.e., the difference between the incongruent colour preview and no preview object conditions) was not significant, Q_{HSD} (2,24) = 1.28, $p > 0.05$. Neither the trial block main effect, F (1,13) = 2.86, $p > 0.05$, nor the preview display by trial block interaction were significant, $F < 1$.

In the congruent colour preview condition one target object was the same colour as the preview object and the other target object was not. However, were the reports of the two target objects equally likely to be conjunction errors? Or alternatively, were the reports of the target object that matched the congruent preview object more likely to be conjunction errors than the reports of the other target object? To answer this question a repeated-measures t test of the conjunction error data from the congruent colour preview condition was undertaken. The independent variable for the purposes of this analysis was whether the target object was the same colour as the preview object (i.e., the previewed target object) or a different colour (i.e., the non-previewed target object). For example, if the preview object was blue and the target objects were a blue circle and a red triangle then the previewed object was the blue circle and the non-previewed object was the red triangle. A conjunction error of the previewed object would occur if the participant reported a red circle. A conjunction error of the non-previewed object would occur if the participant reported a blue triangle. It was found that there were significantly more conjunction errors when reporting the non-previewed target objects (mean = 11.5) than when reporting the previewed target objects (mean = 8.93), t (13) = 2.30, $p < 0.05$.

Feature errors

Analysis of the feature error data was undertaken to determine whether it was possible for the processes that cause feature errors to have mediated the negative cost-plus-benefit preview effect upon conjunction errors. If so then the feature error data would exhibit the same pattern of means as the conjunction error data. However, this was not the case. Feature error scores were lowest in the congruent colour preview condition, next lowest in the no preview object condition and highest in the incongruent colour preview condition (see Table 2.1). The conjunction error scores exhibited a different pattern of means, as described above.

A two-way repeated-measures ANOVA of the feature error data was performed. Mean feature error scores were significantly different in the three preview display conditions, F (2,26) = 34.95, $p < 0.01$. Post-hoc analysis using Tukey's honestly significant difference test ($MSe = 2.60 \times 10^{-3}$) found that the cost-plus-benefit effect, Q_{HSD} (2,26) = 49.8, $p < 0.01$, the benefit effect, Q_{HSD} (2,26) = 17.7, $p < 0.01$, and the cost effect, Q_{HSD} (2,26) = 8.11, $p < 0.01$, were all significant. Neither the trial block main effect, F (1,13) = 3.29, $p > 0.05$, nor the preview display by trial block interaction were significant, F (2,26) = 1.34, $p > 0.05$.

Is the colour reported during a feature error randomly selected or biased to be the same as the preview colour? An analysis of the feature error data from the incongruent preview condition was undertaken to answer this question. The analysis involved subdividing feature errors into two sub-categories. A *same-as-preview* feature error occurred when a participant reported that a target object was the same colour as the preview object. A *different-to-preview* feature error occurred when a participant reported that a target object was a different colour to the preview object. For example, if the preview object was green and the target objects were a blue circle and a red triangle then reporting a green circle would have been a same-as-preview feature error and reporting a purple circle or an orange circle would have been a different-to-preview feature error. There was one possible same-as-preview feature error and there were two possible different-to-preview feature errors. The expected proportion of same-as-preview feature errors was estimated to be 0.126 by dividing the observed proportion of different-to-preview feature errors by two. A two-tailed one-sample *t* test was performed comparing the observed same-as-preview feature error scores with this expected score. The mean proportion of same-as-preview feature errors (0.211) was significantly higher than the expected mean, t (13) = 12.0, $p < 0.001$. Therefore, it appears that feature error reports in the incongruent feature preview condition were biased to be the same as the preview colour.

2.3.4 Discussion

The main finding of this experiment was that congruent colour feature previews caused more conjunction errors than incongruent colour feature previews. In other words, there was a *negative* cost-plus-benefit preview effect upon conjunction error scores. However, a different outcome had been predicted. It had been expected that congruent colour previews would facilitate visual feature integration and thereby cause fewer illusory conjunctions than incongruent colour previews would.

A second finding of this experiment was that congruent colour previews caused *fewer* (colour) feature errors than incongruent colour previews. In other words, there was a cost-plus-benefit preview effect upon feature error scores, This is the opposite of the effect that was found with conjunction error scores. The finding is important because it leads to the conclusion that the processes that cause feature errors, i.e., non-veridical feature abstraction (Treisman & Schmidt, 1982) or feature guessing (Prinzmetal, 1981), cannot account for the preview effect upon conjunction errors.

It had been expected that previewing would have positive effects on both conjunction errors and feature errors. Therefore, it had been expected that either an analysis involving a baseline model (Treisman & Schmidt, 1982) or a multinomial model (Ashby et al., 1996) would need to have been performed to determine whether the effect of previewing upon conjunction errors could be attributed to the production of illusory conjunctions. However, the unexpected finding of different effects upon conjunction errors and feature errors meant that these analyses were unnecessary.

It had been expected that congruent colour previews would facilitate visual feature integration and thereby cause fewer illusory conjunctions than incongruent colour previews would. However, this was not the observed effect. Congruent colour previews caused more conjunction errors than incongruent colour previews did. The negative cost-plus-benefit preview effect may occur because although individual preview features do not affect feature integration, conjunctions of preview features do. In other words previews affect integration when they convey information about how features are combined in the target display. However, this could not be the result of top-down priming. Imagine a trial where the target objects were a blue circle and a red triangle and square objects are task-neutral with regard to shape identification. A congruent feature preview (e.g., a blue square) may cause participants to expect a blue target object rather than green one but it will not cause participants to expect a blue circle rather than a red circle or a blue triangle. Therefore, feature previews are unlikely to cause top-down priming of feature integration.

However, it may be that feature previewing affects integration by the bottom-up priming of object tokens. A congruent feature preview will activate an object token that describes an object comprised of a target feature and a task-neutral feature; e.g., a blue square. This may facilitate the integration of *blue* with *square* but interfere with the integration of *blue* with any other shape. Therefore, integration of the blue circle target object will be impeded. An incongruent feature preview will activate an object token that describes an object comprised of a task-relevant feature (i.e., one that is a target feature on other trials but not on the present trial) and a task-neutral feature; e.g., a green square. This will not affect the integration of a blue circle or a red triangle. One problem with this account is that dual-process theory of preview effects (Posner & Snyder, 1975a, b) suggests that bottom-up priming does not cause a cost effect.

Nevertheless, determining that the processes that cause feature errors did not mediate the preview effect on conjunction error scores does not ensure that the effect was mediated by illusory conjunctions. Another possible explanation of the preview effect on conjunction errors is that participants adopted, what shall be termed, a preview-report strategy. The probe was present only briefly and on occasion the participants may not have known or may not have been confident of either or both of the probe colours. Therefore the participants would have needed a strategy to complete the forced-choice report task. One strategy could be to guess the identities of the unknown colours (Prinzmetal, 1981). However, a preview effect would not have occurred if the strategy led to a random selection from the alternatives. However, if the strategy process was biased such that the preview colour was more likely to be reported than any other colour then a negative cost-plus-benefits preview effect would occur. Perhaps the participants' strategy involved knowingly reporting the preview colour; i.e., a preview-report strategy.

The following example demonstrates how a preview-report strategy could bring about the observed preview effect. Imagine a congruent preview trial in which the target objects were a blue circle and a red triangle, and the preview object was blue. If the participant did not register the colours of the target items and reported the preview colour instead then they would be equally likely to report a blue circle (i.e., a correct report) or a blue triangle (i.e., a conjunction error). Therefore, there would be extra correct reports and conjunction errors in this condition. Also imagine an incongruent preview trial in which the target objects were a blue circle and a red triangle, and the preview object was green. If the participant did not register the colours of the target items and reported the preview colour instead then they would be equally likely to report a green circle or a green triangle, both of which would be feature errors. Therefore, there would be extra feature errors expected in this condition. Consequently, the preview-report strategy account also offers an explanation of the preview effect upon feature error scores.

Another possible explanation of the observed preview effect on conjunction errors is that it was mediated by the migration of features from the preview display to the probe display, i.e., *pre-target intrusions* (McLean, Broadbent & Broadbent, 1983). Several researchers have found evidence that illusory conjunctions can occur between temporally separate displays (Gathercole & Broadbent, 1984; Intraub, 1985; Keele et al., 1988; Lawrence, 1971; McLean et al., 1983). These feature transpositions might be referred to as *temporal* illusory conjunctions to distinguish them from the (spatial) illusory conjunctions that occur between spatially-separated objects in the same display. Perhaps, in the present experiment, the features of the preview object migrated from an internal representation of the preview display into the corresponding representation of the probe display. If the colour of a congruent preview object were to migrate then more correct reports and conjunction errors would occur. If the colour of an incongruent preview object were to migrate then more feature errors would occur.

Two additional findings are compatible with the preview-report strategy and temporal illusory conjunction accounts. One of these findings is that in the congruent colour preview condition there were significantly more conjunction errors when reporting the non-previewed target than when reporting the previewed target objects. In other words on a trial where the preview was blue and the probe objects were a blue circle and a red triangle, participants were more likely to report a blue triangle than a red circle. This finding may be explained in terms of the priming of visual integration in that the preview causes the blue feature to prepared for integration. In other words, using Treisman's (1990, 1992; Treisman & Schmidt, 1982) metaphor of integrated features being conjoined with "perceptual glue" perhaps previewed features are more "sticky". A sticky feature will more easily be integrated leading to more veridical conjunctions (and therefore more correct reports) but also more illusory conjunctions (and therefore more conjunction errors). The finding may also be explained in terms of the preview-report strategy. Participants whose strategy is to report the preview colour when a target colour is unknown are more likely to report blue triangles than red circles in the above example.

The other finding, compatible with both the preview-report strategy and temporal illusory conjunction accounts, is that there were significantly more same-as-preview feature errors than expected given the numbers of different-to-preview errors. In other words, on a trial in which the preview object was green and the probe objects were a blue circle and a red triangle, the participants were more likely to report the circle or the triangle was green than report that they were purple or orange. This finding strongly supports the preview-report strategy account of the preview effects in the present experiment. The finding does not appear to be explicable in terms of the priming of visual integration, however, it may be attributable to an effect of previewing upon the process of feature abstraction. It has been suggested that feature errors are caused by non-veridical feature abstraction (Treisman & Schmidt, 1982). Perhaps feature previewing can bias this process to cause feature errors that are the same as the preview feature.

In summary, a negative cost-plus-benefit preview effect upon conjunction error scores was found. Four plausible explanations of the effect have been proposed. First, the priming of feature integration hypothesis; i.e., bottom-up and top-down priming mechanisms (Posner & Snyder, 1975b) may affect the integration of the target items. Second, similar priming mechanisms may affect the abstraction or guessing of target features thereby causing conjunction errors by chance. This explanation was ruled-out because the preview effect on feature errors was not the same as the preview effect on conjunction errors. Third, participants may report the previewed colour as being a property of one of the target objects because of a deliberate preview-report strategy. Fourth, participants may report the previewed colour as being a property of one of the target objects because the preview colour migrates into the representation of the target display. These last two explanations were supported by analyses of conjunction errors in the congruent preview condition and of feature errors in the incongruent preview condition. Experiments 2 and 3 were undertaken to decide between the competing explanations of the feature preview effect on conjunction errors.

2.4 Experiment 2: Colour Previewing and Illusory Conjunctions

2.4.1 Introduction

In Experiment 1 a negative cost-plus-benefits feature preview effect upon conjunction error scores was found. However, there are three putative explanations of this effect that are compatible with the results. First, the priming of visual feature integration may have caused the effect. Second, the effect may have been the result of participants strategically reporting the colour they had seen in the preview display. Third, the effect may have been caused by the colour of the preview object migrating into the internal representation of the probe display. Experiment 2 was conducted in order to decide between these accounts.

In most respects Experiment 2 was the same as Experiment 1. The main difference was that in Experiment 1 the participants reported the colours of the target objects whereas in Experiment 2 the participants reported the shapes of the target objects. Consequently, pre-target intrusions were not possible in the present experiment. If the preview effect that was found in Experiment 1 was caused by a strategy of reporting the preview colour then the effect would occur in Experiment 2. The strategy was possible in Experiment 1 because the preview display contained a colour that could appear in the probe display and the participants were instructed to report the probe colours. The strategy was not possible in Experiment 2 because the participants' task was to indicate which shapes were conjoined with the given colours in the probe display.

However, if the effect that was found in Experiment 1 was caused by the automatic or strategic priming of visual feature integration or the migration of features from the preview display to the probe display then the effect should also occur in Experiment 2. Also, if the effect that was found in Experiment 1 was caused by the migration of features from the preview display to the probe display then the same effect should occur in Experiment 2. Changing the report task should not affect the migration of features from the preview into the target display. For example, imagine a probe display in which the objects are a blue circle and a red triangle. On a *congruent feature preview* trial the preview object might be blue. If this feature were to migrate from the preview display to the probe display then participants would report a blue circle (a correct report) or a blue triangle (a conjunction error). On an *incongruent feature preview* trial the preview object might be green. If this feature were to migrate from the preview display to the probe display then participants would report either a green circle or a green triangle, both of which are feature errors.

In summary, if a negative cost-plus-benefit preview effect had occurred in Experiment 2 then two explanations of the effect in Experiment 1 would have remained plausible, i.e., the priming of integration or temporal illusory conjunctions. However, if no preview effect had occurred in Experiment 2 then the most plausible explanation would have been that the effect was caused by a strategy of reporting the preview colour.

The present experiment not only provides evidence regarding the possibility that previewing can affect visual integration, it also provides evidence regarding the possibility that previewing can affect feature abstraction. In Experiment 1 colour feature previews were found to affect the production of feature errors. It was suggested that this effect was mediated by the priming of visual feature abstraction. Colour and form are commonly thought to be detected in independent pathways or registered by separate feature modules (e.g., Felleman & Van Essen, 1991; Livingstone & Hubel, 1988; Treisman & Gelade, 1980; Zeki & Shipp, 1988). Therefore, the detection of colours should occur independently of shapes. Furthermore, the priming of the process of colour detection should not affect the abstraction of a shape feature. If this suggestion is true then colour feature previews would not be expected to affect the production of shape feature errors. Therefore, a preview effect on feature errors was not expected in the present experiment.

2.4.2 Method

Participants

Fifteen psychology undergraduates at the University of Plymouth participated as part of the course requirements. They had either normal or corrected-to-normal vision and no known visual deficits. Each person participated in a single experimental session lasting about 30 minutes.

Design

The experiment was a one-way repeated-measures design. The independent variable had four levels. In the congruent colour preview condition, the preview object had the same colour as one of the probe objects. In the incongruent colour preview condition, the preview object had a different colour to both the probe objects. In the no preview object condition the preview display did not contain a preview object. In the neutral preview condition, the preview object had a colour that was considered to be task-neutral because it never appeared as a colour of the probe objects.

The neutral colour preview condition was incorporated for comparison with congruent and incongruent colour preview conditions in cost-benefit analysis (Jonides & Mack, 1984; Posner & Snyder, 1975a) instead of the no preview object condition as this would be a more appropriate control if the feature previews had general preparatory effects (Jonides & Mack, 1984). The no preview object condition was included to enable comparison with the neutral colour preview condition to determine whether such general preparatory effects did occur.

Apparatus and Stimuli

The apparatus and viewing conditions were the same as in Experiment 1. The stimuli consisted of three displays; a preview display, a probe display and a mask display. As in Experiment 1 all the stimulus displays had a black background.

The probe stimuli were similar to those employed in Experiment 1, with one exception. In Experiment 1 there were only four different target shapes. In Experiment 2 a fifth shape was incorporated so that there would be equal numbers of shapes and colours. This meant that Experiments 2 and 3 could have identical designs. The probe shapes were either a circle, a cross, a diamond, a five-pointed star or a triangle.

There were seven different preview displays. Six of the displays were similar to the displays used in Experiment 1. In the *no preview object* condition the preview display did not contain a preview object. Five other preview displays contained the centrally located preview object rendered in one of five colours: blue, green, magenta, orange and red. Additionally, there was a display for the neutral colour preview condition that contained a centrally located grey square. The dimensions of the preview objects were the same as in Experiment 1, i.e., 1.68° of visual angle in height and width. There was a centrally located fixation point in all the preview displays. The height and width of the fixation point were approximately 0.27° of visual angle. However, unlike Experiment 1 the fixation point was always a white square. The diamond-shaped fixation point employed in Experiment 1 may have primed the diamond shaped probe items used in Experiment 2. In the no preview object condition the preview display contained only the fixation point. In the other conditions the fixation point was superimposed on a centrally located preview object.

The response displays were similar to those in Experiment 1 except for the icons that appeared on the on-screen buttons. The button icons in the top row buttons were the same colour as one of the probe objects in each of the five shape alternatives in a random order across the buttons. The icons in the bottom row buttons were the same colour as the other probe object in each of the five shape alternatives in a different random order across the buttons. For example, a probe display comprised of a red triangle and a blue circle would have been followed by a response display with one row of buttons containing red icons in the five shapes and the other row of buttons containing blue icons in the five shapes.

Procedure

The procedure was the same as in Experiment 1 except for the following.

Unlike Experiment 1 there were seven different preview displays. One display did not contain a preview object. This was presented on no preview object trials. Another display contained a grey square preview object. This was presented on neutral colour preview trials. The other five of displays contained preview objects in each of the five colours. These displays were presented on congruent and incongruent colour preview trials. There were equal numbers of congruent and incongruent trials. On a congruent colour preview trial the preview colour was the same as one of the target colours. On an incongruent colour preview trial the preview colour was different to either of the target colours.

There were 20 no preview object trials, 20 neutral colour preview trials, 100 congruent preview trials and 100 incongruent preview trials in which the probe objects had a different shape. There were also 5 no preview trials, 5 neutral preview trials, 20 congruent preview trials and 20 incongruent preview trials in which the probe objects had the same shape. On these dummy trials conjunction errors could not occur and consequently the data from them was not analysed.

On each trial a forced-choice partial report of the two probe objects was made. The participants' task was to select the buttons that contained icons of the probe objects that they believed they had seen in the probe display. The response display provided a choice of shapes but the colours were always those that had appeared in the probe display. When two button presses had been made the response for that trial was complete and a plain dark field was displayed. The participant initiated the next trial, which commenced after a one second delay. No performance feedback was given during the experiment.

Table 2.2. *Mean proportions of conjunction errors and feature errors by condition in Experiment 2*

	Preview display			
		Colour preview		
	No object	Neutral	Congruent	Incongruent
Conjunction errors	0.157	0.180	0.183	0.165
Shape feature errors	0.222	0.193	0.210	0.213

2.4.3 Results

Conjunction errors and feature errors were scored in a similar way to Experiment 1. A conjunction error occurred when a participant reported the shape of one probe object conjoined with the colour of the other probe object. A (shape) feature error occurred when a participant reported a shape that was not present in the probe array. The raw frequencies for each response type were transformed to proportions as in Experiment 1. Means of these scores are shown in Table 2.2.

Analysis of the conjunction error data was undertaken to discover whether colour feature previewing affected conjunction error scores in this experiment. However, conjunction error scores were roughly the same in all conditions (see Table 2.2). A one-way repeated-measures ANOVA was performed on the conjunction error data. The mean conjunction error scores in the four conditions were not significantly different, $F < 1$. This finding does not support the conclusion that colour feature previewing can affect the production of illusory conjunctions.

Analysis of the feature error data was undertaken to determine whether it was possible for the preview effect upon conjunction errors to have been mediated by the same processes that cause feature errors. However, there was little difference in the mean proportion of responses classified as feature errors in the four conditions (see Table 2.2). A one-way repeated-measures ANOVA was performed on the feature error data. The mean feature error scores in the four conditions were not significantly different, $F(3,14) = 1.73$, $p > 0.05$.

2.4.4 Discussion

The main finding of this experiment was that colour feature previewing did not affect conjunction error scores. However, a negative cost-plus-benefit preview effect was found in Experiment 1. In both experiments, colour features were previewed before the target displays were presented. The main difference between the two experiments was that in

Experiment 2 the participants reported the shapes of the target objects, whereas in Experiment 1 the participants reported the colours of the target objects. In other words, the participants in Experiment 2 were not able to strategically report the previewed feature but the participants in Experiment 1 were. The absence of a preview effect upon conjunction error scores in Experiment 2 suggests that the effect found in Experiment 1 was the result of the participants reporting the colour they had seen in the preview display.

A second finding of this experiment was that colour feature previewing did not affect feature error scores. In Experiment 1 colour feature previews were found to affect the production of feature errors. It was suggested that this effect was either mediated by the priming of visual feature abstraction or because participants were biased to report the colour of the preview. The finding of this experiment equally supports these two explanations.

However, there is another possible explanation of the lack of a preview effects in the present experiment. The different outcomes in Experiments 1 and 2 may simply have been because the participants in these experiments undertook different report tasks. Experiment 3 was undertaken to rule out the possibility that the preview effect was absent in Experiment 2 simply because the report task was different to that employed in Experiment 1.

2.5 Experiment 3: Shape Previewing and Illusory Conjunctions

2.5.1 Introduction

Experiment 2 was conducted in order to decide between three putative explanations of the negative cost-plus-benefits preview effect upon conjunction error scores found in Experiment 1. In both experiments colour previews were presented before the target displays. The main difference between the two experiments was that in Experiment 2 the participants could not report the previewed feature (i.e., they reported the target shapes) whereas in Experiment 1 the participants could report the previewed feature (i.e., they reported the target colours). No evidence of a preview effect upon conjunction error scores was found in Experiment 2. This suggests that the effect found in Experiment 1 was the result of the participants strategically reporting the colour they had seen in the preview display.

However, Experiments 1 and 2 do not completely reject the possibility that feature previewing can affect visual feature integration. There are two possibilities that have not been excluded. First, perhaps colour previewing affects integration but the preview effect occurred in Experiment 1 but not in Experiment 2 because different report tasks were performed. The participants in Experiment 1 reported the colours of the target objects, the participants in Experiment 2 reported the shapes of the target objects. Why might feature previewing affect the report of colours but not the report of shapes? Maybe colours of the stimuli used in these experiments are available for report before the shapes. Consequently, the tachistoscopic recognition task causes more shape features to be misidentified than colour features. An illusory conjunction can only occur if the constituent features are correctly abstracted. Experiment 2 may have been insensitive to a preview effect upon illusory conjunctions because of the large number of shape feature errors.

Second, perhaps colour previewing does not affect the integration of visual features but shape previewing does. Experiments 1 and 2 only tested the possibility that colour previewing can affect feature integration. Shape previewing may affect feature integration even though colour previewing appears not to.

Therefore, Experiment 3 was undertaken to determine whether shape previewing can affect the numbers of illusory conjunctions when the participants' task is to report the colours of two target objects. As in Experiment 2, participants could not strategically report the previewed features.

2.5.2 Method

Participants

The participants were 15 psychology undergraduates at the University of Plymouth who took part as a course requirement. They had either normal or corrected-to-normal vision and reported having no major visual deficits. Each person participated in a single experimental session lasting about 30 minutes.

Design

The experiment had a one-way repeated-measures design. The independent variable, preview display type, had four levels. In the congruent shape preview condition, the preview object was the same shape as one of the probe objects. In the incongruent shape preview condition, the preview object was a different shape to both the probe objects. In the no preview object condition the preview display did not contain a preview object. In the neutral shape preview condition, the preview object had a shape that was thought to be task-neutral. The shape of the neutral object was never a property of the probe objects.

Apparatus and Stimuli

The apparatus and viewing conditions were the same as employed in Experiments 1 and 2. The stimuli consisted of three displays; a preview display, a probe display and a mask display. As in Experiments 1 and 2 all the stimulus displays had a black background.

There were seven different preview displays. The preview display for the *no preview object* condition did not contain a preview object. The preview display for the neutral shape preview condition contained a centrally located grey square. The other five preview displays contained a centrally located preview object, rendered in grey, in each of the target shapes; circle, triangle, diamond, cross and five-pointed star. The dimensions of the preview objects were the same as in Experiments 1 and 2, i.e., 1.68° of visual angle in height and width. There was a centrally located fixation point in all the preview displays. The height and width of the fixation point was approximately 0.27° of visual angle. Like Experiment 2 the fixation point was always a white square. In the no preview object condition the preview display contained only of the fixation point. In the other conditions the fixation point appeared superimposed at the centre of the preview object.

The probe, mask and response displays were the same as those employed in Experiment 1.

Procedure

The procedure was the same as Experiments 1 and 2 except were stated. There were seven different preview displays. One display did not contain a preview object. This was presented on the no preview object trials. Another display contained a grey square preview object. This was presented on neutral shape preview trials. The other five of displays contained preview objects in each of the five shapes. These displays were presented on congruent and incongruent preview trials. There were equal numbers of congruent and incongruent shape preview trials. On a congruent shape preview trial the preview shape was the same as one of the target shapes. On an incongruent shape preview trial the preview shape was different to both of the target shapes. The response task was the same as employed in Experiment 1.

Table 2.3. *Mean proportions of conjunction errors and feature errors by condition in Experiment 3*

	Preview display			
		Shape preview		
	No object	Neutral	Congruent	Incongruent
Conjunction errors	0.140	0.130	0.130	0.122
Colour feature errors	0.238	0.236	0.252	0.252

2.5.3 Results

The responses were scored in the same way as in Experiment 1. A conjunction error occurred when a participant reported the colour of one probe object conjoined with the shape of the other probe object. A (colour) feature error occurred when a participant reported a colour that was not present in the probe array. The raw frequencies (per participant per condition) of conjunction errors and feature errors were transformed to proportions of the total number of object responses. Means of the resulting scores are shown in Table 2.3.

Analysis of the conjunction error data was undertaken to discover whether shape feature previewing affected the number of conjunction errors. However, conjunction error scores were roughly the same in all conditions (see Table 2.3). A one-way repeated-measures ANOVA was performed on the conjunction error data. The mean conjunction error scores in the four conditions were not significantly different, $F < 1$. This finding does not support the conclusion that shape feature previewing can prime the production of illusory conjunctions.

Analysis of the feature error data was undertaken to determine whether it was possible for the preview effects upon conjunction errors could have been mediated by the same processes that cause feature errors. However, there was little difference in the mean proportion of responses classified as feature errors in the four conditions (see Table 2.3). A one-way repeated-measures ANOVA was performed on the feature error data. The mean feature error scores in the four conditions were not significantly different, $F < 1$.

2.5.4 Discussion

The main finding of this experiment was that colour feature previewing did not affect conjunction error scores. This compliments the findings of Experiment 2. It appears that the response task in Experiments 2 and 3 did not enable participants to strategically report the previewed feature whereas the task in Experiment 1 did. Therefore, the lack of a preview effect on conjunction errors in Experiment 2 seems not to be due to the participants reporting the target shapes rather than the target colours as in Experiment 1.

Together, the findings of Experiments 2 and 3 suggest that feature previewing does not affect feature integration and that the negative cost-plus-benefit preview effect found in Experiment 1 was caused by a deliberate strategy. It seems that the participants reported the colour they had seen in the preview display. Consequently there is no evidence to suggest that feature previewing can affect visual feature integration.

2.6 General Discussion

Three experiments were undertaken to determine whether feature preview stimuli can affect the integration of subsequently presented target stimuli. In all the experiments the target stimuli were two colour-filled geometric shapes. Feature preview displays, containing a single task-relevant shape or colour, were presented before the target displays in these experiments. The participants' task was to report the colour and shape of the two objects in the target display. There were two feature preview conditions. On a congruent feature preview trial the pre-target display contained a feature that was also present in the target display. On an incongruent feature preview trial the pre-target display contained a feature that did not appear in the target display. A (cost-plus-benefit) preview effect would be said to occur if the accuracy of participants' reports of a target display is different in the congruent feature preview condition than in incongruent feature preview condition. The participants' visual integration performance was quantified by the number of conjunction errors they made.

In Experiment 1, the colour features were previewed and the participants reported the colours of the target items. A negative cost-plus-benefit preview effect was found. This effect was consistent with the priming of visual integration. However, it was also plausible that the effect was caused by the participants deliberately reporting the preview colour instead of probe colours. Some additional analyses supported this alternative account.

Two further experiments were undertaken in which it was not possible for participants to report the previewed feature. In Experiment 2 colour features were previewed and the participants reported the shapes of the target items and in Experiment 3 shape features were previewed and the participants reported the colours of the target items. Neither of these experiments supported the existence of an effect of feature previewing upon conjunction error scores. Therefore, the preview effect found in Experiment 1 appears to have been caused by the participants using a strategy. Taken together, the three experiments described in this chapter do not provide any evidence that feature previewing can effect visual feature integration and the production of illusory conjunctions.

Although feature previewing did not appear to affect conjunction error scores in Experiments 1, 2 and 3, it did appear to affect feature error scores. Several explanations of this effect are possible. Prinzmetal (1981) holds that feature errors are caused by participants guessing the identities of target features. Perhaps previewing influences the numbers of guesses that are needed to be made. Alternatively, perhaps the guessing process is biased to produce feature reports that are the same as the previewed feature. Treisman & Schmidt (1982) maintained that feature errors are caused by non-veridical feature abstraction. Perhaps previewing can affect the feature abstraction process. If so this might also account for preview effects on the time course of visual identification (e.g., Di Pace et al., 1997; Taylor, 1977).

Although, the experiments reported in this chapter do not support the conclusion that feature previewing can affect visual feature integration it is possible that other forms of previewing may affect integration and illusory conjunctions. Although visual integration does not appears to be primed by single features perhaps it may be primed by a preview object comprising two or more features. In the next chapter the effects of conjunction previewing, in which a conjunction of features is previewed, on feature integration and illusory conjunctions were investigated.

CHAPTER 3: THE EFFECT OF CONJUNCTION PREVIEWING UPON VISUAL FEATURE INTEGRATION

3.1 Outline of Chapter

This chapter describes three experiments that were undertaken to determine whether *conjunction previewing*, i.e., the previewing of a pairing of a colour feature with a shape feature, can influence the production of conjunction errors. The results of these experiments establish the existence of an effect of conjunction previewing upon conjunction error scores and support the conclusion that the effect may be mediated by bottom-up and top-down priming (Posner & Snyder, 1975b) of illusory conjunction formation.

Experiment 4, which is described in Section 3.3, investigated the effect of conjunction previewing upon the whole-report of two probe objects. The congruent conjunction preview stimulus was the same colour and shape as one of the probe objects and the incongruent conjunction preview stimulus was the same colour as one of the probe objects and the same shape as the other probe object. A cost-plus-benefit preview effect on conjunction error scores was found. Feature error scores did not exhibit the same effect, therefore, the preview effect upon conjunction errors does not appear to be attributable to the processes that cause feature errors; e.g., the guessing of features (Prinzmetal, 1981) and non-veridical feature identification (Treisman & Schmidt, 1982).

Experiment 5, which is described in Section 3.4, investigated how preview-probe stimulus-onset asynchrony (SOA) interacts with the effect of conjunction previewing upon conjunction errors. The conjunction preview effect was replicated, but it did not appear that preview-target SOA affects the magnitude of the effect. Consequently, there is little evidence that a top-down priming mechanism is not responsible for the preview effects found in Experiments 4 and 5.

Experiment 6, which is described in Section 3.5, investigated how the predictive validity of the preview displays interacts with the effect of conjunction previewing upon conjunction errors. A significant cost-plus-benefit effect of conjunction previewing upon conjunction error scores was found only when there were three congruent trials to every one incongruent trial. Therefore, it appears that a top-down priming mechanism may also be involved in the conjunction preview effect.

The results of the three experiments are discussed together in Section 3.6. It was concluded that both bottom-up and top-down priming of the production of illusory conjunctions may cause the conjunction preview effect. However, several alternative explanations of the effect are also proposed. The consequences of the experimental findings for theories of integration are considered.

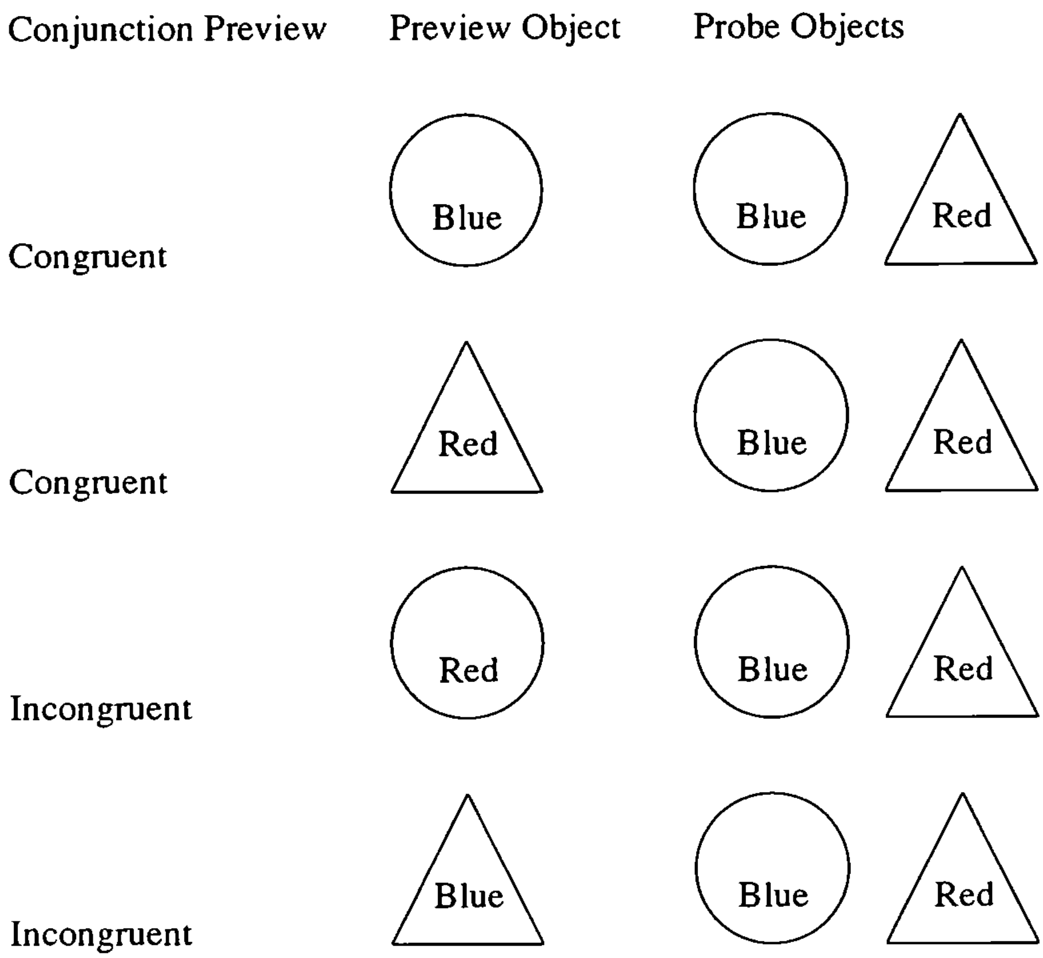

Figure 3.1. Congruent and incongruent conjunction preview objects for a probe display consisting of a blue circle and a red triangle. Note that all the probe objects have a colour and a shape that are also present in the probe display. The congruent and incongruent conjunction previews differ only in whether the colour and shape are features of the same probe object (i.e., a congruent conjunction preview) or are features of different probe objects (i.e., an incongruent conjunction preview).

3.2 Introduction

In Chapter 1 it was suggested that visual previewing may interact with the process of visual feature integration, thereby affecting the production of illusory conjunctions. However, in Chapter 2 no evidence was found to support the existence of an effect of *feature previewing* upon feature integration. Nevertheless, it may be possible for some other form of visual previewing to affect feature integration. This chapter reports several experiments in which the effects of *conjunction previewing* upon visual feature integration were investigated. *Conjunction previews* present the viewer with a conjunction of two visual features.

In conjunction previewing the preview display contains an object composed of two features that also appear in the subsequent target display. There are two conjunction preview conditions. On a *congruent* conjunction preview trial, the preview display contains an object that is identical to one of the objects in the target display of that trial. On an *incongruent* conjunction preview trial, the preview display contains an object composed of two features that appear in different target objects. For example, on a trial where the probe objects are a blue circle and a red triangle a congruent conjunction preview display would contain a blue circle or a red triangle and an incongruent conjunction preview display would contain a blue triangle or a red circle (see Figure 3.1). Therefore, congruent and incongruent conjunction previews differ not in the features they contain, both contain a colour and a shape that are also present in the probe display. Instead, they differ in the way those features are conjoined in the probe display. In the congruent conjunction preview the two features belong to the same probe object and in the incongruent conjunction preview the two features belong to different probe objects. A conjunction preview effect could be said to occur if the accuracy of participants' reports of a target display is different in the congruent conjunction preview condition than in incongruent conjunction preview condition.

As in Experiments 1, 2 and 3, the effect of previewing upon visual integration was quantified by the number of *conjunction errors* made. A conjunction error is a report of a non-existent object whose features actually appear in separate objects in the target display. It was expected that congruent conjunction previews would cause fewer conjunction errors than incongruent conjunction previews would. This preview effect was a prediction of the priming of feature integration hypothesis. This hypothesis states that bottom-up or top-down priming of the process of visual integration will affect the production of illusory conjunctions. Congruent previews will be expected to *facilitate* veridical integration and therefore will *reduce* the number of illusory conjunctions that occur. Incongruent previews will be expected to *interfere* with veridical integration and therefore *increase* the number of illusory conjunctions that occur.

Although feature previewing did not appear to affect conjunction error scores in Experiments 1, 2 and 3, it did appear to affect feature error scores. Nevertheless, conjunction previewing was not expected to affect feature error scores in the present experiments. This was because the feature preview effects of the congruent and incongruent conjunction previews were the same. The objects in both the congruent and incongruent conjunction preview displays consisted of two features, one colour and one shape, that were the same as features of the two objects. In the experiments reported in this chapter, the participants were required to report the colour and shape of the two target objects. A conjunction preview, irrespective of whether it was congruent or incongruent, would affect the report of one colour and one shape. Therefore, the effects of the two types of conjunction preview upon the processes that cause feature errors were expected to be equal.

The design of congruent and incongruent conjunction previews had an important consequence for the analysis of whether a conjunction preview effect upon conjunction errors, if found, was mediated by the processes that cause feature errors. Observed conjunction errors are not only caused by illusory conjunctions but can also be produced by errors of feature abstraction such as illusory features and feature guesses. Consequently, in Experiment 1 it had been intended that an analysis of the expected number of conjunction errors given the number of feature errors would be undertaken; i.e., a baseline analysis (e.g., Treisman & Schmidt, 1982). However, this analysis was unnecessary because, unexpectedly, the pattern of means for conjunction errors was different to the pattern of means for feature errors. The advantages of this method over baseline analysis were noted. If, as expected, conjunction previewing did not affect feature error scores then a significant effect of conjunction previewing would imply that the effect may have been caused by different numbers of illusory conjunctions occurring in the two preview conditions.

The priming of integration hypothesis suggests that a conjunction preview effect upon conjunction error scores might be due to either bottom-up or top-down priming (Posner & Snyder, 1975a, b) of visual feature integration processes, which results in the production of illusory conjunctions. It would be interesting to determine whether both bottom-up and top-down priming mechanisms could account for a conjunction preview effect if found.

Two methods are widely used to determine whether a preview effect is caused by bottom-up or top-down processes (Posner & Snyder, 1975a, b). One method involves the manipulation of the time between the onsets of the preview and probe displays, i.e., the preview-probe *stimulus-onset asynchrony* (SOA)[20]. It is thought that it takes time to generate a specific expectation regarding the probe, following the presentation of the preview (Posner & Snyder, 1975a, b). When the preview-probe SOA is long participants are able to generate such expectations and therefore top-down priming is possible. However, when the preview-probe SOA is very brief, there is insufficient time to generate a specific expectation and top-down priming will not occur. Preview effects that happen under these conditions are usually attributed to bottom-up priming processes (e.g., Simon, 1988; Taylor, 1977). Experiment 5, which is reported in this chapter, was undertaken to

[20] A variety of terms are used to describe the temporal relationship of the preview and the probe; e.g., inter-stimulus interval (Carr et al., 1982; Humphreys & Quinlan, 1988), stimulus-onset asynchrony (Marangolo, et al., 1993; Posner & Snyder, 1975; Taylor, 1977), cue lead time (Laarni & Häkkinen, 1994; Laarni, Koski & Nyman, 1996), and prime duration (Arguin & Bub, 1995).

determine the effect of manipulating the preview-probe SOA upon conjunction previewing.

Another widely-used method for determining whether a preview effect is attributable to bottom-up or top-down priming involves the manipulation of the *predictive validity* of the *selective preview* displays[21]. Predictive validity can be operationalized as the ratio between the numbers of congruent and incongruent preview trials. When there are more congruent trials than incongruent trials, participants are thought to expect that a congruent trial is more likely to occur than an incongruent trial. This is thought to lead to top-down priming (Posner & Snyder, 1975a, b). When there are equal numbers of congruent and incongruent conjunction preview trials, participants are thought not to have expectations and therefore do not employ top-down priming. Preview effects under these conditions are usually attributed to bottom-up priming (e.g., Arguin & Bub, 1995; Di Pace et al., 1997; Humphreys & Quinlan. 1988; Marangolo et al., 1993; Taylor, 1977). Experiment 6, described later in this chapter, was undertaken to determine the effect of manipulating predictive validity upon conjunction previewing.

In summary, the three experiments described in this chapter were undertaken to test whether conjunction previewing can affect visual feature integration and to investigate possible causes of the effect. Experiment 4 was performed to discover whether conjunction previewing can affect the production of conjunction errors. Experiments 5 and 6 were performed to discover whether the preview effect found in Experiment 4 is attributable to bottom-up and top-down priming processes.

[21] The adjective *selective* is used to describe congruent and incongruent previews as opposed to neutral or control previews (Jonides & Mack, 19984).

3.3 Experiment 4: Conjunction Previewing and Illusory Conjunctions

3.3.1 Introduction

Experiment 4 was conducted to discover whether conjunction previewing can affect the production of conjunctions errors. On each experimental trial, a target display containing two colour-filled geometric shapes was presented. The participants used a mouse-controlled pointer to report the colours and shapes of both probe objects. A conjunction error occurred when a participant reported an object that was the colour of one target object and the shape of the other target object; for example, if the target objects were a blue circle and a red triangle and the participant reported either a red circle or a blue triangle. A feature error occurred when a participant reported that a target object was a colour or a shape that did not appear in the target display at all; for example, if the target objects were a blue circle and a red triangle and the participant reported a green circle or a blue cross.

A preview or pre-target display was presented before the probe display. There were three different preview conditions. In the *congruent conjunction preview* condition the preview object was the same colour and shape as one of the probe objects. In the *incongruent conjunction preview* condition the preview object was the same colour as one of the probe objects and the same shape as the other probe object. In the *no preview object* condition there was no object in the preview display.

3.3.2 Method

Participants

Eighteen psychology undergraduates at the University of Plymouth participated as part of the course requirements. All had normal or corrected-to-normal vision.

Design

A one-way repeated-measures design was employed. There were three levels of the independent variable. In the congruent conjunction preview condition, an object that had the same colour and shape as one of the probe objects was presented before the probe display. In the incongruent conjunction preview condition, an object that had the same colour as one of the probe objects and the same shape as the other probe object was presented before the probe display. In the no preview object condition, there was no object presented before the probe display. There were 16 experimental trials in each of the conditions.

Apparatus and Stimuli

The experiment was mediated by an Acorn Archimedes A5000 computer. The stimuli were displayed on an Acorn AKF18 60 Hz colour monitor. The stimuli consisted of three displays; a preview or pre-target display, a probe or target display and a mask or post-target display. All the stimulus displays had a black background. There was also a response display, which enabled the participants to report the target items.

The contents of the preview display were determined by the trial's condition. In the no preview object condition the preview display contained only of centrally located white fixation point. In the other two conditions the preview displays contained a centrally located colour-filled geometric object; i.e., a *preview object*. In the congruent conjunction preview condition the preview object was the same colour and shape as one of the probe objects. In the incongruent colour preview condition the preview object was the same colour as one of the probe objects and the same shape as the other probe object. The preview objects were the same size as in Experiments 1, 2 and 3; i.e., the height and width of each item was approximately 1.68° of visual angle. A white square fixation point was superimposed on the preview objects at their centre; i.e., the fixation point was at the centre of the display. The height and width of the fixation point were approximately 0.27° of visual angle.

The layout of the probe display was the same as in the previous experiments. The probe display consisted of two probe objects (see Figure 2.2 in Chapter 2). The probe objects were colour-filled geometric shapes. The two probe colours were selected from a pool of five colours: blue, green, magenta, orange and red. The two probe shapes were selected from a pool of five shapes: circle, cross, diamond, five-pointed star and triangle. On experimental trials the colours and shapes were randomly selected without replacement. This ensured that the two probe colours and the two probe shapes were both different. As in Experiments 1, 2 and 3, the height and width of each probe item was approximately 1.68° of visual angle.

The two probe objects were located so that their centres were at either end of an unseen line approximately 4.2° in length. The midpoint of this line coincided with the centre of the display. Consequently, the retinal eccentricities (i.e., the distance from the point of fixation) of the two probe objects were 2.1°. The angle between the unseen line and the horizontal meridian was randomly determined on each trial. This was necessary to ensure that participants' attention was equally divided between the two probe objects. If the participants had been able to predict where the probe objects would appear then one of the probe objects may have received a higher attentional priority than the other probe object.

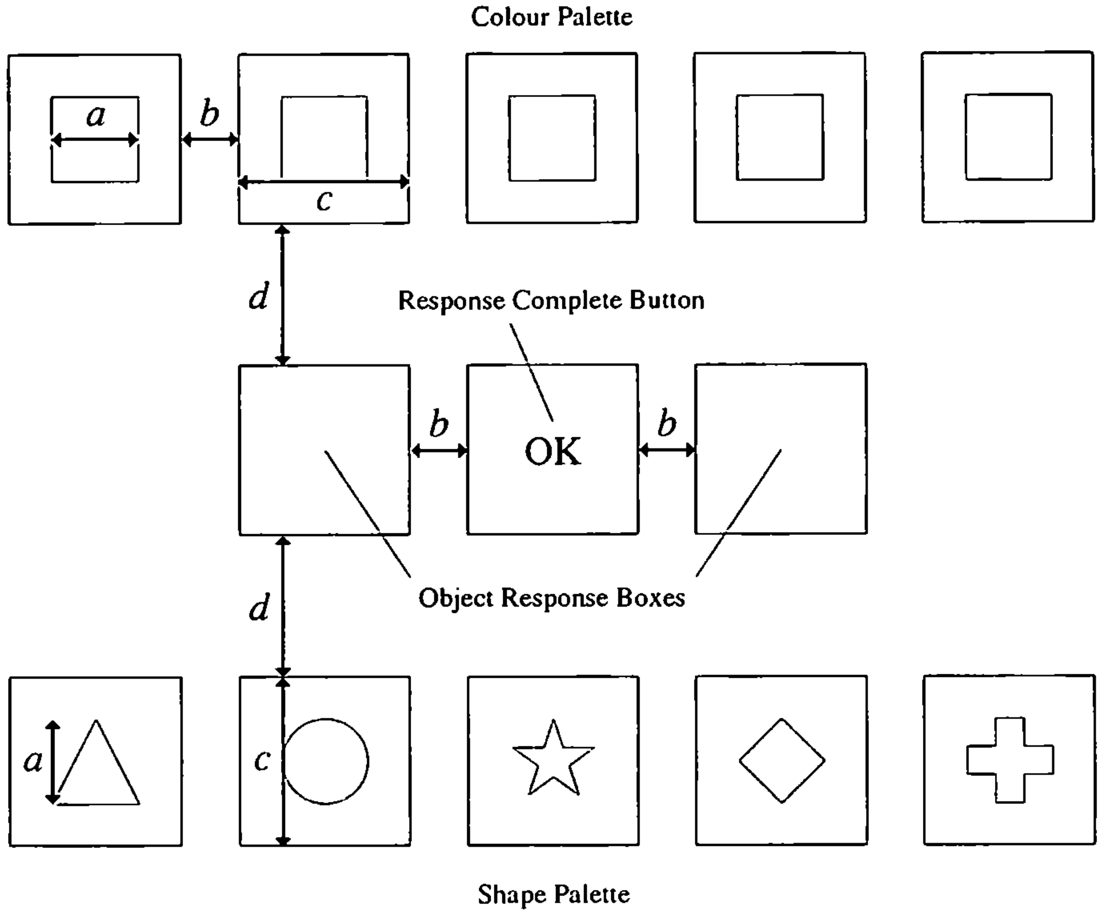

Figure 3.2. Layout and approximate dimensions of the *drag-and-drop* response display in degrees of visual angle. The height and width of icons (distance *a*) was 0.76°; the horizontal spacing between boxes (distance *b*) was 0.38°; the height and width of boxes (distance *c*) was 1.99°; and the vertical spacing between the palettes and the object response boxes (distance *d*) was 1.53°.

The mask displays were the same as in Experiments 1, 2 and 3. Each mask display consisted of two feature masks at the same locations as the probe items on that trial. Each mask was a 10 by 10 block of feature chunks randomly selected from the possible shapes and colours. Each feature chunk was approximately 0.05° of visual angle in size and the whole mask had the same height and width as the probe items.

The response display comprised of a palette of shape icons, a palette of colour icons, two response boxes, one for each probe object, and the response complete button (see Figure 3.2). Each palette consisted of a row of five colour or shape icons superimposed on a larger black square. The black squares were set against a grey background. Colour icons were squares of the five feature colours. Shape icons were rendered in the same grey as the screen background. The location of feature icons within the palette was randomized on each trial. The palette of colours was presented at the top of the display and the palette of shapes was presented at the bottom of the display. Along the horizontal median was a row of three black squares. The flanking squares were the *object response boxes* into which participants composed their responses. The central square, the *response complete button*, contained the label *OK* rendered in white.

Procedure

Each participant was given written and verbal instructions before undertaking a practise session of 30 trials, randomly selected from the full experiment. The practise session was to familiarise the participants with the stimuli and the task. The full experiment then commenced after a brief delay and lasted about half an hour. The stimuli were viewed under dim lighting conditions from a distance of approximately 75 cm.

On each of the experimental trials three stimulus displays were presented successively; a preview display, a probe display and a masking display. At the end of each trial a response display was presented and the participant reported the colours of the target objects.

The preview display was presented for 500 msecs. A tone was sounded at the onset of the display to alert the participants. As in Experiments 1, 2 and 3, the participants had been instructed to direct their gaze towards the fixation point but to ignore the preview object, which was referred to in written and verbal instructions as a *distractor object* (see Taylor, 1977). A relatively long preview exposure duration was considered necessary to ensure that participants had correctly abstracted and integrated the preview features before the target appeared. Too brief an exposure duration may have caused the preview features to be free-floating in which case conjunction previewing may not have been effective[22].

Next the probe display was presented for 100 msecs. The display contained two coloured geometric shapes, the probe objects. On experimental trials the colours and shapes of the probe objects were both different allowing conjunction errors to occur. Immediately after the probe display, a masking display appeared for 500 msecs.

Finally the response display was presented until the identities of the probe objects were reported. The response screen comprised of a palette of shape icons, a palette of colour icons, two object response boxes and a response complete button. On each trial the participant made a forced-choice, non-verbal, whole report of the colours and shapes of the two probe objects. They controlled an on-screen pointer, using the computer mouse, to drag-and-drop icons from the palettes into the object response boxes[23]. When a colour icon and a shape icon were dropped into an object response box the composite coloured shape icon was displayed in the box. Participants were able to change the colour or shape in a response box by dragging-in the desired replacement feature icon. The participants were required to fill both response boxes with a composed coloured shape icon for them to be able to proceed to the next trial. When a participant thought that they had completed their report they would press the response complete button. If the report was incomplete an error tone would be sounded indicating to the participant that they needed to drag-in the missing

[22] It was considered prudent first to discover whether previews that are presented for relatively long time are effective and later to investigate how brief the preview duration can be.

[23] Essentially this task is a mechanised colour version of the task used by Butler & Morrison (1984) in which the participants drew the target stimuli onto a template.

feature or features. If the report was complete then a blank display would be presented for one second followed by the next trial. The participants were not informed about the accuracy of their final report during the experiment.

Many of the trials were dummy trials. These were included to control participants' expectations either about the predictive relationship between the preview and probe displays or about the co-occurrence of features within the probe display. Participants' responses to the dummy trials were not analysed.

Some dummy trials were included so that participants would not be able to predict the identity of probe features from their knowledge of the preview. These dummy trials were included to disguise the fact that the conjunction previews always contained two features that were also in the target array; i.e., to minimize strategic priming effects of the previews upon non-veridical feature identification and feature guessing. In these dummy trials the preview display contained one of the following; an object the same colour as one of the probe items but having a shape not present in the probe display, an object the same shape as one of the probe items but having a colour not present in the probe display, or an object comprised of a colour and shape not present in the probe display. There were 25 of each of these type of trials.

Other dummy trials were included to control participants' expectations about the co-occurrence of features within the probe display. These were necessary so that if conjunction previewing had affected feature error scores then an analysis using a baseline model would be possible. It is an implicit assumption of the baseline model that the responses to each probe object are independent. The two object responses on a trial would not have been independent if participants had been able to use knowledge of the colour or shape of one probe object to help determine the colour or shape of the other. For example, had there only been trials on which both probe colours were different, a participant who correctly detected that one object was red could have inferred that the other item was not red. As a result the participants' judgements about the two colours would not have been independent. Consequently, on 9 of the 25 trials in each preview condition the features of the two probe objects matched in some way. These matching probe feature trials were the dummy trials. On four of these trials the colours of the probe objects matched, on a further four trials the shapes of the probe objects matched and on the other one trial both the colours and the shapes of the probe objects matched[24]. It was not possible for conjunction errors to occur on these trials. The responses to these trials were not classified nor analysed.

[24] The ratio of the numbers of these different types of trials meant that the probe colours and shapes were independent. The colours and shapes of the probe items were selected from pools of five colours and five shapes. Consequently, there were a possible 625 permutations of the two colours and two shapes appearing in the probe display. On 400 of the permutations the colours and shapes of the two probe objects were different. On 100 of the permutations the colours of the two probe objects were different but the shapes were the same. On another 100 of the permutations the shapes of the two probe objects were different but the colours were the same. Finally, on the other 25 permutations the two probe objects were the identical.

Table 3.1. *Mean proportions of conjunction errors and feature errors by condition in Experiment 4*

	Preview display		
		Conjunction preview	
	No object	Congruent	Incongruent
Conjunction errors	0.089	0.071	0.128
Feature errors	0.269	0.224	0.274

3.3.3 Results

The responses to each of the two probe objects on each trial were classified as one of four types; correct reports, conjunction errors, feature errors and double feature errors. A correct report occurred when the colour and shape of a probe object was correctly identified. A conjunction error occurred when the colour of one probe object was reported to be conjoined with the shape of the other probe object. Feature errors could occur in two ways. A (colour) feature error occurred when the shape of a probe object was correctly identified but its reported colour was not in the probe. A (shape) feature error occurred when the colour of a probe object was correctly identified but its reported shape was not in the probe. Double feature errors occurred when neither the colour nor the shape of a reported object were in the probe. No statistical analyses were performed on the double feature error data. The raw frequencies (per participant per condition) of conjunction errors and feature errors were transformed to proportions of the total number of object responses[25]. Table 3.1 displays the mean proportions of conjunction errors and feature errors in the two conjunction preview conditions and the no preview object control condition.

Analyses were undertaken to answer two key questions. First, an ANOVA was performed upon the conjunction error data to discover whether congruent conjunction previewing caused more conjunction errors than incongruent conjunction previewing did. Second, an ANOVA was performed upon the feature error data to determine whether any preview effects found to act upon conjunction errors was mediated by non-veridical feature abstraction or the guessing of features rather than by the generation of illusory conjunctions. Also, two additional analyses were performed to see whether the effect of conjunction previewing was a consequence of participants reporting the identity of whole preview objects resulting in pre-target intrusions.

[25] There were two objects to be reported on each trial, therefore the number of object reports is twice the number of trials.

Conjunction errors

The conjunction error data supports the existence of a cost-plus-benefit conjunction preview effect. Table 3.1 shows that the mean proportion of responses classified as conjunction errors was lower in the congruent conjunction preview condition than in the incongruent conjunction preview condition.

A one-way repeated-measures ANOVA was performed on participants' conjunction error scores in the three preview conditions. It was necessary to transform the data because the sphericity assumption of ANOVA was violated and the data were scored as the proportion of responses upon which a conjunction error occurred (see Appendix 2). The analysis showed there to be at least one significant difference in mean scores between conditions, F (2,34) = 4.31, $p < 0.05$. Post-hoc analysis using Tukey's honestly significant difference (HSD) test ($MS_e = 1.344 \times 10^{-2}$) revealed significantly fewer conjunction errors under the congruent conjunction preview condition than under the incongruent conjunction preview condition, Q_{HSD} (3,34) = 3.98, $p < 0.05$; i.e., there was a significant cost-plus-benefit conjunction preview effect. The differences between mean scores in the congruent conjunction preview condition and the no preview object condition, Q_{HSD} (3,34) = 0.98, $p > 0.05$, and between the incongruent conjunction preview condition and the no preview object condition, Q_{HSD} (3,34) = 3.01, $p > 0.05$, were not significant; i.e., there was no evidence of separate cost and benefit conjunction preview effects.

In the incongruent conjunction preview condition, the colour of one target object and the shape of the other target object were the same as the colour and shape of the preview object. A conjunction error could be a report of the previewed colour and shape or the non-previewed colour and shape. Were the two types of conjunction error equally likely to occur? To answer this question a repeated-measures t test of the conjunction error data from the incongruent conjunction preview condition was undertaken. The independent variable for this analysis was whether the reported object was the same as the preview object (i.e., a previewed conjunction error) or composed of the non-previewed target features (i.e., the non-previewed conjunction error). For example, if the preview object was a blue triangle and the target objects were a blue circle and a red triangle then the report of a blue triangle was a previewed conjunction error and the report of a red circle was a non-previewed conjunction error. There were significantly more previewed conjunction errors (mean proportion of responses = 0.051) than non-previewed conjunction errors (mean proportion of responses = 0.031), $t(17) = 2.21$, $p < 0.05$.

Feature errors

Analysis of the feature error data was undertaken to determine whether the cost-plus-benefit conjunction preview effect could be attributable to the processes that cause feature errors rather than be mediated by illusory conjunctions. Conjunction previewing did not appear to affect feature error scores.

A one-way repeated-measures ANOVA was performed on the feature error scores across the three preview conditions. There was no significant differences in mean scores between conditions, $F(2,34) = 2.59$, $p > 0.05$. Therefore, the cost-plus-benefit preview effect upon conjunction errors does not appear to be mediated by the processes that cause feature errors (i.e., non-veridical feature abstraction or feature guessing).

Correct reports

The task was to report two probe objects. In the congruent conjunction preview condition one target object was identical to the preview object and the other target object was not. However, were correct reports of the two target objects equally likely or was the target object that matched the preview object more accurately reported? To answer this question a repeated-measures t test of the correct reports data from the congruent conjunction preview condition was undertaken. The independent variable was whether the target object was the same as the preview object (i.e., the previewed target object) or different (i.e., the non-previewed target object). For example, if the preview object was a blue circle and the target objects were a blue circle and a red triangle then the previewed object was the blue circle and the non-previewed object was the red triangle. There were significantly more correct reports of previewed target objects (mean proportion of responses = 0.719) than of non-previewed target objects (mean proportion of responses = 0.576), t (17) = 2.52, $p <$ 0.05.

Responses to target objects pairs

In each trial two target objects were reported. the report of each object could result in a correct report, conjunction error and feature error. It is possible that the above analyses of correct report, conjunction error and feature scores may ignore interactions between the reports of the two target objects. There were 15 possible outcomes. A Table of mean scores for each possible outcome in each preview condition appears in Section 8.1.4.

The most common outcome was that both objects were correctly reported, which occurred on 36% of trials. The second most common outcome, occurring on 26% of trials, was that one object was correctly reported whilst the other resulted in a shape feature error (e.g., a blue circle and a red triangle reported as a blue circle and a red cross). Two outcomes both occurred on approximately 9% of trials. In one outcome, one object was correctly reported whilst the other resulted in a colour feature error (e.g., a blue circle and a red triangle reported as a blue circle and a green triangle). In the other outcome, one object was correctly reported whilst the other resulted in a double feature error (e.g., a blue circle and a red triangle reported as a blue circle and a green cross).

The fifth, sixth and seventh most frequent outcomes all incorporated at least one conjunction error. On 5% of trials the other object resulted in a shape feature error (e.g., a blue circle and a red triangle reported as a red circle and a blue cross). On another 5% of trials the other object also resulted in a conjunction error (e.g., a blue circle and a red triangle reported as a red circle and a blue triangle). In other words on these trials the true colours of the target objects were transposed in the participant's report. On 3% of trials the other object was correctly reported (e.g., a blue circle and a red triangle reported as a blue circle and a red circle).

The table in Section 8.1.4 shows that all the outcomes that incorporate at least one conjunction error were more frequent in the incongruent conjunction preview condition than in the congruent conjunction preview condition. This supports the findings from the analyses of conjunction error scores. The table also shows that all except one of the outcomes that incorporate at least one colour feature error or shape feature error were more frequent in the incongruent conjunction preview condition than in the congruent conjunction preview condition. The exception to this trend was when both target objects resulted in shape feature errors (e.g., a blue circle and a red triangle reported as a blue cross and a red diamond).

Baseline analyses

Baseline analyses were undertaken for each experimental condition. For each object reported there were three possible colour feature errors and three possible shape feature errors but only two possible conjunction errors. For example if the target objects were a blue circle and a red triangle, in reporting the identity of the blue circle the possible colour feature errors would be green circle, orange circle or purple circle. The possible shape feature errors would be blue cross, blue diamond and blue star. The possible conjunction errors would be red circle and blue triangle. Therefore, if both types of response are caused by the misidentification or guessing of features there should be one conjunction error for every three feature errors, i.e., the baseline or expected level for the proportion of conjunction errors for this experiment is a third of the proportion of feature errors.

One sample t tests were undertaken to compare the observed conjunction error scores with the expected score determined from the baseline model. In the no preview object condition the difference between the expected conjunction error score (0.090) and the observed mean score (0.089) was not significant, $t\ (17) = 0.06$, $p > 0.05$. the difference between the expected (0.075) and observed (0.071) conjunction errors scores in the congruent conjunction preview condition was also not significant, t (17) = 0.24, $p > 0.05$. Unlike in the other conditions, in the incongruent conjunction preview condition the observed mean conjunction error score (0.128) was greater than the expected score (0.091) although the difference was not significant, t (17) = 1.50, $p > 0.05$.

It is an implicit assumption of the model that there is a strong positive linear relationship between conjunction error and feature error scores. However, this assumption is not supported by the Pearson's product-moment correlations between conjunction error and feature error scores in each condition (no preview object, r (17) = 0.005, $p > 0.05$; congruent conjunction preview, r (17) = 0.138, $p > 0.05$; and incongruent conjunction preview, r (17) = -0.016, $p > 0.05$). Therefore, the baseline model may be inappropriate for these data. Furthermore, there is no evidence of a monotonic relationship between conjunction error and feature error scores. Spearman's rank-order correlations between conjunction error and feature error scores in each condition were not significant (no preview object, r (17) = -0.061, $p > 0.05$; congruent conjunction preview, r (17) = 0.162, $p > 0.05$; and incongruent conjunction preview, r (17) = 0.058, $p > 0.05$).

3.3.4 Discussion

The main finding was the significant cost-plus-benefit conjunction preview effect upon conjunction error scores. It appears that fewer conjunction errors are caused by congruent conjunction previews than by incongruent conjunction previews. This finding is compatible with the priming of feature integration hypothesis. However, on its own the finding does not establish that the difference in conjunction errors is due to a difference in the number of illusory conjunctions.

Although a significant cost-plus-benefit conjunction preview effect was found there was no evidence of separate cost and benefit effects. Nevertheless, the control condition may not have been appropriate to determine the separate cost and benefit effects of conjunction previewing. The displays used in the congruent and incongruent conditions contained a probe object, whereas the displays used in the control condition did not contain a preview object at all. There may have been a general warning effect (Jonides & Mack, 1984) of any prime object on the production of conjunction errors. Therefore, the separate cost and benefits that were observed in this experiment may have incorporated a general warning effect.

A second finding was that conjunction previewing did not appear to affect feature error scores. Therefore there is no evidence that the processes that produce feature errors (i.e., feature guesses or feature misidentifications) caused the preview effect on conjunction error scores. The congruent and incongruent conjunction previews had been designed to have the same effects on feature abstraction and feature guessing. This result suggests that the function of this aspect of the design was successful.

Taken together the two main findings are compatible with there being a preview effect upon the production of illusory conjunctions. In other words, it appears that incongruent conjunction previewing may cause more illusory conjunctions than congruent conjunction previewing does. If the effect of conjunction previewing upon conjunction errors does involve the production of illusory conjunctions then theories of visual feature integration will need to account for it.

The data were reclassified to show the responses to each of the two target objects in a trial. There were cost-plus-benefit preview effects with all of the types of reports that incorporated one or more conjunction errors. This supports the main finding. However, it should also be noted that there were cost-plus-benefit preview effects with nearly all the reports that comprised at least one feature error.

Baseline analyses showed that there were more conjunction errors than expected in the incongruent conjunction preview condition but the difference was not significant. In the other conditions there were fewer conjunction errors than expected. Consequently, there is no evidence that more conjunction errors occurred than would be expected given the numbers of feature errors.

However, the simple baseline model used may not be appropriate for the data from this experiment. It is an implicit assumption of the model that there is a strong positive linear relationship between conjunction error and feature error scores. However, there was not a strong positive correlation between conjunction error and feature error scores in any of the three conditions. There are two possible reasons for these weak correlations. One possible reason is that the simple baseline model used is inappropriate for data from this experiment. It is an implicit assumption of the baseline analysis used in this experiment that the response to each target object was independent of the other. However, this assumption appears to be untenable. If the independence assumption had been true then there would have been far fewer trials upon which two conjunction errors occurred together, On such trials the report of the target colours and shapes are transposed relative to their true relationships; e.g., a blue circle and a red triangle reported as a blue triangle and a red circle. This was the outcome on 4.7% of trials. However, the expected percentage of such trials, calculated by squaring the mean proportion of conjunction errors, was only 0.9%. Furthermore, a conjunction error and a correct report occurred together on only 2.6% of trials, even though it is expected that two conjunction errors occurring together will be be less frequent than just one conjunction error.

If paired conjunction errors had been caused by a pair of feature misidentifications or feature guesses then pairs of colour feature errors (0.2% of trials) and pairs of shape feature errors (1.5% of trials) should have been far more frequent than observed. For a given pair of target objects there are three possible pairs of colour feature errors and three possible pairs of shape feature errors but only one possible pair of conjunction errors. Therefore, the expected percentage of paired conjunction errors is 0.85%, far less than the observed percentage. It appears that the two target object reports per trial were not independent.

Consequently the baseline model used to analyse the data in this experiment appears to have been inappropriate.

The other possible reason for the weak correlations between feature error and conjunction error scores is that a large proportion of the conjunction errors were not both caused by the misidentification or guessing of features. Even if participants did not independently report the two target objects in a display, one would expect there to be a monotonic relationship between feature error scores and conjunction error scores. However, there is no evidence of such a relationship in any of the conditions. Consequently it appears that feature errors and conjunction errors may be caused by different processes.

So how might the effect of conjunction previewing be explained? As is often the case with new findings there are several equally plausible accounts. The most interesting explanation (as far as students of visual integration and illusory conjunctions may be concerned) would be if the effect is caused by previewing interacting with the process of visual feature integration, thereby affecting the generation of illusory conjunctions. If this were found to be the case then a new avenue of research would be available for the study of visual feature integration and illusory conjunctions. Detailed discussion of some alternative explanations of the conjunction preview effect is referred to later (see Section 3.6).

It is widely believed (e.g., Neely, 1977; Posner & Snyder, 1975b) that preview effects are caused by two priming processes; top-down and bottom-up priming. Therefore, it is to be expected that there are top-down and bottom-up priming effects upon the integration of visual features. It has been suggested that bottom-up and top-down priming processes can be identified by the way the duration between the onsets of the preview and probe displays interacts with a preview effect (Posner & Snyder, op. cit.). Bottom-up priming is not thought to occur when preview-probe inter-stimulus interval is very long; i.e., 2 secs or more (Posner & Snyder, 1975b). This is because the residual effects of priming are thought to dissipate quickly. After this time the activation levels or the thresholds that are thought to be affected by the preview, have returned to normal. Prime-probe SOA in the range of 80 to 250 msecs has been reported to generate bottom-up priming effects (e.g., Posner & Snyder, 1975a).

The top-down priming mechanism is thought not to affect behaviour when the preview-probe stimulus-onset asynchrony (SOA) is under 100 msecs (Posner & Snyder, 1975a; Taylor, 1977). It has been suggested that a stimulus exposed for this length of time will not enable participants to generate a specific expectation about the target (Posner & Snyder, 1975b). In the present experiment the preview-probe SOA was 500 msecs so it was possible for both bottom-up and top-down priming to have caused the preview effect. Also, if the preview-probe SOA is too brief then the preview might fail to activate the topographic maps or object file representations that may be the locus of the priming of feature integration. If the integration of features of the preview stimulus is not complete then priming of object token representations cannot take place. In the present experiments the preview-probe SOA was 500 msecs to ensure that the features of the preview display were abstracted and integrated veridically.

It has been suggested that bottom-up and top-down priming can be identified by observing the interaction with the preview effect of varying the numbers of congruent and incongruent trials; i.e., the predictive validity of the preview stimuli (Posner & Snyder, 1975a). The bottom-up priming mechanism is thought not to take account of predictive validity as it is driven by bottom-up constraints, which ensures that each trial is independent of the others. However, the top-down priming mechanism is affected by predictive validity. Taylor (1977) found that predictive validity affects costs and benefits only when prime-probe SOA is 400 msecs or more. It is considered that if the numbers of congruent and incongruent trials are equal then it would not be rational for participants to use previewed information to predict the contents of the probe. It would not be possible for participants to predict the identity of one of the probe objects given their knowledge of the preview display. Consequently, preview effects that occur when there are equal numbers of congruent and incongruent preview trials are normally attributed to bottom-up priming processes rather than top-down ones. But, if there were more congruent trials than incongruent trials then such predictions would be rational. Therefore, it would be possible for both bottom-up and top-down priming mechanisms to account for preview effects when there are more congruent than incongruent trials. When, there are more incongruent trials than congruent trials the rational strategy would be to expect the preview object not to appear in the target. Perhaps certain tasks would suggest an alternative expectation based on the preview. In the present experiment there were equal numbers of congruent and incongruent conjunction preview trials so the preview effect appears to have been mediated by an bottom-up priming process.

Researchers often confirm whether a preview effect is attributable to bottom-up or top-down priming using cost-benefit analysis (Jonides & Mack, 1984; Posner & Snyder, 1975a). Bottom-up priming is thought to be characterized by a significant benefit effect in the absence of a significant cost effect. Top-down priming is associated with a significant cost effect and a significant benefit effect together. It was not possible to confirm either pattern of effects in Experiment 4 as neither the cost effect nor the benefit effect was significant.

There were two other findings of Experiment 4 that were compatible with the priming of integration hypothesis. However, these findings also suggested alternative explanations of the observed effects. On congruent conjunction preview trials participants were significantly more likely to correctly report the probe object that was identical to the preview object (i.e., the previewed probe) than correctly report the other (i.e., non-previewed) probe object. For example, imagine a trial in which the preview object had been a blue circle and the probe objects had been a blue circle and a red triangle. The participants were more likely to report having seen a blue circle than a red triangle.

There are several possible explanations for this effect. First, it may have been a consequence of the integration of the features of the previewed probe having been more successful than the integration of the features of the non-previewed probe. This is compatible with the priming of integration hypothesis. Second, the effect may have been caused by the identification of the features of the previewed probe having been more accurate than the identification of the features of the non-previewed probe. In other words the finding is in accordance with the view that previewing a feature facilitates the accuracy of reporting of that feature (see Chapter 2). Third, the effect may have been caused by the intrusion of the preview object into the report of the probe display. Therefore, the effect may not be rightly called a preview effect at all, rather a pre-target intrusion effect (McLean et al., 1983). There are two possible reasons why pre-target intrusions might occur in the present experiment; the participant may perform a preview-report strategy (see Chapter 2) or the preview objects may migrate into the probe display (Botella & Eriksen, 1992; Botella et al., 1992; Broadbent & Broadbent, 1987; Intraub, 1985; Keele et al., 1988; Lawrence, 1971; McLean et al., 1983). These alternative accounts of the effects observed in the present experiment are discussed in more detail in Section 3.6.

Another finding was also compatible with the priming of integration hypothesis but again suggested alternative explanations of the results. In the incongruent conjunction preview condition there were significantly more previewed conjunction errors than non-previewed conjunction errors. For example, imagine a trial in which the preview object had been a blue circle and the probe objects had been a red circle and a blue triangle. Participants would be more likely to report having seen a blue circle than a red triangle. In other words previewing a non-veridical conjunction causes the report of that conjunction. Three explanations of this effect are possible. First, the effect may be described thus; the additional illusory conjunctions caused by the incongruent conjunction preview tend to involve the same conjunction of features as in the preview. Maybe the previewed incongruent conjunction primes the production of illusory conjunctions of the previewed features. Second, the effect may have been caused by the identification of the previewed features having been more accurate than the identification of the other target features.

Consequently, the finding may be attributed to the facilitation of reporting previewed features. Third, the effect may have been caused by the intrusion of the preview object into the report of the probe display. Again these pre-target intrusions may have been caused by a preview object report strategy or by the temporal migration of preview objects.

Preview effects have sometimes been explained as being due to the preparation or selection of a motor plan in response to the preview rather than the activation of a particular stimulus (Arguin & Bub, 1995; La Berge, et al., 1970; Simon, 1988). However, the conjunction preview effect cannot be due to response selection because until the response display was presented, the participants did not know what actions would be necessary to complete a report. This is because arrangement of the feature palettes was randomized on each trial.

In summary, a significant cost-plus benefit conjunction preview effect upon conjunction error scores was found. This preview effect was found not to be mediated by the mechanisms that cause feature errors. One explanation of these findings is that conjunction previewing activates an object-centred object token representation and this subsequently influences the production of illusory conjunctions during the integration of the target display. This may occur because of bottom-up or top-down priming processes or both. These explanations will be investigated further in the following two experiments in this chapter. In these experiments the interaction of preview-probe SOA and predictive validity with conjunction previewing was investigated. Other accounts of the effect suggest the conjunction preview effect may be better described as a pre-target intrusion effect. Perhaps participants adopt a high-level strategy based on the expectation that an object identical to the preview object will appear in the target display. Alternatively, perhaps preview objects migrated into the perception of the probe display. These alternative explanations of the findings of Experiment 4 are discussed further in Section 3.6.

3.4 Experiment 5: Preview-Probe Stimulus-Onset Asynchrony (SOA) and the Conjunction Preview Effect

3.4.1 Introduction

Experiment 4 found evidence of a cost-plus-benefit conjunction preview effect upon conjunction errors. It was suggested that the preview effect may have been caused by priming processes similar to those posited by Posner & Snyder (1975a, b). However, on its own Experiment 4 does not tell us which of these priming mechanisms accounts for the effect of conjunction previewing.

One way of determining whether a preview effect is caused by a bottom-up priming process or a top-down priming process is to observe how preview-probe SOA interacts with the effect. Top-down priming is not expected to be affected by a delay between the presentation of the preview and the presentation of the probe. If top-down priming causes the conjunction preview effect then a pause of 2 secs or more should not have much effect on this process. It seems unlikely that a participant will consciously generate an expectation then forget it after a second or so. Consequently, it would be expected that a conjunction preview effect will occur under both levels of preview-probe SOA.

On the other hand, if the conjunction previewing effect is caused by a bottom-up priming process then a delay of 2 secs would enable the activation in the primed representation to return to its baseline level before the probe appears. Therefore, we would expect bottom-up conjunction previewing to have little effect upon reporting the probe and the conjunction preview effect would only occur when the preview-probe SOA was 500 msecs.

The present experiment was undertaken to determine whether the conjunction preview effect was mediated by a bottom-up priming process or a top-down priming process or by both. The preview-probe SOA was manipulated and the consequences for the conjunction preview effect were observed. Congruent and incongruent conjunction previews were presented under two levels of preview-probe SOA. The method used in the 500 msecs

SOA condition was essentially the same as that used in Experiment 4. The only difference between the 500 msecs and 2 secs SOA conditions was that in the latter there was a 1.5 sec delay between the offset of the preview display and the onset of the prime display (see Figure 3.3).

In Experiment 4, the participants undertook some dummy trials, in which the probe objects were either the same colour, the same shape or the same colour and shape. These trials had been included so that, if necessary, a baseline analysis could be performed to determine whether more conjunction errors had occurred than expected. There were also dummy trials upon which the preview object contained features that were not present in target display. As there was no effect of conjunction previewing upon feature error scores a baseline analysis was not required.

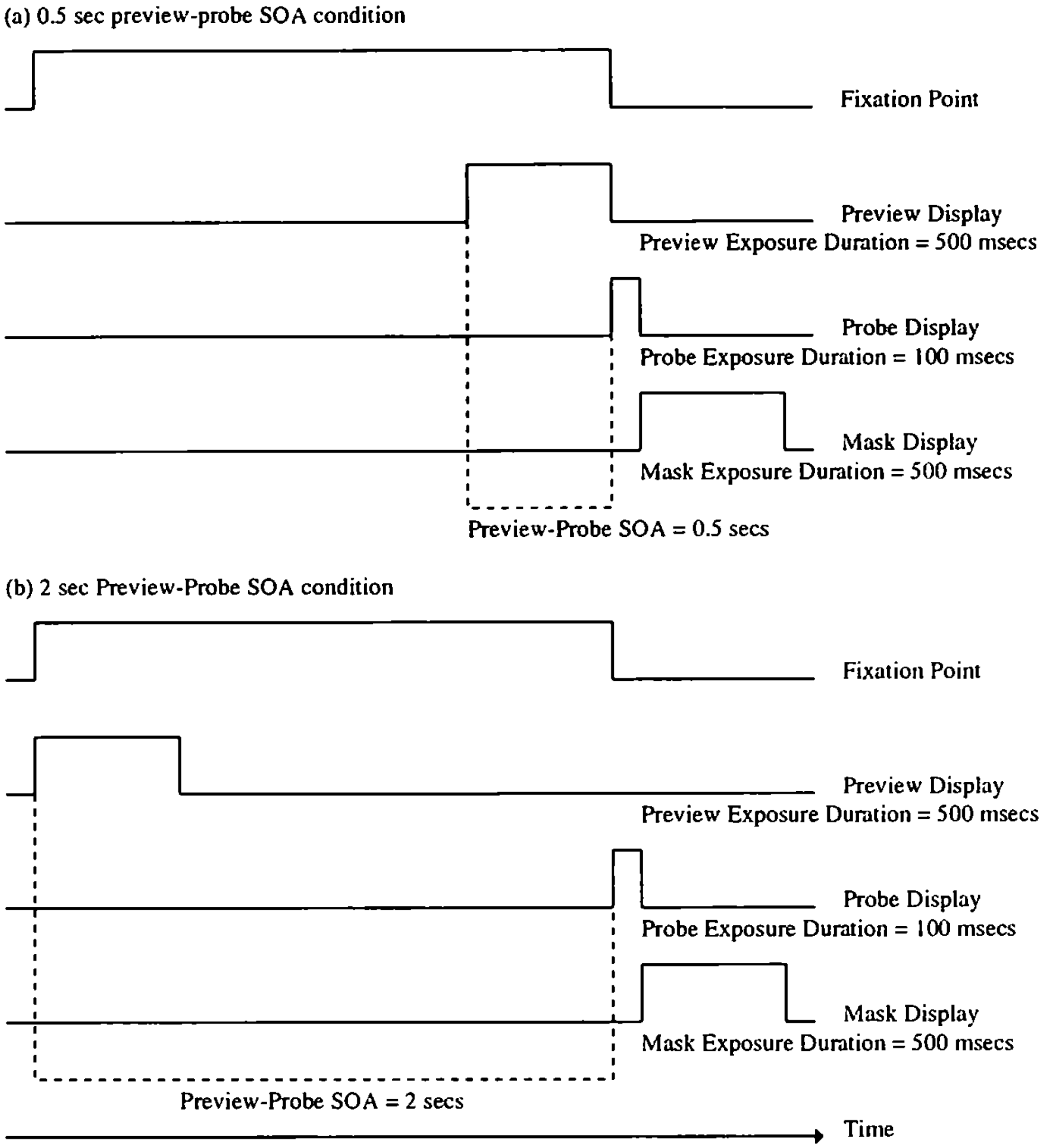

Figure 3.3. Presentation of stimuli in the two stimulus-onset asynchrony (SOA) conditions of Experiment 5.

3.4.2. Method

Participants

Sixteen psychology undergraduates at the University of Plymouth participated as part of the course requirements or for a nominal fee. All had normal or corrected-to-normal vision.

Design

The experiment had a two-way fully repeated-measures design. The independent variables were preview type and preview-probe stimulus-onset asynchrony (SOA). Preview type had three levels. In the congruent conjunction preview condition, an object that had the same colour and shape as one of the probe objects was presented before the probe display. In the incongruent conjunction preview condition, an object that had the same colour as one of the probe objects and the same shape as the other probe object was presented before the probe display. In the neutral object preview condition, an object comprised of a colour and shape that never features of the probe objects was presented before the probe display. The preview-probe SOA was either 500 msecs or 2 secs. There were 30 trials in each cell of the design. Unlike Experiment 4 there were no dummy trials.

Apparatus and Stimuli

Like Experiment 4, the displays were generated by an Acorn Archimedes A5000 computer and displayed on an Acorn AKF18 60 Hz colour monitor. The stimuli consisted of four displays; a preview or pre-target display, a fixation-only display, a probe or target display and a mask display. These displays all had a black background.

On all trials the preview display contained a square fixation point presented at the centre of the screen overlaid upon a preview object. On congruent conjunction preview trials the preview object was the same colour and shape as one of the probe objects. On incongruent conjunction preview trials the preview object was the same colour as one of the probe objects and the same shape as the other probe object. On neutral object preview trials the preview object was a grey square. The preview objects were the same size as in Experiment 4. The fixation-only display consisted of a square fixation point, height and width 0.27° of visual angle, located at the centre of the display.

In all conditions there was a white square fixation point located at the centre of the preview display, superimposed on a centrally located preview object. The other contents of the preview display were determined by the trial's condition. In the congruent conjunction preview condition the preview object was the same colour and shape as one of the probe objects. In the incongruent colour preview condition the preview object was the same colour as one of the probe objects and the same shape as the other probe object. In the neutral preview condition, the preview object was a grey square. Preview objects, probe objects and the fixation point were the same size as in Experiment 4.

The probe and mask displays were generated in the same way as in Experiment 4. On all trials the two probe objects had different colours and different shapes. The response displays were identical to those of Experiment 4.

Procedure

Each participant was given written and verbal instructions before undertaking a practise session of 30 trials, randomly selected from the full experiment. The full experiment was then commenced after a brief delay and lasted about half an hour. The stimuli were viewed under dim lighting conditions from a distance of approximately 75 cm.

The procedure for presenting the stimuli used in the previous experiment was amended to accommodate the preview-probe SOA (see Figure 3.3). During the presentation phase of 500 msecs SOA trials the following occurred. A brief tone was sounded whilst the fixation-only display was presented for 1.5 secs. Then the preview display was presented for 500 msecs. This was followed by the probe display, which was presented for 100 msecs, and finally the masking display, which was presented for 500 msecs. On 2 sec preview-probe SOA trials the fixation-only display was presented between the preview display and the probe display for 1.5 secs. This arrangement ensured that the fixation point was present for an equal period of time in trials at both levels of preview-probe SOA. The response method was the same as in Experiment 4. The participants were informed by the experimenter at the outset that the colours and shapes of the two probe objects on a given trial would always be different.

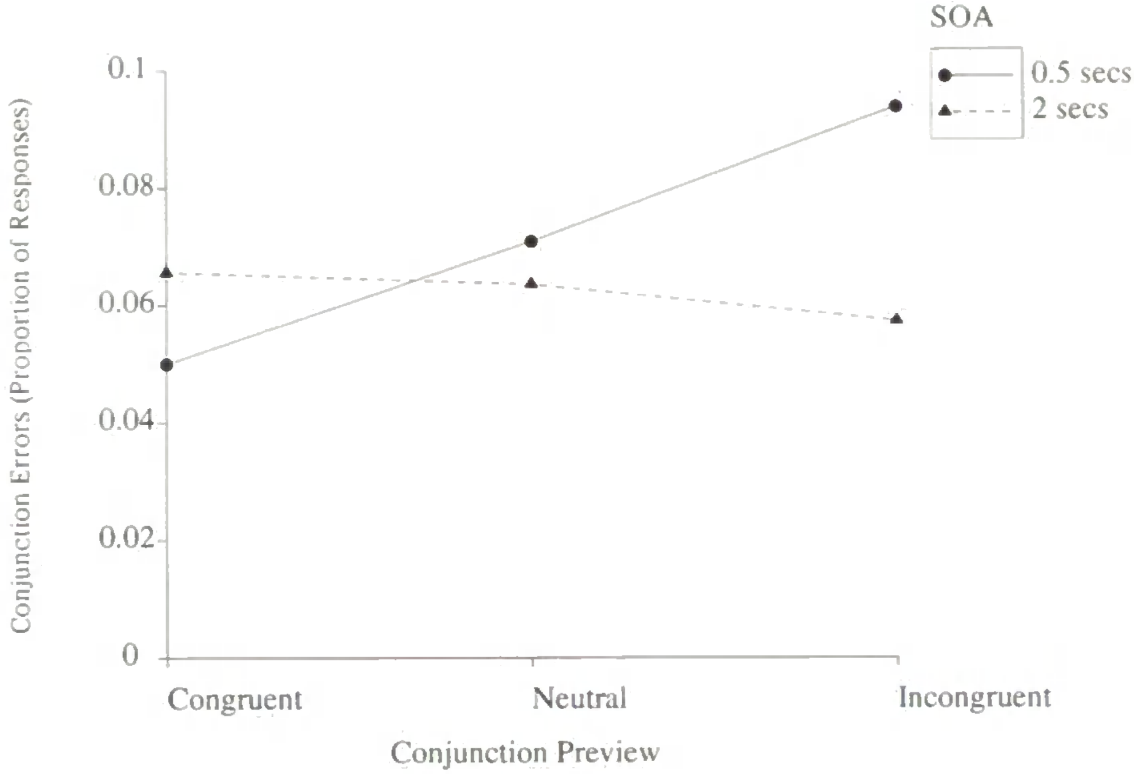

Figure 3.4. Mean proportion of responses classified as conjunction errors by conjunction preview type and preview-probe stimulus-onset asynchrony (SOA) in Experiment 5.

3.4.3. Results

Conjunction errors and feature errors were scored and transformed to proportions in the same way as in Experiment 4. As before, analyses of variance were performed upon the conjunction error and feature error scores.

Analysis of the conjunction errors data was undertaken to discover whether there was evidence of conjunction preview effects at each level of preview-probe SOA. Figure 3.4 presents the mean proportion of responses classified as conjunction errors by conjunction preview type and preview-probe SOA. A three-by-two fully repeated-measures design ANOVA was performed on the conjunction error data.

Figure 3.4 shows that in the 0.5 sec preview-probe SOA condition the mean proportion of conjunction errors was highest in the incongruent conjunction preview condition, next highest in the neutral object preview condition and lowest in the congruent conjunction preview condition. The figure also shows that in the 2 sec preview-probe SOA condition the mean proportion of conjunction errors was highest in congruent conjunction preview condition, next highest in the neutral object preview condition and lowest in the incongruent conjunction preview condition.

The main effect of preview type was significant, F (2,30) = 3.70, $p < 0.05$. Tukey's HSD tests ($MS_e = 6.78 \times 10^{-4}$) were performed. There was a significant difference between the congruent and incongruent conjunction preview conditions, Q_{HSD} (3,30) = 3.85, $p < 0.05$, i.e., there was evidence of a cost-plus-benefit preview effect upon conjunction errors. The differences between the neutral object and congruent conjunction conditions, Q_{HSD} (3,30) = 2.04, $p > 0.05$, and the neutral object and incongruent conjunction conditions, Q_{HSD} (3,30) = 1.81, $p > 0.05$, i.e., the benefit and cost effects respectively, were not significant.

Figure 3.4 shows the effect of preview type was not the same at the different levels of SOA. However, the interaction between preview type and SOA was not significant, F

(2,30) = 2.97, $p > 0.05$. Figure 3.4 also shows that conjunction error scores were higher when SOA was 0.5 sec than when it was 2 sec. However, the preview-probe SOA main effect was not significant, $F(1,15) = 3.04, p > 0.05$.

Analysis of the feature error data was undertaken to determine whether the preview effects upon conjunction errors could have been mediated by illusory features or guessing, rather than illusory conjunctions. A three-by-two fully repeated-measures design ANOVA was performed on the feature error data. Neither of the main effects nor the interaction was significant.

As in Experiment 4, analyses were performed to determine whether participants were more likely to report the target colour and target shape that were identical to the preview object than the other target colour and target shape. In the incongruent conjunction preview condition there were two types of conjunction error. One type is the report of the previewed colour and shape (i.e., a previewed conjunction error) and the other is the report of non-previewed colour and shape (i.e., a non-previewed conjunction error). For example, if the preview object was a blue triangle and the target objects were a blue circle and a red triangle then the report of a blue triangle was a previewed conjunction error and the report of a red circle was a non-previewed conjunction error.

A two-way repeated-measures ANOVA of the conjunction error data from the incongruent conjunction preview condition was undertaken. One independent variable for this analysis was whether the conjunction error was previewed or non-previewed. The other independent variable was preview-probe SOA. The difference between the mean proportion of previewed conjunction errors (0.077) and the mean proportion of non-previewed conjunction errors (0.074) was in the same direction as in Experiment 4 but not significant, $F < 1$. The two-way interaction was not significant either, $F < 1$.

In the congruent conjunction preview condition there were two types of correct report. One type is the report report of the previewed colour and shape (i.e., a previewed correct report) and the other is the report of non-previewed colour and shape (i.e., a non-previewed correct report). For example, if the preview object was a blue circle and the target objects were a blue circle and a red triangle then the report of a blue circle was a previewed correct report and the report of a red triangle was a non-previewed correct report.

A two-way repeated-measures ANOVA of the correct report data from the congruent conjunction preview condition was undertaken. One independent variable for this analysis was whether the correct report was a previewed or non-previewed. The other independent variable was preview-probe SOA. The difference between the mean proportion of previewed correct reports (0.640) and the mean proportion of non-previewed correct reports (0.556) was in the same direction as in Experiment 4 and was significant, F (1,15) = 9.74, $p < 0.01$. The two-way interaction was not significant, $F < 1$.

3.4.4 Discussion

Evidence of a main effect of preview type upon conjunction error scores was found. Post-hoc tests provided evidence of a difference between the congruent conjunction preview condition and the incongruent conjunction preview condition. This finding compliments the finding in Experiment 4 of a cost-plus-benefit preview effect. As in Experiment 4, there was no evidence of separate benefit and cost conjunction preview effects.

It was also found that conjunction previewing did not appear to affect feature error scores. Consequently, there is no evidence that the preview effects on conjunction errors were caused by those processes that cause feature errors; e.g., the misidentification of features or guessing of unknown features. It is plausible, therefore, that the cost-plus-benefit preview effect on conjunction errors was caused by illusory conjunctions.

The rationale for this experiment was to investigate whether the conjunction preview effect upon conjunction errors was affected by preview-probe SOA to determine whether or not it was possible for the conjunction preview effect effect to have been mediated by a top-down priming process. Top-down priming is expected to be unaffected by a delay between the presentation of the preview and target displays. The preview type by preview-probe SOA interaction upon conjunction error scores was not significant suggesting that the conjunction previewing effect was similar in the 0.5 sec and 2 sec SOA conditions. Consequently, on the face of it there is no evidence that the conjunction preview effect is not mediated by a top-down priming mechanism.

However, the above conclusion must be qualified because the observed interaction was close to the prescribed significance level. Furthermore, the interaction effect was disordinal. In the 500 msecs preview-probe SOA condition there were *fewer* conjunction errors with congruent conjunction previews than with incongruent conjunction previews, as in Experiment 4. By contrast, in the 2 sec preview-probe SOA condition there were *more* conjunction errors with congruent conjunction previews than with incongruent conjunction previews. Should these results be borne out, perhaps by a more powerful experiment, then there would be evidence that a delay between the preview and target displays interferes with the mechanism that causes the previewing effects upon conjunction error scores. Such a finding would be contrary to the top-down priming account but it would support the bottom-up priming account. The bottom-up effect of previewing is thought to decay quickly after preview offset (Posner & Snyder, 1975a, b). The finding would be consistent with the conjunction preview effect being caused by the combined effect of top-down and bottom-up priming of feature integration.

As in Experiment 4, on incongruent conjunction preview trials participants were more likely to make a conjunction error that was identical to the preview object than a conjunction error of the non-previewed probe colour and shape, although the effect was not significant. On congruent conjunction preview trials participants were significantly more likely to correctly report the probe object that was identical to the preview object than correctly report the non-previewed probe object. These findings are discussed further in

Section 3.6.

The purpose of the next experiment was to examine how predictive validity interacts with conjunction previewing to determine whether the conjunction preview effect is caused by top-down priming, bottom-up priming or both.

3.5 Experiment 6: Predictive Validity and the Conjunction Preview Effect

3.5.1 Introduction

Cost-plus-benefit preview effects upon conjunctions errors were found in both Experiments 4 and 5 when the preview offset immediately precedes probe onset. Two aspects of the conditions under which the preview effect was observed in both these experiments suggest that a bottom-up priming process may mediate the effect. First, the effect occurred when there were equal numbers of congruent and incongruent conjunction preview trials. Second, there was some evidence that the delay between the onsets of the preview and probe stimuli affects the magnitude of the conjunction preview effect. The preview effect was smaller when there was a 2 sec delay, although the effect was short of the prescribed significance level. Nevertheless, it may also be possible that under certain conditions a top-down priming process can also influence illusory conjunction formation.

One way of determining whether a top-down priming process is involved in a preview effect is to observe how predictive validity interacts with the effect. Predictive validity can be operationalized as the ratio of congruent preview trials to incongruent preview trials per experiment (Di Pace et al., 1997). Top-down priming is thought to be affected by predictive validity but bottom-up priming is not (Posner & Snyder, 1975b). When predictive validity is medium, i.e., when there are equal numbers of congruent trials than incongruent trials, there is an equal probability that on any given trial the probe display will contain an object identical to the preview object. Therefore, it would not be rational for participants to expect one of the probe objects to be identical to the preview object.

When predictive validity is high, i.e., when there are more congruent trials than incongruent trials, there is a better than chance probability that on any given trial the probe display will contain an object identical to the preview object. Therefore, it would be rational for participants to expect one probe object will be identical to the preview object. Consequently, top-down priming will be expected to occur. Nevertheless, bottom-up priming may also occur under these conditions. A preview effect found when predictive validity is high can be attributed to both top-down and bottom-up priming processes.

When predictive validity is low, i.e., when there are fewer congruent trials than incongruent trials, there is a worse than chance probability that on any given trial the probe display will contain an object identical to the preview object. Therefore, it would not be a rational strategy for participants to expect to see a probe object that is identical to the preview object. However, the participants may adopt a strategy in which they expect the properties of the preview object to appear in different target objects. The absence of a significant preview effect may be attributable to no priming having occurred or to the opposite effects of bottom-up priming and exclusive top-down priming having cancelled each other out.

In the present experiment predictive validity was manipulated to discover whether it is possible for the cost-plus-benefit preview effect to occur under low predictive validity and high predictive validity as well as medium predictive validity. If the preview effect were to be replicated under high predictive validity but not under low predictive validity then it would be suggested that the preview effect can be mediated by a top-down priming process. If the preview effect were to be replicated under low predictive validity then further support would be provided for the conclusion that the preview effect can be caused by an bottom-up priming process.

3.5.2 Method

Participants

Twenty-four psychology undergraduates at the University of Plymouth participated as part of the course requirements or for a nominal fee. All had normal or corrected-to-normal vision.

Design

A two-way partial repeated-measures design was employed. The repeated-measures factor, preview type, had two levels. In the congruent conjunction preview condition, an object that had the same colour and shape as one of the probe objects was presented before the probe display. In the incongruent conjunction preview condition, an object that had the same colour as one of the probe objects and the same shape as the other probe object was presented before the probe display. The between-subjects factor, predictive validity, had three levels; high, medium and low.

Apparatus and Stimuli

The same apparatus and stimuli were used as in Experiment 5.

Procedure

Participants were randomly allocated to the three predictive validity conditions. In the high predictive validity condition there were three congruent conjunction preview trials to every one incongruent conjunction preview trial. In the medium predictive validity condition there were equal numbers of congruent and incongruent conjunction preview trials. In the low predictive validity condition there was one congruent conjunction preview trial to every three incongruent conjunction preview trial.

Each participant was given written and verbal instructions before undertaking a practise session of 30 trials, randomly selected from the full experiment. The stimuli were viewed under dim lighting conditions from a distance of approximately 75 cm. The full experiment consisted of 200 trials and lasted about half an hour. The presentation of the stimuli was the same as in the 0.5 sec SOA condition of Experiment 5 except there were no neutral object trials. The response method was the same as in Experiments 4 and 5. The participants were informed by the experimenter at the outset that the colours and shapes of the two probe objects on a given trial would always be different.

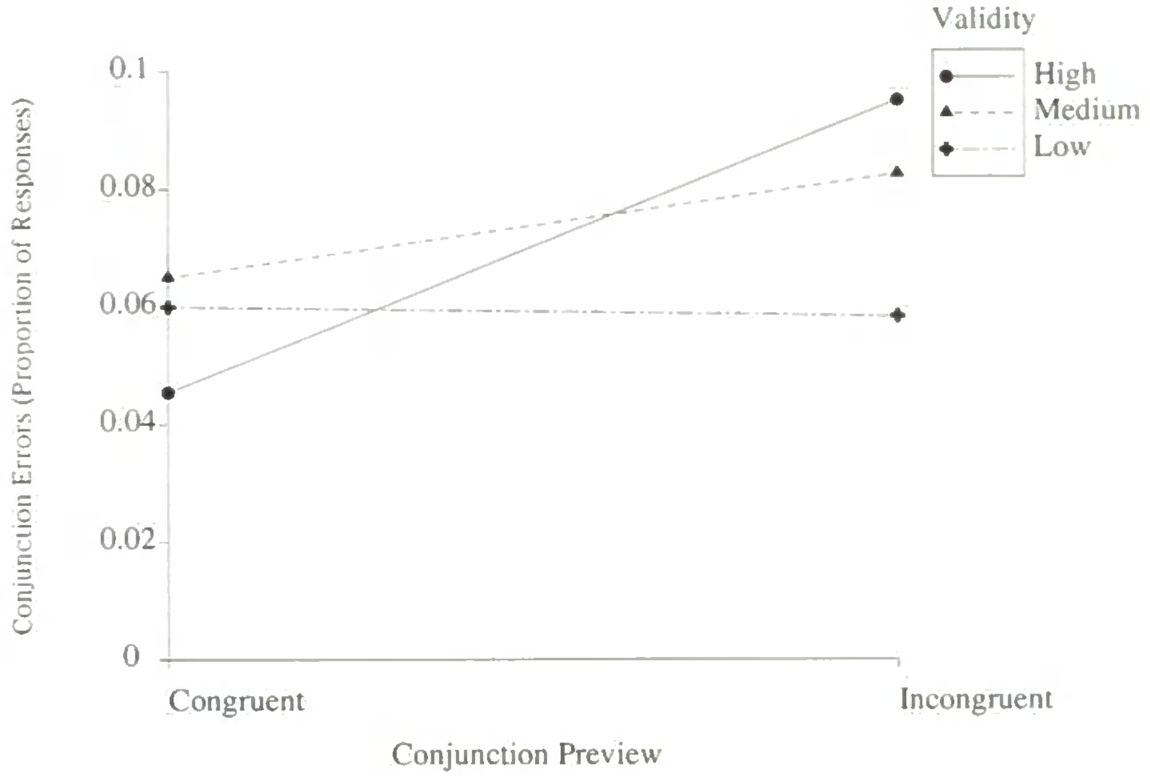

Figure 3.5. Mean proportion of responses classified as conjunction errors by preview conjunction congruence (congruent and incongruent conjunction previews) and predictive validity (high, medium and low; i.e., ratios of congruent to incongruent preview trials of 3:1, 1:1 and 1:3 respectively) in Experiment 6.

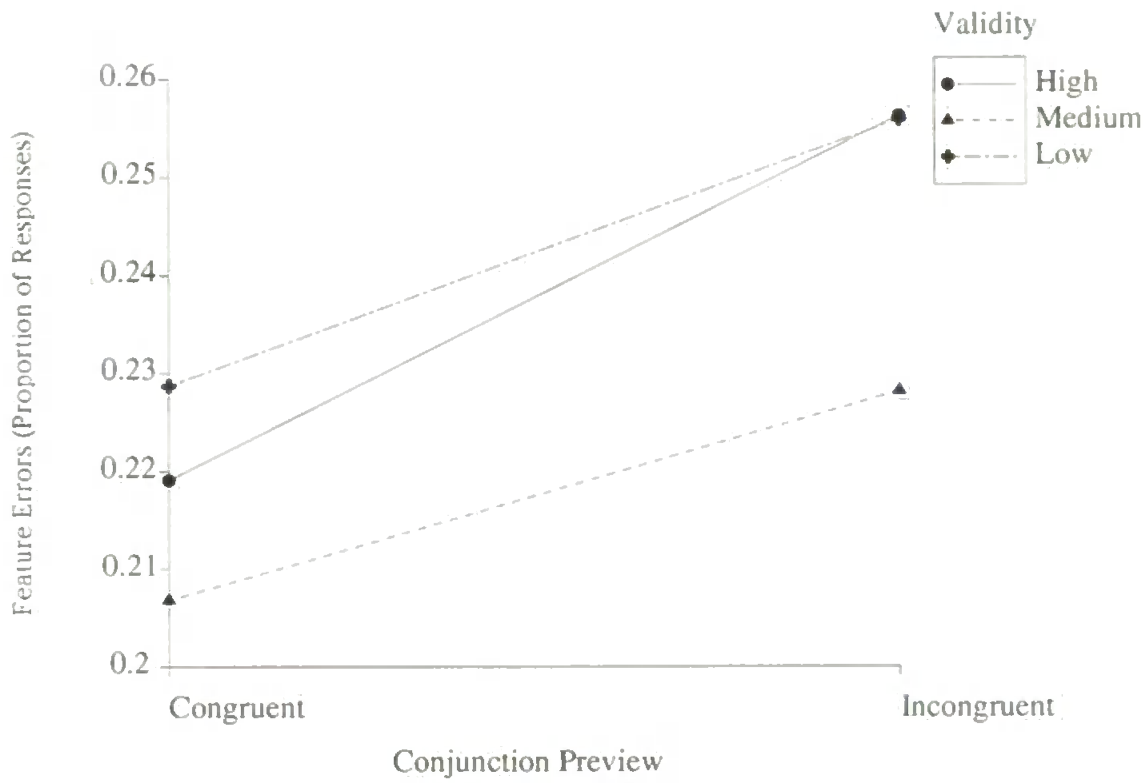

Figure 3.6. Mean proportion of responses classified as feature errors by preview conjunction congruence (congruent and incongruent conjunction previews) and predictive validity (high, medium and low; i.e., ratios of congruent to incongruent preview trials of 3:1, 1:1 and 1:3 respectively) in Experiment 6.

3.5.3 Results

Conjunction errors and feature errors were scored and transformed to proportions in the same way as in Experiments 4 and 5. ANOVAs were performed upon the conjunction error and feature error scores.

Analysis of the conjunction error data was performed to discover whether congruent conjunction previewing had caused more conjunction errors than incongruent conjunction previewing across the levels of predictive validity. Figure 3.5 displays the mean proportion of responses classified as conjunction errors by preview conjunction congruence and predictive validity. The graph shows that, the difference in mean scores between the congruent and incongruent conjunction preview conditions was greatest in the high predictive validity condition and least in the low predictive validity condition.

A partial repeated-measures ANOVA was performed upon the conjunction error data. The preview type main effect was significant, F (1, 21) = 11.63, $p < 0.001$. The mean conjunction error score was higher in the incongruent conjunction preview condition (0.079) than in the congruent conjunction preview condition (0.057). The predictive validity main effect was not significant, $F < 1$.

However, the preview type by predictive validity interaction was also significant, F (2, 21) = 5.47, $p < 0.05$. Therefore, the analysis of the simple effects of preview type at each of the three levels of predictive validity was undertaken. In the high predictive validity condition, the mean conjunction error scores were found to be significantly lower under congruent conjunction previewing than incongruent conjunction previewing, F (1, 7) = 16.03, $p < 0.001$; i.e., a significant cost-plus-benefit preview effect was found. In the medium predictive validity condition, the difference between mean conjunction error scores under congruent and incongruent conjunction previewing was found not to be significant, F (1, 7) = 1.97, $p > 0.05$. Therefore, this experiment failed to replicate the finding of a cost-plus-benefit conjunction preview effect upon conjunction errors that had been found previously in Experiments 4 and 5. In the low predictive validity condition, the difference between mean conjunction error scores under congruent and incongruent conjunction previewing was also found not to be significant, $F < 1$.

Analysis of the feature error data was undertaken to determine whether the cost-plus-benefit preview effect upon conjunction errors was mediated by illusory features or guessing rather than illusory conjunctions. Unlike Experiments 4 and 5 significant differences were found in the feature error data. Figure 3.6 displays the mean proportion of responses classified as feature errors by conjunction preview type and predictive validity. The figure shows that mean feature error scores were greater in the incongruent conjunction preview condition than the congruent conjunction preview condition, irrespective of the level of predictive validity.

A three-by-two partial repeated-measures design ANOVA was performed on the feature error data. The preview type main effect was significant, $F\ (1, 21) = 8.13$, $p < 0.05$. However, the preview type by predictive validity interaction was not significant, $F < 1$. The variance was also partitioned to determine the significance of the simple effect of preview conjunction congruence at each of the three levels of predictive validity. None of these simple effects were significant; high predictive validity, $F\ (1, 7) = 2.66$, $p > 0.05$. medium predictive validity, $F\ (1, 7) = 2.79$, $p > 0.05$, and low predictive validity, $F\ (1, 7) = 3.38$, $p > 0.05$. The predictive validity main effect was not significant either, $F < 1$.

As in Experiments 4 and 5, analyses were performed to determine whether participants were more likely to report the target colour and target shape that were identical to the preview object than the other target colour and target shape. In the incongruent conjunction preview condition, previewed and non-previewed conjunction errors were compared. If the preview object was a blue triangle and the target objects were a blue circle and a red triangle then the report of a blue triangle would be a previewed conjunction error and the report of a red circle would be a non-previewed conjunction error.

A two-way partial repeated-measures ANOVA of the conjunction error data from the incongruent conjunction preview condition was undertaken. The repeated measures factor was whether the conjunction error was previewed or non-previewed. The between-subjects factor was predictive validity. The difference between the mean proportion of previewed conjunction errors (0.085) and the mean proportion of non-previewed conjunction errors (0.072) was in the same direction as in Experiments 4 and 5 but was not significant, $F(1,21) = 2.52$, $p > 0.05$. The two-way interaction was not significant either, $F < 1$.

In the congruent conjunction preview condition, previewed and non-previewed correct reports were compared. If the preview object was a blue circle and the target objects were a blue circle and a red triangle then the report of a blue circle would be a previewed correct report and the report of a red triangle would be a non-previewed correct report.

A two-way partial repeated-measures ANOVA of the correct report data from the congruent conjunction preview condition was undertaken. The repeated measures factor was whether the correct report was previewed or non-previewed. The between-subjects factor was predictive validity. The difference between the mean proportion of previewed correct reports (0.693) and the mean proportion of non-previewed correct reports (0.627) was in the same direction as in Experiments 4 and 5 and was significant, $F(1,21) = 17.48$, $p < 0.001$. The two-way interaction was not significant, $F(2,21) = 3.13$, $p > 0.05$.

Baseline analyses were undertaken for each experimental condition. The same method was used as in Experiment 4. One sample t tests were undertaken to compare the observed conjunction error scores with the expected score determined from the baseline model. In the high predictive validity congruent conjunction preview condition the observed mean conjunction error score (0.045) was significantly lower than the expected score (0.073), $t(7) = 2.68$, $p < 0.05$. In the high predictive validity incongruent conjunction preview condition the observed mean conjunction error score (0.095) was higher than the expected score (0.085) but the difference was not significant, t (7) = 0.91, $p > 0.05$. In the medium predictive validity congruent conjunction preview condition the observed mean conjunction error score (0.065) was not significantly lower than the expected score (0.069), t (7) = 0.16, $p < 0.05$. In the medium predictive validity incongruent conjunction preview condition the observed mean conjunction error score (0.082) was not significantly higher than the expected score (0.076), t (7) = 0.26, $p < 0.05$. In the low predictive validity congruent conjunction preview condition the observed mean conjunction error score (0.060) was not significantly lower than the expected score (0.076), t (7) = 1.06, $p < 0.05$. In the low predictive validity incongruent conjunction preview condition the observed mean conjunction error score (0.058) was not significantly lower than the expected score (0.085), t (7) = 2.14, $p < 0.05$.

3.5.4 Discussion

The experiment was concerned with whether the cost-plus-benefit conjunction previewing effects on conjunction error scores is caused in by a bottom-up priming process, a top-down priming process or both. If the preview effect is caused by bottom-up priming alone then its magnitude should not be affected by predictive validity. If the preview effect is caused at least in part by top-down priming then its magnitude should be affected by predictive validity. The magnitude of the preview effect should be greater under high predictive validity than under medium predictive validity and it should be greater under medium predictive validity than under low predictive validity.

Overall, conjunction errors were more frequent in the incongruent conjunction preview condition than in the congruent conjunction preview condition; i.e., there was a cost-plus-benefit preview effect upon conjunction errors. This finding compliments the finding in Experiment 4 of a cost-plus-benefit preview effect.

It also appears that predictive validity affects the magnitude of the effect. The magnitude is largest in the high predictive validity condition, next largest in the medium predictive validity condition and smallest in the low predictive validity condition. Simple effects analyses support the existence of a cost-plus-benefit preview effect upon conjunction errors when predictive validity is high, but not when predictive validity is either medium or low.

These findings cannot be attributable to the effect of bottom-up priming alone. Otherwise predictive validity would not have affected the magnitude of the conjunction preview effect. Therefore, it is possible that the preview effect is at least in part mediated by a top-down priming process. However, it is less clear whether the results can be accounted for by a top-down priming process alone or whether they support the operation of both priming processes. The findings support versions of both explanations.

One explanation of the results is that the conjunction preview effect is mediated by top-down priming only. It has been argued (e.g., Posner & Snyder, 1975b) that top-down priming involves the generation of expectations or hypotheses about the forthcoming target. If predictive validity is high then it is logical for the participant to expect a target object to be identical to the preview object.

However, when predictive validity is medium in the current experiment (i.e., when there are equal numbers of congruent and incongruent conjunction preview trials) it would not be logical for the participants to expect a target object to be identical to the preview object. But, a cost-plus benefit conjunction preview effect was found in Experiments 4 and 5 when there were equal numbers of congruent and incongruent conjunction preview trials. Furthermore, when predictive validity is low then it would be logical for the participants to expect one target object to be the same colour as the preview object and the other target object to be the same shape as the preview object. Nevertheless, there was no evidence of a negative conjunction preview effect under low predictive validity in the present experiment.

Nevertheless, the top-down priming explanation can be revived if one assumption is changed. The above account of expectation generation assumes that participants are perfectly rational decision makers and have perfect knowledge of the ratio of congruent to incongruent trials. It is quite possible that this assumption is false. Perhaps participants' expectations may be influenced by a reasoning bias (Evans, 1989). They may overestimate the ratio of congruent conjunction preview trials to incongruent conjunction preview trials perhaps due to the availability of the former (Kahneman & Tversky, 1973). Consequently, participants may have expected the preview to be predictive in the medium predictive validity condition.

Another explanation of the results is that the conjunction preview effect is mediated by top-down priming and bottom-up priming together. Perhaps, in the high predictive validity condition the preview effect is caused by both priming processes, and in the medium predictive validity condition preview effect is caused mainly by bottom-up priming. It might be argued that the lack of a preview effect in the low predictive validity condition suggests that there is no evidence of bottom-up priming. Bottom-up priming should cause a preview effect irrespective of predictive validity. However, in this condition participants should expect mostly incongruent conjunction trials to occur. In which case top-down priming and bottom-up priming would be pitted against each other, perhaps cancelling each other out.

The medium predictive validity condition was similar in design to Experiment 4 and the 0.5 sec SOA condition of Experiment 5. In these earlier experiments significant cost-plus-benefit conjunction preview effects upon conjunction errors had been found. The failure to replicate the preview effect in the medium predictive validity condition of the present experiment is perhaps due to a lack of power. In Experiment 4 there had been 18 participants and in Experiment 5 there had been 16 participants. Only 8 participants undertook the 1:1 predictive validity condition in the present experiment. It appears that the effect size was insufficient to obtain a significant result with so few participants.

There was a significant cost-plus-benefit conjunction preview effect on the feature error data. Therefore it is possible that, in the present experiment, the preview effect upon conjunction errors was caused by the same mechanisms that cause feature errors; i.e., feature misidentification and feature guessing. Nevertheless, there were more conjunction errors than expected in the incongruent conjunction preview condition under high and medium predictive validity, although neither difference was significant. Furthermore, in the high predictive validity congruent conjunction preview condition the observed mean conjunction error score was significantly lower than the expected score. This finding suggests that the baseline model may have overestimated the expected score.

Unlike in Experiment 4, on incongruent conjunction preview trials participants were not significantly more likely to make a conjunction error that was identical to the preview object than a conjunction error of the non-previewed probe colour and shape, although the effect was in the same direction. On congruent conjunction preview trials participants were significantly more likely to correctly report the probe object that was identical to the preview object than correctly report the non-previewed probe object. These findings are discussed further in Section 3.6.

3.6 General Discussion

The three experiments reported in this chapter were undertaken to determine whether conjunction previewing can affect conjunction error scores and to investigate plausible accounts of this effect. In all three experiments the participants reported the colour and shape of two objects in a briefly presented probe display. In the main conditions, congruent and incongruent conjunction preview displays were presented before the probe displays. The effects of conjunction previewing upon conjunction errors and feature errors were observed.

In Experiment 4 conjunction previewing was found to affect the production of conjunction errors. This is a novel finding and is potentially important for theories of visual integration and illusory conjunctions. It was also found that there was not a significant effect of conjunction previewing upon feature error scores. Therefore, it was concluded that congruent and incongruent conjunction previews may affect the numbers of illusory conjunctions produced.

Experiments 5 and 6 were performed to discover whether the effect of conjunction previewing could be attributable to bottom-up priming mechanisms, top-down priming mechanisms or both. Experiment 5 investigated the effects of preview-probe SOA upon conjunction previewing. It was found that the preview effect on conjunction error scores occurred irrespective of SOA. Therefore, the experiment provided no evidence that top-down priming upon feature integration does not cause the conjunction preview effect. Again conjunction previewing did not appear to affect feature errors. Consequently the effect found in this experiment may be attributed to the differential generation of illusory conjunctions. However, there is a suggestion that the size of conjunction preview effect may be reduced when the presentation of the preview display does not immediately precede the presentation of the probe display. If borne out by a more powerful experiment then this would support bottom-up priming of feature integration.

Experiment 6 investigated the effects of predictive validity (i.e., the ratio of the number of congruent trials to the number of incongruent trials) upon conjunction previewing. It was found that predictive validity interacted with the preview effect on conjunction error scores. A significant conjunction preview effect was found to occur only in the high predictive validity condition. It was suggested that this effect may have been caused by the top-down priming of feature integration.

In Experiments 4 and 5 the conjunction preview effects on the feature error data were not significant. Consequently, it was concluded that the preview effect upon conjunction errors may not be attributable to the guessing or misidentification of the target features. However, a significant cost-plus-benefit conjunction preview effect on the feature error data was found in Experiment 6. Furthermore, there were fewer feature errors in the congruent conjunction preview condition than in the incongruent conjunction preview condition in Experiments 4 and 5. Therefore, it might be argued that in all three experiments the preview effect upon conjunction errors was caused by the same mechanisms that cause feature errors; i.e., feature misidentification and feature guessing. According to this argument the failure to find significant preview effects in Experiments 4 and 5 was due to a lack of power. However there is a reason for doubting this account of conjunction previewing effect on conjunction errors. In Experiment 4 there was no evidence of a relationship between conjunction error and feature error scores. If the same mechanisms cause both conjunction errors and feature errors then such a relationship should be expected.

However, the priming of visual feature integration is not the only plausible explanation of the conjunction previewing effect on conjunction error scores. It is possible that the preview effect was caused not by the priming of a physical representation of the visual scene but by the priming of an equivalent lexical or semantic representation (Posner & Snyder, 1975b). Also the effect may have been caused by the intrusion of the preview object into the report of the probe display. If so the effect would be more accurately described as a pre-target intrusion effect (McLean et al., 1983). There are two possible explanations of why pre-target intrusions may have occurred that can fully account for the results of Experiments 4, 5 and 6. These alternative explanations of the conjunction preview effect are discussed in more detail below.

3.6.1 Priming of Lexical or Semantic Representations of Objects

Perhaps the conjunction preview effect is not mediated by the priming of the object token domain but by the priming of some other description of the target stimuli. Posner & Snyder's (1975a, b) account of preview effects proposes that the presentation of a stimulus will automatically activate many different representations. Each of these representational domains will encode different properties of the stimulus. Posner & Snyder proposed that three different representational domains that register visual letter and word stimuli. One domain encodes the stimulus' physical form. There may be several distinct physical level representations; for example, a featural domain (e.g., Treisman & Gelade, 1980) and an object token domain (Kahneman & Treisman, 1984). Posner & Snyder (op. cit.) also suggested that there is a word level representation that encodes any name associated with the stimulus. If the stimulus is a picture of a cat then the word level representation will describe the word *cat*. Finally, Posner & Snyder also proposed the existence of a semantic level domain, which encodes the meanings of the words described at the word level. It may be that the conjunction preview effect is mediated by the activation of lexical or semantic representations of the preview and target stimuli rather than object token representations. This possibility is explored in Chapter 5.

3.6.2 Preview-Report Strategy

The participants in illusory conjunction experiments are not always able to accurately report the colours and shapes of the probe objects. Perhaps on some trials the processing of the target stimuli is not completed. In order to complete a forced choice report participants may attempt to guess the identities of unknown features (Prinzmetal, 1981). However, maybe the participants in the Experiment 4, 5 and 6 performed a different strategy to enable them to complete the report. In Chapter 2 it was concluded that a preview-report strategy was responsible for the apparent preview effect found in Experiment 1. Perhaps a similar strategy can account for the effect of conjunction previewing. If so then it would be better to refer to the conjunction preview effect as a pre-target intrusion effect (McLean et al., 1983).

A preview-report strategy might bring about the observed effect as follows. The preview object was the same as one of the probe objects on a large number of trials (particularly in the high predictive validity condition of Experiment 6 where a large preview effect was found). During the course of the experiment participants may come to expect that one of the target objects will be identical to the preview object. The participants may have reasoned that when they were unsure of the identity of one of the probe objects then it would be a useful strategy to report the identity of the preview object. On congruent conjunction preview trials this would result in a correct report. However, on incongruent conjunction preview trials it would cause a conjunction error. Therefore more conjunction errors would be expected to occur in the incongruent conjunction preview condition than in the congruent conjunction preview condition. This strategy differs slightly from the one proposed to account for the findings of Experiment 1; that strategy was to report a previewed feature, this one is to report a previewed object.

There were findings from Experiments 4, 5 and 6 that support the preview report strategy explanation of the conjunction preview effect. In both conjunction preview conditions, participants were found to be more likely to report having seen a target object that was the same as the preview object than an object comprising the remaining target features. On incongruent conjunction preview trials participants were more likely to make a conjunction error that was identical to the preview object than a conjunction error of the non-previewed probe colour and shape, although the effect was significant only in Experiment 4. On congruent conjunction preview trials participants were significantly more likely to correctly report the probe object that was identical to the preview object than correctly report the non-previewed probe object. Taken together these findings suggest that participants are inclined to report an object identical to the preview object.

However, it is not clear why participants would use a preview-report strategy when there are equal numbers of congruent and incongruent conjunction preview trials. Under these conditions the strategy is likely to result in as many errors as correct reports. The strategy maybe indicative of a reasoning bias (Evans, 1989). Perhaps, participants' intuitive judgements of the relative probabilities of congruent and incongruent trials was biased by a difference in availability (Kahneman & Tversky, 1973). If the availability of congruent trials was greater than that of incongruent trials then participants may have judged congruent trials to be more likely than incongruent trials.

3.6.3 Temporal Illusory Conjunctions

Another way in which pre-target intrusions might have occurred in Experiments 4, 5 and 6 is as a result of *temporal illusory conjunctions*. This term refers to the migration of a visual feature or an object between displays presented at different times. They are thought to occur under conditions of rapid serial presentation (e.g., Botella & Eriksen, 1992; Botella, et al., 1992; Broadbent & Broadbent, 1987; Intraub, 1985; Keele et al., 1988; Lawrence, 1971; McLean et al., 1983). For instance, Keele et al. (1988) found that features migrated between displays, when each display in the sequence was presented for 83 msecs.

In Experiments 4, 5 and 6 the preview displays were exposed for 500 msecs and the target displays were exposed for 100 msecs. Perhaps, temporal illusory conjunctions occur under these conditions. If so they might bring about the conjunction preview effect in the following way. If the preview object migrated to the target display then the participant would report this object. When the conjunction preview is congruent, the temporal migration of the preview object would result in a correct report. When the conjunction preview is incongruent, a temporal migration would result in a conjunction error. Therefore, conjunction error scores would be higher in the incongruent conjunction preview condition than in congruent conjunction preview condition, i.e. the conjunction preview effect would occur. The migration of single *features* from the preview display to the target display would not cause this preview effect. The temporal migration of a preview feature to the target display would result in equal numbers of correct reports and conjunction errors irrespective of the type of conjunction preview. The effect will only occur if whole preview objects are displaced to the target display.

The temporal illusory conjunction account is also unable to explain why, as found in Experiment 5, the conjunction previewing effect occurs when preview-target SOA is 2 secs. This is because migrations are only thought to occur between displays that are closely located in time (Botella & Eriksen, 1992; Botella et al., 1992; Broadbent & Broadbent, 1987; Intraub, 1985; Keele et al., 1988; Lawrence, 1971; McLean et al., 1983). The maximum duration over which temporal illusory conjunctions have been recorded is under a second (Keele et al., 1988). In Experiment 5 the inter-stimulus interval was 1.5 secs.

However, one piece of evidence runs counter to this explanation. Temporal illusory conjunctions are normally thought to occur when the objects in successive displays are closely located spatially, in particular if they share the same location (e.g., Keele et al., 1988). This was not the case in the present experiments; the inter-item distance between preview and target objects was relatively large. The possibility that the conjunction preview effect can be mediated by temporal migrations is explored in Chapters 4 and 5.

The temporal illusory conjunction account of the conjunction preview effect may be compatible with the priming of feature integration hypothesis. It is possible that temporal illusory conjunctions are caused by a priming mechanism in the rapid serial visual presentation paradigm (e.g., Keele et al., 1988). If so a theory of visual integration that could account for the conjunction preview effect would explain the existence of both temporal and spatial illusory conjunctions.

3.6.4 Theoretical Implications of the Conjunction Preview Effect

If the conjunction preview effect is mediated by the production of illusory conjunctions and does involve either of the priming mechanisms described earlier, then theories of visual integration need to be compatible with such priming mechanisms.

Feature Integration Theory and Object Reviewing Theory

Feature integration theory (FIT) holds that normal veridical feature integration is a serial process involving the deployment of an attentional spotlight (Treisman, 1990; Treisman & Gelade, 1980). The features that the spotlight illuminates at any given moment are transferred to an object file (Treisman, 1990, 1992 & 1993). The visual system maintains an object file for each object that is present in a visual scene. Within each object file is an object-centred structural description of the object it stands for (Kahneman & Treisman, 1984).

Maybe the process that updates object files over time (Kahneman, Treisman and Gibbs, 1992) mediates the effect of conjunction previewing upon the numbers of illusory conjunctions. This may provide an account of bottom-up priming of the integration of visual features that is compatible with FIT. In conjunction previewing experiments there is one preview object and there are two target objects. The object reviewing process may cause the object file that stands for the preview object to be used later to stand for one of the target objects. A new object file would need to be set-up for the other target object.

If the preview object and one of the target objects are linked then the object file standing for the preview object will be re-used to stand for the target object. On congruent conjunction preview trials the preview object and the target object are identical. Consequently, the object file for the preview object will not need updating. It will not be necessary to integrate the target object's features and therefore fewer illusory conjunctions will occur. On incongruent conjunction preview trials the preview object and the target object are not identical. Therefore, the object file for the preview object will need updating. Under tachistoscopic presentation conditions the object reviewing process may sometimes fail to update the object token. If so, viewers may report the previous contents of the file in error. In the incongruent conjunction preview condition this would result in a conjunction error. Therefore more conjunction errors would be expected to occur in the incongruent conjunction preview condition than the congruent conjunction preview condition.

For an object file to be re-used in this way the preview object and a target object must be linked in some way. It has been suggested that a correspondence process identifies when two stimuli separated in time are instances of the same object. It is thought that correspondence is determined from the spatiotemporal properties of the stimuli (Kahneman et al., 1992). Therefore, in object reviewing paradigm studies (Gordon & Irwin, 1996;

Henderson, 1994; Henderson & Anes, 1994; Kahneman et al., 1992) linking between the preview object and target object is established either by a moving frame or because the spatiotemporal relationship between the preview and probe objects causes apparent motion. However, the conjunction preview effect occurred even though there were no moving frames and the presentation conditions did not cause apparent motion between the preview and target objects. If the conjunction preview effect involves the object reviewing mechanism then correspondence between the preview object and one of the target objects must be established by some other means.

Perhaps linking is established when the preview and target objects possess a common colour or shape; i.e., correspondence is determined by reference to the contents of the object file. Kahneman et al. (1992) do not accept that object files can be accessed in this way. Their claim is supported by some of their experimental findings. Nevertheless, there is evidence that the direction of apparent motion can be determined by shape correspondence (Shechter, Hochstein & Hillman, 1988) and by colour correspondence (Green, 1989; Kolers & Green, 1984). If the conjunction preview effect is mediated by object reviewing then the correspondence of the preview and target objects must be established from their non-spatial properties. If true, Kahneman et al.'s (1992) claim would be false.

However, it does not appear that object reviewing theory can account for the effect of conjunction previewing. This is because when the same object file encodes the preview object and of the target objects the impletion process causes viewers to experience the stimuli as two states of an object existing over time. For object reviewing to account for the findings of this experiment it would be necessary to demonstrate that participants saw the preview and target objects as successive states of the same object. However, none of the participants reported this phenomenon when interviewed informally after the experiment. Also several independent judges who were shown the stimuli reported that the preview object did not move. Consequently, there is little evidence to support this explanation of the bottom-up priming of visual integration.

Perhaps the top-down priming of object files may account for the conjunction preview effect. However, Kahneman et al. (1992) did not propose that the mere expectation that a particular object may appear in the future will generate an object file. It is thought that object files encode existing objects and sometimes illusory objects. It is not thought that they can encode expected objects. If an object file is generated when someone expects an object to appear then we would experience seeing the expected object. But we do not experience seeing expected objects during the preview-probe ISI of previewing studies. Nevertheless, it is possible that the top-down activity caused by a participant's expectation of the forthcoming probe objects may affect the activation thresholds for features within an object file. These expectations may shift the thresholds for registering these features by the object file and thereby cause their detection to be facilitated or inhibited.

One object previewing study offers some support for the idea of top-down priming of object files. Henderson (1994) undertook experiments similar to Kahneman et al.'s (1992) experiments except that on some trials the case of preview letter was different to that of the target letter. This manipulation did not eliminate object-specific effects. Henderson (1994) took the results as evidence of the priming of long term memory representations or object types (Kahneman & Treisman, 1984) as predicted by detector priming theory (Henderson, 1994; Henderson & Anes, 1994). The finding may also be explained in terms of top-down priming of object tokens. The expectation of a particular letter may affect the evidence thresholds of many detectors that encode the letter in different cases and fonts.

Location Uncertainty Theory and the Recurrent Architecture Network Model

Location uncertainty theory (LUT; Ashby et al., 1996; Prinzmetal & Keysar, 1989) and possibly the recurrent architecture network (RAN) model (Green, 1991) hold that objects are explicitly encoded by a set of topographically organized feature maps (Ashby et al., 1996; Prinzmetal & Keysar, 1989). Each detector in a map encodes the conjunction of a particular feature at a particular location. An object will activate units in different feature maps that encode features at the same location. For example, a blue circle will be encoded by the activation of a unit (or several units) in the *blue* feature map and a unit in the *circle* feature map. The active feature detectors must encode the same location for them to be considered conjoined. The RAN model appears to offer the same explanation of how object tokens are encoded.

Within the framework of LUT, visual integration is considered to involve the parallel propagation of activation to a set of topographically organized feature maps. Posner & Snyder's (1975a) priming mechanisms are compatible with network-based theories like LUT. According to the recurrent architecture network (RAN) model, both feature detection and feature integration are performed by a multiple soft-constraint satisfaction process (Green, 1991). Upon normal relaxation the output of the network will encode a veridical representation of the objects contained in the visual scene. However, if the input scene ceases to be displayed before the relaxation process is completed then errors of feature detection and integration will occur. The network may be constrained to return a best-fit response under these circumstances. Under certain conditions feature detection may be reasonably accurate but integration may be incomplete in which case the best-fit response may result in an illusory conjunction. It is not difficult to imagine how Posner & Snyder's (1975a, b) priming mechanisms might be incorporated into the RAN approach. However, in a recurrent network the activation of any single unit affects the activations of all other unit in the network. Therefore any priming activation is likely to have benefits and costs.

However, the conjunction preview effect occurred even though the preview object and the probe objects appeared at different locations. The preview objects were located centrally and the target objects were located extra-foveally. Therefore, the preview and probe objects will activate different units in the feature maps; i.e., the topographic feature map descriptions of the preview and target objects do not overlap. For priming to occur it is thought that the same resources must be activated by the preview and the probe (Posner &

Snyder, 1975a). Consequently, the LUT account of object tokens cannot account for the conjunction preview effect.

It appears that conjunction previewing is mediated by the activation of an object-centred object token representation. This does not mean that topographic feature maps are not employed by the visual system. Rather, the suggestion is that feature maps do not encode object tokens. According to FIT, object files contain an object-centred structural description of an object (Treisman, 1992 & 1993). Consequently, if conjunction previewing does affect integration by activating object tokens then the descriptions of the preview and target objects are apparently object-centred as in FIT rather than viewer-centred or world-centred as in LUT and the RAN model.

3.7 Conclusions

The results of three experiments established the existence of a cost-plus-benefit conjunction preview effect affecting conjunction error scores. This is a novel finding and is potentially important for theories of visual integration and illusory conjunctions. The effect does not appear to involve illusory features or feature guessing. Attempts at cost-benefit analysis of the preview effect were unsuccessful. Therefore, the experiments described in Chapter 4 were concerned with providing a cost-benefit analysis of the conjunction preview effect on conjunction error scores. It is suggested that the preview effect is caused by the priming of visual object tokens, Several other explanations of the conjunction preview effect were also proposed. The experimental evidence favours some of these explanations but not others. The experiments that are reported in Chapter 5 investigated the plausibility of the preview object report strategy account and the temporal illusory conjunctions account.

CHAPTER 4: COST-BENEFIT ANALYSIS OF THE CONJUNCTION PREVIEW EFFECT

4.1 Outline of Chapter

This chapter describes two experiments in which cost-benefit analysis was performed to investigate the effect of conjunction previewing upon conjunction errors. These experiments also investigated whether it is necessary for the task-relevant features (i.e., features that are properties of the probe objects) in conjunction preview displays to be properties of a single object for the conjunction preview effect to occur.

Experiment 7, which is described in Section 4.3, was designed to investigate the cost and benefit of conjunction previewing upon the whole-report of two probe objects. Two control conditions were required for cost-benefit analysis. In these conditions the preview display contained two preview objects. One preview object was the same colour as a target object and the other preview object was the same shape as a target objects. However, there was little evidence of a cost-plus-benefit preview effect upon conjunction error scores. The locations of the preview items may have caused the preview effect to be absent.

Experiment 8, which is described in Section 4.4, was also designed to investigate the cost and benefit of conjunction previewing upon the whole-report of two probe objects. The design was similar to Experiment 7 except that the preview objects were located centrally and did not indicate the locations of the forthcoming probe objects. Again, there was little evidence of a cost-plus-benefit preview effect upon conjunction error scores.

In Section 4.5 the results of the two experiments are discussed together. The results of these experiments are inconclusive. It was not possible to perform the planned cost-benefit analyses in either experiment because the conjunction preview effect was not significant. Also there was little evidence that the conjunction preview effect can occur with temporally conjoined preview features.

4.2 Introduction

The experimental evidence reported in Chapter 3 established that conjunction previewing affects conjunction error scores. However, it appears that the observed effects may be attributable to both bottom-up and top-down priming mechanisms. To better understand the conjunction preview effect and its causes it would be useful to discover the conditions under which separate bottom-up and top-down priming processes occur. It has been suggested that bottom-up and top-down priming can be distinguished by the pattern of performance costs and benefits produced (Jonides & Mack, 1984; Posner & Snyder, 1975a, b).

Cost-benefit analysis is widely used to determine whether a preview effect is mediated by bottom-up or top-down priming (Jonides & Mack, 1984; Posner & Snyder, 1975a, b). In cost-benefit analysis the results found with congruent and incongruent previews, collectively known as selective previews, are compared with the results in a control condition. The benefit effect is the difference in the dependent variable between the congruent preview condition and the control condition. The cost effect is the difference in the dependent variable between the incongruent preview condition and the control condition. It has been suggested that the presence of a benefit effect but no cost effect is evidence of bottom-up priming (Posner & Snyder, 1975a, b). It has also been suggested that finding a cost effect and a benefit effect is evidence of top-down priming (Posner & Snyder, 1975a, b).

The experiments that are reported in this chapter were undertaken to permit a meaningful cost-benefit analysis of the conjunction preview effect. The cost-benefit analyses performed on the data from Experiments 4 and 5, which are described in Chapter 3, were inconclusive. This was because the *no preview object* and *neutral preview object* conditions in these experiments did not serve as adequate controls. The *no preview object* condition may not have accounted for the general warning effects of conjunction preview objects. The neutral preview object condition may not have accounted for the effect of conjunction previews upon feature abstraction. Given the inadequacies of the *no preview object* and *neutral preview object* conditions, a new type of control condition was required.

There were three characteristics of the control preview display that enabled a meaningful cost-benefit analysis of conjunction previewing to be undertaken. First, the control preview displays needed to have the same general preparatory effects as the congruent and incongruent conjunction preview displays (Jonides & Mack, 1984). In other words all three previews should be equally salient. Second, the control preview displays should have the same effects upon the reporting of individual features as the conjunction preview displays. It is known that colour previews can affect the latency of reporting colour targets (Di Pace et al., 1997; Marangolo et al., 1993) and that shape previews can affect the latency of reporting shape targets (Taylor, 1977, Quinlan & Humphreys, 1988). An appropriate control for conjunction previewing should have the same effects on the report of colour and shape features as the selective previews. These first two requirements were satisfied because the control preview displays contained exactly the same features as the conjunction preview displays. For example, if the conjunction preview display for a given target display is a *blue circle* then the control preview display for that target display should also contain the properties *blue* and *circle*.

The third necessary characteristic of the control preview display was that it should not preview the way the two previewed features are combined in the target display. Therefore, although the preview display contained two task-relevant features they should not preview a veridical target object or an illusory conjunction of target features. To satisfy this third requirement these two features were properties of two different preview objects. The colour was a property of one preview object and the shape was a property of the other preview object. Therefore the colour and shape were temporally but not physically conjoined. A preview display containing a task-relevant colour and task-neutral shape object with a task-neutral colour and task-relevant shape object will satisfy all three requirements.

Consider a trial in which the target display contained a blue circle and red triangle. The preview displays will contain *two* objects composed of task-relevant features (e.g., red, blue, circle and triangle) and task-neutral features (e.g., grey and square). A congruent conjunction preview display will contain an object composed of two task relevant features that are conjoined in the target display and an object comprised of two task-neutral features; e.g., the display will consist of a blue circle and a grey square. An incongruent conjunction preview display will contain an object composed of two task relevant features that are not conjoined in the target display and an object comprised of task-neutral features; e.g., the display will consist of a blue triangle and a grey square.

In fact there are two possible control conditions. In one control condition, the congruent temporal conjunction preview condition, the display will contain two task relevant features that are conjoined in the target display. These features are conjoined with task-neutral features in the probe display; e.g., the display will consist of a blue square and a grey circle. An incongruent temporal conjunction preview display will contain two task relevant features that are *not* conjoined in the target display. These features are conjoined with task-neutral features in the probe display; e.g., the display will consist of a blue square and a grey triangle.

For cost-benefit analysis of the conjunction preview effect to be considered meaningful two conditions must be met. First, it must be demonstrated that the conjunction preview effect occurs when the preview displays contain two objects. It is possible that the presence of the additional task-neutral object may interfere with the preview effect in some way. If this is the case then this approach for the cost-benefit analysis of conjunction previewing will not be successful.

Second, the congruent and incongruent control conditions should cause roughly similar numbers of conjunction errors. For cost-benefit analysis to be meaningful the two temporal conjunction previews must have a similar effect. If this were found it would imply that some other preview effect occurs that has not previously been considered. One possibility is that it is not necessary for the previewed features to be physically conjoined for the conjunction preview effect to take place. Instead it may be sufficient simply for the preview shape to be an attribute of one object and the preview colour to be an attribute of another preview object. If this were the case then the effect would more appropriately be referred to as the temporal conjunction preview effect because the features are temporally conjoined, i.e., they appear and disappear at the same time, rather than physically conjoined. If this is the case it would have a bearing on the account of the preview effect.

In summary, the experiments described in this chapter were undertaken for two reasons. First, to allow cost-benefit analysis of conjunction preview effect to be performed. Second, to determine whether the previewed feature conjunction need comprise a single object or can appear in two different objects for the preview effect to occur. The following section describes the first of these experiments.

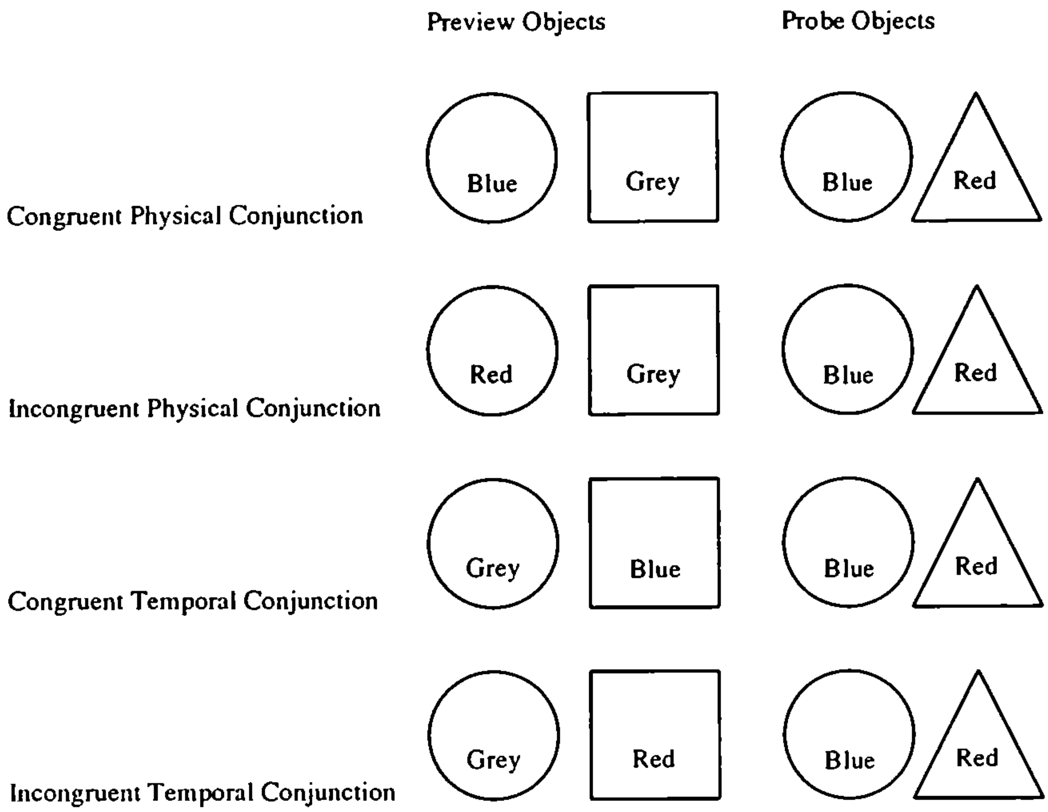

Figure 4.1. Examples of physical and temporal conjunction preview displays in Experiments 7 and 8 for a probe display consisting of a blue circle and a red triangle. Note that all the preview displays contain a colour and a shape that is also present in the probe display. The congruent and incongruent conjunction previews differ only in whether the previewed task-relevant colour and shape are features of the same probe object or are features of different probe objects.

4.3 Experiment 7: Cost-Benefit Analysis of Conjunction Preview Effect 1

4.3.1 Introduction

The primary aim of this experiment was to perform a meaningful cost-benefit analysis of the conjunction preview effect. To this end it was necessary for the preview displays to contain two objects (see Figure 4.1).

In the two conjunction preview conditions the preview display contained a task-relevant object and a task-neutral object. In other words the two task-relevant features were physically conjoined; i.e., they were properties of the same object. In the congruent conjunction preview condition the task-relevant object was the same as one of the target objects. In the incongruent conjunction preview condition the task-relevant object was the colour of one target object and the shape of the other target object. The task-neutral object was a grey square. This object was considered task-neutral because the target objects were never grey nor square.

In the control conditions in the preview displays contained two objects each of which was comprised of a task-relevant feature and a task-neutral feature. In other words the task-relevant features were not physically conjoined. But these features were temporally conjoined, i.e. they appeared and disappeared at the same times. There were two temporal conjunction control conditions, somewhat analogous to the congruent and incongruent conjunction preview conditions. In the congruent temporal conjunction preview condition the task-relevant features also belonged to one of the target objects. In the incongruent temporal conjunction preview condition the task-relevant features also belonged to different target objects.

4.3.2 Method

Participants

Twenty-one psychology undergraduates at the University of Plymouth participated as part of the course requirements or for a nominal fee. All had normal or corrected-to-normal vision and reported having no major visual deficits.

Design

A one-way repeated-measures design was employed. There were six conditions determined by manipulation of the contents of the preview display. There were 25 trials in each condition.

In four of the conditions the preview display contained two preview objects. The preview objects were colour-filled geometric shapes. One of the preview colours and one of the preview shapes also appeared in the probe display. The other preview colour and the other preview shape were neutral to the report task. This colour and shape did not ever appear in the target display and were not available to be reported. The task neutral colour was grey the task neutral shape was square.

In the congruent conjunction preview condition one of the preview objects was identical to one of the target objects. The other preview object was composed of the two task-neutral features; i.e., it was a grey square. In the incongruent conjunction preview condition one of the preview objects was the same colour as one of the target objects and the same shape as the other target object. The other preview object was composed of the two task-neutral features. In the congruent temporal conjunction preview condition one of the preview objects was the same colour as one of the target objects and was a task-neutral shape (square). The other preview object was the same shape as the target object whose colour was previewed and was a task-neutral colour (grey). In the incongruent temporal conjunction preview condition one of the preview objects was the same colour as one of the target objects and was a task-neutral shape (square). The other preview object was the same shape as the target object whose colour was *not* previewed and was a task-neutral colour (grey).

The no object and neutral object conditions, were control conditions enabling the general preparatory effect (Jonides & Mack, 1984) of the temporal conjunction previews to be quantified. In the no object condition the preview display did not contain any objects. In the neutral object condition the preview display contained two objects composed task-neutral features; i.e., both were grey squares.

Apparatus and Stimuli

The target, mask and response displays were generated and displayed in the same way as in Experiments 5 and 6. The displays were generated by an Acorn Archimedes A5000 computer and displayed on an Acorn AKF18 60 Hz colour monitor. The stimuli consisted of three displays; a preview display, a probe display and a mask display. There was also a response display. All the displays had a black background. The stimuli were viewed under dim lighting conditions from a distance of approximately 75 cm.

Only the preview displays differed from Experiments 5 and 6. There were two preview objects and a fixation point in each preview display, except in the no preview object condition in which there were none. The preview objects and the fixation point were the same sizes as in Experiments 4, 5 and 6. The height and width of the preview objects was approximately 1.68° of visual angle. The height and width of the fixation point was approximately 0.38° of visual angle. The preview objects were located on an unseen line passing through the centre of the display. The objects' locations were approximately 2.10° of visual angle from the centre of the display. The line of orientation of the preview objects was at right angles to the line of orientation of the target objects. The fixation point was located at the centre of the display.

In the congruent physical conjunction preview condition the colour and shape of one of the preview objects was the same as one of the target objects. The other preview object was a grey square. In the incongruent physical conjunction preview condition the colour and shape of one of the preview objects was the same as the colour of one of the target objects and the shape of the other target object. The other preview object was a grey square. In the congruent temporal conjunction preview condition one of the preview objects was square and the same colour as one of the target objects. The other preview object was grey and the same shape as the target object that had given its colour to the first preview object. In the incongruent temporal conjunction preview condition one of the preview objects was square and the same colour as one of the target objects. The other preview object was grey and the same shape as the remaining target object. In the neutral object condition the preview objects were both grey squares.

In the no object condition the preview display did not contain preview objects. Instead there were two markers, identical to the fixation point, located where the preview objects would have been in the other conditions. These markers were necessary to control for the cueing of the location of target objects by the location of preview objects in the other conditions.

The layout of the probe display was the same as in the previous experiments. The probe display consisted of two probe objects (see Figure 2.2 in Chapter 2). The probe objects were coloured geometric shapes. The two probe colours were randomly selected without replacement from a pool of five colours: blue, green, magenta, orange and red. The two probe shapes were randomly selected without replacement from a pool of five shapes: circle, cross, diamond, five-pointed star and triangle. Consequently, the two objects in a probe display had different colours and different shapes. The height and width of each probe item was approximately 1.68° of visual angle. The two probe objects were located so that their centres were at the ends of an unseen line approximately 4.2° in length. The midpoint of this line coincided with the centre of the display. Consequently, the retinal eccentricities (i.e., the distance from the point of fixation) of the two probe objects were 2.1°. The angle between the unseen line and the horizontal meridian was randomly determined on each trial. This was necessary to ensure that participants' attention was equally divided between the two probe objects. If the participants had been able to predict where the probe objects would appear then one of the probe objects may have received a higher attentional priority than the other probe object.

The mask and response displays were the same as in Experiments 4, 5 and 6. The mask display consisted of two feature masks at the same locations as the probe items. Each mask was a 10 by 10 block of feature chunks randomly selected from the possible shapes and colours. Each feature chunk was approximately 0.05° of visual angle in size and the whole mask had the same height and width as the probe items.

The response displays were the same as in Experiments 4, 5 and 6. They consisted of a palette of shape icons, a palette of colour icons, two response boxes, one for each probe object, and the response complete button (see Figure 2.4 in Chapter 3). Each palette consisted of a row of five colour or shape icons superimposed on a larger black square. The black squares were set against a grey background. Colour icons were squares of the five feature colours. Shape icons were rendered in the same grey as the screen background. The location of feature icons within the palette was randomized on each trial. The palette of colours was presented at the top of the display and the palette of shapes was presented at the bottom of the display. Along the horizontal median was a row of three black squares. The flanking squares were the *object response boxes* into which participants composed their responses. The central square, the response complete button, contained the label *OK* rendered in white.

Procedure

The procedure was the same as in Experiments 5 and 6. Each participant undertook a single experimental session lasting about 45 minutes. The experiment consisted of 150 trials. On each trial the following occurred. First, a tone was sounded and a preview display was presented for 0.5 secs. Next, a target display was presented for 0.1 secs followed by a masking display that was present for 0.5 secs. The response screen was then presented until the participant completed their response. The response screen comprised of a palette of shape icons, a palette of colour icons, two object response boxes and a response complete button. The participants were instructed to compose the two coloured shapes they had seen in the probe display in the object response boxes. Participants dragged-and-dropped icons from the palettes into the response boxes using an on-screen pointer controlled by the computer mouse. When a colour icon and a shape icon were dropped into an object response box the composite coloured shape icon was displayed in the box.

Participants were able to change the colour or shape in a response box by dragging-in the desired alternative feature icon. Participants had to fill both response boxes with a composed coloured shape icon for them to be able to proceed to the next trial.

The colours and shapes of the two objects in a probe display were always different. Consequently, the response method precluded participants from reporting that the probe colours or shapes were the same. If a participant inadvertently dropped the same feature icon into both response boxes, then the computer would sound an error tone and the second drag-and-drop would be unsuccessful. Participants had to fill both response boxes with a composed coloured shape icon for them to be able to proceed to the next trial.

When participants thought that they had completed their report they would press the response complete button. If the report was complete then a blank display would be presented for one second followed by the next trial. The presentation of the blank display was to prevent participants' perception of the stimuli in the next trial from being previewed by the previous response display. If the report was incomplete an error tone would be sounded. Participants were not informed about the accuracy of their report. Prior to undertaking the full experiment the participants were given a practise session of 30 trials to familiarise them with the stimuli and the response method.

Table 4.1. *Mean proportions of conjunction errors and feature errors by condition in Experiment 7*

	Preview display					
	Controls					
			Temporal preview		Conjunct. preview	
	No object	Neutral	Congr.	Incongr.	Congr.	Incongr.
Conjunction errors	0.050	0.067	0.050	0.070	0.061	0.103
Feature errors	0.260	0.238	0.259	0.238	0.225	0.233

4.3.3 Results

Conjunction errors and feature errors were scored and transformed to proportions in the same way as in the previous experiments. Table 4.1 displays the mean proportions of conjunction errors and feature errors for each condition.

A one-way ANOVA of the conjunction error data was undertaken. The arcsine transformation was applied to the data because the homogeneity of variance and sphericity assumptions were violated and the data were in the form of proportions (see Appendix 3). No evidence of differences between the six conditions was found, $F\ (5,100) = 1.64$, $p > 0.05$. Nevertheless, the cost-plus-benefit conjunction preview effect upon conjunction errors was in the same direction and magnitude as previous experiments, i.e. fewer conjunction errors occurred in the congruent conjunction preview condition than in the incongruent conjunction preview condition (see Table 4.1).

A one-way ANOVA of the feature error data was to be undertaken to determine whether any effect on the conjunction error scores could have been mediated by illusory features or feature guessing. However, as no significant effects on conjunction error scores were found the analysis of the feature error data was unnecessary.

Analyses were performed to determine whether participants were more likely to report the target colour and target shape that were identical to the preview object than the other target colour and target shape.

In the incongruent physical conjunction preview condition, previewed and non-previewed conjunction errors were compared. If the preview objects were a blue triangle and a grey square (i.e., a task neutral preview object) and the target objects were a blue circle and a red triangle then the report of a blue triangle would be a previewed conjunction error and the report of a red circle would be a non-previewed conjunction error. The difference between the mean proportion of previewed conjunction errors (0.101) and the mean proportion of non-previewed conjunction errors (0.105) was not significant, $t\ (20) = 0.44$, $p > 0.05$.

In the incongruent temporal conjunction preview condition, previewed and non-previewed conjunction errors were compared. If the preview objects were a blue square and a grey triangle, and the target objects were a blue circle and a red triangle then the report of a blue triangle would be a previewed conjunction error and the report of a red circle would be a non-previewed conjunction error. The difference between the mean proportion of previewed conjunction errors (0.065) and the mean proportion of non-previewed conjunction errors (0.074) was not significant, $t\ (20) = 0.82$, $p > 0.05$.

In the congruent physical conjunction preview condition, previewed and non-previewed correct reports were compared. If the preview objects were a blue circle and a grey square, and the target objects were a blue circle and a red triangle then the report of a blue circle would be a previewed correct report and the report of a red triangle would be a non-previewed correct report. The difference between the mean proportion of previewed correct reports (0.703) and the mean proportion of non-previewed correct reports (0.598) was significant, $t\ (20) = 2.61$, $p < 0.05$.

In the congruent temporal conjunction preview condition, previewed and non-previewed correct reports were compared. If the preview objects were a blue square and a grey circle, and the target objects were a blue circle and a red triangle then the report of a blue circle would be a previewed correct report and the report of a red triangle would be a non-previewed correct report. The difference between the mean proportion of previewed correct reports (0.657) and the mean proportion of non-previewed correct reports (0.581) was not significant, $t\ (20) = 1.57$, $p > 0.05$.

4.3.4 Discussion

The main goal of this experiment was to measure the benefits and costs of conjunction previewing upon conjunction error scores. Significant cost-plus-benefit conjunction preview effects were found in Experiments 4, 5 and 6, i.e., congruent conjunction previews caused significantly fewer conjunction errors than incongruent conjunction previews. The cost-plus-benefit conjunction preview effect observed in the present experiment was in the same direction as observed in these other experiments but the difference was not significant. Consequently, cost-benefit analysis of the conjunction preview effect was not possible.

Nevertheless, identifying why the conjunction preview effect was not significant in the present experiment may inform the explanation of the effect. The different outcomes in the present experiment and the previous experiments may have been caused by differences in the methods used.

One way in which the method of the present experiment differed from the method of the previous experiments was that there were different numbers of objects in the preview display. In Experiments 4, 5 and 6 the preview displays contained a single preview object. In the present experiment, it was necessary to use preview displays that contained two objects, in order to have an appropriate control condition for the cost-benefit analysis of conjunction previewing. One object was task-relevant, i.e., it was composed of features that also appeared in the probe display. The other object was task-neutral, i.e., it was composed of features that never appeared in the probe display.

Another way in which the method of the present experiment differed from the method of the previous experiments was where the preview objects appeared. In Experiments 4, 5 and 6 the single preview objects were located centrally. In the present experiment the pair of preview objects could not occupy the same central location as one object would obscure the other. Instead the objects were located 2.1 degrees of visual angle from the centre of the display. Perhaps foveal presentation of the preview object causes the effect of conjunction previewing to more powerful than extra-foveal presentation of the preview object does. One possible explanation is that more resources are dedicated to the processing of foveal stimuli than extra-foveal stimuli. Perhaps the more resources that are excited by a stimulus then the more activation there will be in the system and the more powerful the bottom-up priming effect of the stimulus will be.

The final way in which the method of the present experiment differed from the method of the previous experiments was the cueing of where the probe objects would appear. In Experiments 4, 5 and 6 the locations of the probe objects could not be predicted before the probe display appeared. In the present experiment the locations of the preview objects indicated where the probe objects would appear. In both the preview and probe displays a straight line could be traced between the objects, which passed through the centre of the display. On all trials, the lines of orientation for the preview and probe displays were perpendicular. This ensured that the preview objects were always the same distance from the probe objects. Perhaps knowing in advance where the preview objects affected where participants fixated or attended. If so this may have interfered with the conjunction preview effect. For example, perhaps the participants were cued to attend to or fixate upon the location of one of the two target objects. The report of a stimulus can be facilitated by prior cue indicating the stimulus' location (Müller & Rabbitt, 1989; Posner, 1980; Posner, et al., 1980). Spatial orienting has been found to affect the occurrence of illusory conjunctions (e.g., Prinzmetal, Presti & Posner, 1986; Briand & Klein, 1987).

It was found that on congruent physical conjunction preview trials participants were significantly more likely to correctly report the probe object that was identical to the preview object than correctly report the non-previewed probe object. Therefore, there is some evidence that the previews in the present experiment had affected participants' reports. However, there was no evidence of a difference between previewed conjunction errors and non-previewed conjunction errors in the incongruent physical conjunction preview condition.

In summary the present experiment failed to find a significant conjunction preview effect with preview displays containing a task relevant object and a task neutral object. This may be because the presence of the task neutral object interferes with the conjunction preview effect of the task relevant object. Also it may be because increased retinal eccentricity reduces the magnitude of the conjunction preview effect. Finally it may be because the locations of the probe objects were cued by the preview display. In order to eliminate some of these accounts Experiment 8 was conducted.

4.4 Experiment 8: Cost-Benefit Analysis of the Conjunction Preview Effect 2

4.4.1 Introduction

The primary aim of Experiment 7 was to perform a meaningful cost-benefit analysis of the conjunction preview effect established in Experiments 4, 5 and 6. However, cost-benefit analysis of the data from Experiment 7 was not possible because the observed effect of conjunction previewing was not significant. There were several differences in the methods adopted between Experiment 7 and Experiments 4, 5 and 6. These differences may account for the absence of a significant conjunction preview effect. In Experiment 7 the preview objects appeared extra-foveally and their locations cued the locations of the target objects whereas in the other experiments the preview objects appeared centrally. Also in Experiment 7 the locations of the target items were cued by the preview display whereas this did not occur in the other experiments.

Experiment 8 has the same primary objective as Experiment 7, i.e., to perform a meaningful cost-benefit analysis of the effect of conjunction previewing. In most regards the two experiments were the same. However, in Experiment 7 the preview objects were located extra-foveally and their locations may have cued the locations of the target objects. In contrast, in Experiment 8 the preview objects appeared centrally and they did not cue the location of the target objects. Therefore if the effect of conjunction previewing is not significant in this experiment then it cannot be due to either of these causes.

4.4.2 Method

Participants

The participants were sixteen psychology undergraduates at the University of Plymouth participating as part of the course requirements or for a nominal fee. All had normal or corrected-to-normal vision and did not report any major visual deficits.

Design

A one-way repeated-measures design was employed. There were four conditions determined by manipulation of the contents of the preview display. These conditions were the same as four of the conditions in Experiment 7. There were 50 trials in each condition.

In all of the conditions the preview display contained two preview objects. The preview objects were colour-filled geometric shapes. One of the preview colours and one of the preview shapes also appeared in the probe display. The other preview colour and the other preview shape were neutral to the report task. This colour and shape did not ever appear in the target display and were not available to be reported. The task neutral colour was grey the task neutral shape was square.

In the congruent conjunction preview condition one of the preview objects was identical to one of the target objects. The other preview object was composed of the two task-neutral features; i.e., it was a grey square. In the incongruent conjunction preview condition one of the preview objects was the same colour as one of the target objects and the same shape as the other target object. The other preview object was composed of the two task-neutral features. In the congruent temporal conjunction preview condition one of the preview objects was the same colour as one of the target objects and was a task-neutral shape (square). The other preview object was the same shape as the target object whose colour was previewed and was a task-neutral colour (grey). In the incongruent temporal conjunction preview condition one of the preview objects was the same colour as one of the target objects and was a task-neutral shape (square). The other preview object was the same shape as the target object whose colour was *not* previewed and was a task-neutral colour (grey).

In Experiment 7 there were two other control conditions; the no object preview condition and the neutral object preview condition. These conditions were not in Experiment 8 because the general warning effect and feature priming effect of the conjunction previews were not the main concern of the experiment and also to keep the number of comparisons to a minimum.

Apparatus and Stimuli

The same apparatus was used as in Experiment 7. The stimuli were generated and displayed in the same way as in Experiment 7 except for the locations of the objects in preview and target displays. In preview displays the fixation point was presented at the centre of the display. The preview objects were located on the horizontal meridian either side of the fixation point, 2.8° apart, measured between the centres of the objects.

The line of orientation of the target objects was randomly determined on each trial as was done in Experiments 4, 5 and 6. Therefore, this line of orientation was not constrained to be at right angles to the line of orientation of the preview objects and the locations of the target objects were not predictable. The target objects were located 4.2° of visual angle from the centre of the display.

Procedure

Each participant undertook a single experimental session lasting about 1 hour. The experiment consisted of 200 trials. In all other regards the procedure was the same as in Experiment 7.

Table 4.2. *Mean proportions of conjunction errors and feature errors by condition in Experiment 8*

	Conjunction preview		Temporal preview	
	Congruent	Incongruent	Congruent	Incongruent
Conjunction errors	0.063	0.074	0.059	0.096
Feature errors	0.216	0.249	0.208	0.224

4.4.3 Results

Conjunction errors and feature errors were scored and transformed to proportions in the same way as in Experiment 7. Table 4.2 displays the mean proportions of conjunction errors and feature errors for each condition.

A one-way ANOVA of the conjunction error data was undertaken. The arcsine transformation was applied to the data because the homogeneity of variance assumption was violated and the data were in the form of proportions (see Appendix 3). No evidence of differences between the four conditions was found, F (3,45) = 1.86, $p > 0.05$. Nevertheless, the cost-plus-benefit conjunction preview effect upon conjunction errors was in the same direction as previous experiments, i.e. fewer conjunction errors occurred in the congruent conjunction preview condition than in the incongruent conjunction preview condition (see Table 4.2).

A one-way ANOVA of the feature error data was to be undertaken to determine whether any effect effects in the conjunction error data could be mediated by illusory features or feature guessing. However, as no significant effects on conjunction error scores were found the analysis of the feature error data was unnecessary.

Analyses were performed to determine whether participants were more likely to report the target colour and target shape that were identical to the preview object than the other target colour and target shape.

In the incongruent physical conjunction preview condition, previewed and non-previewed conjunction errors were compared. If the preview objects were a blue triangle and a grey square (i.e., a task neutral preview object) and the target objects were a blue circle and a red triangle then the report of a blue triangle would be a previewed conjunction error and the report of a red circle would be a non-previewed conjunction error. The difference between the mean proportion of previewed conjunction errors (0.106) and the mean proportion of non-previewed conjunction errors (0.086) was significant, t (15) = 2.14, $p <$ 0.05.

In the congruent physical conjunction preview condition, previewed and non-previewed correct reports were compared. If the preview objects were a blue circle and a grey square, and the target objects were a blue circle and a red triangle then the report of a blue circle would be a previewed correct report and the report of a red triangle would be a non-previewed correct report. The difference between the mean proportion of previewed correct reports (0.700) and the mean proportion of non-previewed correct reports (0.647) was not significant, t (15) = 1.65, $p > 0.05$.

In the incongruent temporal conjunction preview condition, previewed and non-previewed conjunction errors were compared. If the preview objects were a blue square and a grey triangle, and the target objects were a blue circle and a red triangle then the report of a blue triangle would be a previewed conjunction error and the report of a red circle would be a non-previewed conjunction error. The difference between the mean proportion of previewed conjunction errors (0.083) and the mean proportion of non-previewed conjunction errors (0.065) was not significant, t (15) = 1.54, $p > 0.05$.

In the congruent temporal conjunction preview condition, previewed and non-previewed correct reports were compared. If the preview objects were a blue square and a grey circle, and the target objects were a blue circle and a red triangle then the report of a blue circle would be a previewed correct report and the report of a red triangle would be a non-previewed correct report. The difference between the mean proportion of previewed correct reports (0.702) and the mean proportion of non-previewed correct reports (0.060) was significant, t (15) = 3.14 $p < 0.05$.

4.4.4 Discussion

The main goal of Experiment 8 was to measure the benefits and costs of conjunction previewing upon conjunction error scores. The cost-plus-benefit effect of conjunction previewing observed in the present experiment was in the same direction as observed in Experiments 4, 5, and 6 but the difference was not significant. Consequently, cost-benefit analysis of the conjunction preview effect was not possible. This was the same outcome as in Experiment 7.

Several suggestions of why the conjunction preview effect was not significant in Experiment 7 were proposed earlier in this chapter (see Section 4.3.4). One suggestion was that the magnitude of the conjunction preview effect was greatly reduced because the preview object was located extra-foveally. In the present experiment the preview objects appeared in the centre of the display. Consequently, the absence of conjunction previewing in Experiment 7 appears not to be due to the location of the preview object.

Another suggestion why conjunction previewing did not occur in Experiment 7 was because the preview displays cued the locations of the target objects. In Experiment 8 the locations of the target items were not cued. Therefore, the lack of a conjunction preview effect in Experiment 7 appears not to be a consequence of the cueing of target item locations.

Two possible reasons for the non-significant conjunction preview effects in Experiments 7 and 8 remain. First, perhaps the magnitude of the conjunction preview effect is reduced when a task neutral object is also present in the probe display. Second, perhaps the magnitude of the conjunction preview effect is reduced by greater retinal eccentricity of the target items; i.e., when target items are located further away from the centre of the display. In Experiments 4 and 5 the probe objects were located 2.1 degrees of visual angle from the centre of the display. In both experiments there was evidence of conjunction preview effects when there were equal numbers of congruent and incongruent preview trials. In Experiment 6 the probe objects were located 4.2 degrees of visual angle from the centre of the display. In the condition where there were equal numbers of congruent and incongruent conjunction preview trials the effect of conjunction previewing was in the right direction but was not significant. Similarly, in Experiment 8 the probe objects were 4.2 degrees from the centre of the display and there were the same number of congruent and incongruent conjunction preview trials. Therefore, the non-significant conjunction previewing in this experiment may have been a result of the location of the target items.

In all four conditions the previewed response was more likely than the comparable non-previewed response, although the difference was not always significant. In the incongruent physical conjunction preview condition there were significantly more previewed conjunction errors than non-previewed conjunction errors. In the congruent physical conjunction preview condition there were more previewed correct reports than non-previewed correct reports, although not significantly. These two findings, which are similar to those found in Experiments 4-6, suggest that physical conjunction previewing had affected participants' reports. Furthermore, a similar pattern of effects was found in the temporal conjunction preview conditions. In the congruent temporal conjunction preview condition there were significantly more previewed correct reports than non-previewed correct reports. In the incongruent temporal conjunction preview condition there were more previewed conjunction errors than non-previewed conjunction errors but the difference was not significant. Consequently, temporal conjunction previewing also appears to affect participants' reporting. If so temporal conjunction previewing may not be a suitable control for baseline analysis of physical conjunction previewing effects.

4.5 General Discussion

Two experiments were undertaken to perform cost-benefit analysis of the conjunction previewing. However, neither experiment produced a significant cost-plus-benefit conjunction preview effect. The reasons for this outcome were explored. Two possible reasons were eliminated. The lack of a significant conjunction preview effect cannot be due to the preview objects being located peripherally because the effect was not significant in Experiment 8 when the preview objects appeared near to the point of fixation. Neither can it be due to the target object locations having been cued. This may have occurred in Experiment 7 but could not have occurred in Experiment 8.

There are at least two possible reasons why the effect of conjunction previewing was not significant in Experiments 7 and 8. In both experiments the preview displays contained two preview objects. Perhaps the magnitude of the conjunction preview effect is reduced when a task neutral object is also present in the probe display. If this is the case then it may not be possible to perform cost-benefit analysis of conjunction previewing. The magnitude of the conjunction preview effect (i.e., the difference between the mean conjunction error scores for the congruent and incongruent physical conjunction preview conditions) in Experiment 7 (0.020) was somewhat smaller than the conjunction preview effects in Experiment 4 (0.057), the 0.5 sec preview-target SOA condition of Experiment 5 (0.044), the high predictive validity condition of Experiment 6 (0.050) and the preview condition of Experiment 9 (0.033; see Section 5.2.3). However, the magnitude of the conjunction preview effect in Experiment 8 (0.037) was larger than that of Experiments 7 and 9. It appears that reason why the conjunction preview effect is not significant in Experiment 8 is not because of a smaller effect but was because of a larger variance. Even so the variance of the conjunction preview effect in Experiment 8 was smaller than the variances of the conjunction preview effects in Experiments 4 and 5. Perhaps the differences in effect size and variance are largely due to sampling error.

There are no other similarities between Experiments 7 and 8 that set them apart from the experiments in which evidence of conjunction previewing was found. However, it is possible that the reasons for the non-significance of the preview effects were different in the two experiments. The retinal eccentricity of target items is known to affect the numbers of illusory conjunctions (e.g., Ashby et al., 1996). This may affect the magnitude and variance of the conjunction preview effect. In Experiment 8 the probe objects were 4.2 degrees of visual angle from the centre of the display. In Experiments 4 and 5 this distance was 2.1 degrees. It is possible that the magnitude of the conjunction preview effect is reduced when target items are located further away from the point of fixation. In Experiment 6 the probe objects, like Experiment 8, were 4.2 degrees of visual angle from the centre of the display. In this experiment, the conjunction preview effect was not significant when there were equal numbers of congruent and incongruent conjunction preview trials. There were also equal numbers of congruent and incongruent trials in Experiment 8. Retinal eccentricity of the target objects cannot be the cause of the non-significant effect in Experiment 7. In that experiment the preview objects were located the same distance from the point of fixation as in Experiments 4 and 5.

Experiments 7 and 8 also permitted the analysis of whether the previewed colour and shape must be properties of a single object for the conjunction preview effect to occur. In Experiments 4, 5 and 6 the features of the conjunction previews were physically conjoined, i.e., they were properties of a single object. When features are physically conjoined they are also temporally conjoined, i.e., the features appear together at the same time[26]. Consequently, in these experiments, reported in Chapter 3, the preview features were both physically and temporally conjoined. Perhaps the effect of conjunction previewing is a consequence of the mere temporal conjunction of preview features rather than their physical conjunction. If so the conjunction preview effect would occur even if the preview colour and preview shape are properties of different objects, i.e., the features are merely temporally conjoined. In other words, the preview effect may occur when the preview displays contain two objects, each of which contains one of the preview features. This was the case with the preview displays in the temporal conjunction preview control conditions of Experiments 7 and 8. No evidence of a temporal conjunction preview effect was found. However, no evidence of a conjunction preview effect was found either. Until the reasons for this are established it is not reasonable to argue that a temporal conjunction preview effect does not occur.

In summary, the absence of a significant conjunction preview effect in Experiment 8 may have been caused by the presence of a neutral object in the preview display, the high

[26] The defining characteristic of temporal conjunction is that features appear and disappear together.

retinal eccentricity of the target objects or sampling error. The first explanation may also account for the lack of a significant conjunction preview effect in Experiment 7. If the second explanation is correct then the reduced magnitude of the conjunction preview effect in Experiment 7 may have been caused by spatial cueing of the target items or the extra-foveal presentation of the preview objects. It will be necessary to conduct further experiments to compare the effects of one and two object preview displays and different preview object eccentricities in order to decide among these alternative explanations.

CHAPTER 5: THE PRIMING OF FEATURE INTEGRATION HYPOTHESIS AND THE CONJUNCTION PREVIEW EFFECT

5.1 Outline of Chapter

The experiments that are reported in Chapter 3, establish the existence of a conjunction preview effect upon conjunction error scores. It was argued that this effect may be mediated by the bottom-up and top-down priming (Posner & Snyder, 1975a, b) of the object tokens (Kahneman & Treisman, 1984) that encode the properties of the target stimuli. The priming of these object tokens may affect the likelihood that illusory conjunctions of target features will occur. This account has been termed the *priming of feature integration hypothesis* in this thesis. In general, the experimental findings described in Chapter 3 support this hypothesis.

However, three other plausible accounts of the findings were also raised in Chapter 3. First, it is possible that the effect of conjunction previewing was mediated by a strategy in which participants reported the identity of the preview object instead of a target object. Second, it is possible that the effect was caused by the migration of the object in the preview display to the target display, i.e., temporal illusory conjunctions occurred. Third, it is also possible that the priming of either a lexical or a semantic representation of the stimuli mediated the effect rather than the priming of the object token domain. This chapter describes two experiments that were undertaken primarily to test the priming of feature integration hypothesis against these plausible alternative explanations.

Experiment 9, which is described in Section 5.2, investigated the effects of reversing the presentation order of the preview and target stimulus displays on the whole report of the target objects. It was reasoned that if the priming of feature integration hypothesis was true then presenting the target display before the "preview" display would interfere with the priming of feature integration. It was also reasoned that if the preview-report strategy or temporal illusory conjunction accounts of the conjunction preview effect were true then the reversed order of presentation of the target and "preview" displays would still result in a conjunction preview effect on conjunctions errors. There was evidence that a post-target intrusion effect can occur. But there was little evidence that the order of presentation of the preview and target displays affects the magnitude of the conjunction cueing effect. Therefore, it was not possible to reject the temporal illusory conjunction or the preview-strategy explanations of the conjunction preview effect because the relevant interaction was not significant.

Experiment 10, which is described in Section 5.3, investigated the effects of visual object and lexical previewing upon the whole-report of the target objects. It was reasoned that lexical priming of feature conjunctions would not result in a priming effect if this effect is normally mediated by either bottom-up priming or temporal illusory conjunctions, but would result in priming effect if the effect is mediated by top-down priming or the preview-report strategy. Cost-plus-benefit conjunction preview effects upon conjunction errors were found with both visual object previews and lexical previews. The finding of a preview effect with lexical conjunction previews supports the preview-report strategy account and top-down priming of object tokens account of the conjunction preview effect at the expense of the bottom-up priming of object tokens account and the temporal illusory conjunction accounts. There was no evidence of an interaction between preview conjunction congruence and preview type (i.e., visual object or lexical). Consequently, the preview-report strategy explanation is plausible.

Section 5.4 is a general discussion of the results of the experiments that summarizes the main conclusions of the chapter.

5.2 Experiment 9: Preview-Target Presentation Order and the Conjunction Preview Effect

5.2.1 Introduction

The priming of feature integration hypothesis was proposed to explain the effect that conjunction previewing was found to have upon conjunction error scores in Experiment 4. The hypothesis holds that conjunction previews cause the process of visual feature integration to be primed (Posner & Snyder, 1975a, b). The supposed locus of these priming effects is the representational domain that encodes object tokens (Kahneman & Treisman, 1984). These priming effects are thought to result from either the preview stimulus causing bottom-up activation of object tokens or from the viewer expecting that the previewed feature conjunction will appear in the target, which causes top-down activation of the object token representation.

Several other accounts of the effect of conjunction previewing were also proposed in Chapter 3. The preview effect could equally be described as a *pre-target intrusion* (McLean et al., 1983) effect. It has been suggested that pre-target intrusions might occur either as a result of temporal illusory conjunctions (Botella & Eriksen, 1992; Botella et al., 1992; Broadbent & Broadbent, 1987; Intraub, 1985, 1989; Kanwisher, 1991; Keele et al., 1988; Lawrence, 1971; McLean et al., 1983) from the preview display to the target display or because participants were strategically reporting the preview object when some of the target features were unknown. Both temporal illusory conjunctions and the preview-report strategy could cause *post-target intrusions* (McLean, et al., op. cit.). Therefore, if either of these accounts are true then we might expect a similar effect to take place if conjunction preview displays were to be presented *after* the target display[27]. If the post-target display is found to affect the report of the target it could be said that a *post-target intrusion effect* has occurred.

The preview-report strategy account of the conjunction preview effect holds that

[27] The previewing paradigm is one version of the double-stimulation paradigm (Kantowitz, 1974). In another version of this paradigm the target stimulus is presented before the modifying stimulus. Some authors refer to the modifying stimulus in this paradigm as a *backwards prime* (e.g., Taylor, 1977), however, in this thesis the terms *review display* or *post-target display* are preferred.

participants perform a strategy that enables them to complete the forced-choice report in the absence of a complete sensory impression of the target display. This strategy is thought to be mediated by high-level cognitive processes and involve the generation of expectations about what target objects are likely to be present given the identity of the preview object on any given trial. It is suggested that these expectations lead participants to report a target object as having the identity of the preview object; i.e.. a pre-target intrusion.

The preview-report strategy account also predicts that a post-target intrusion effect will occur if the "preview" stimulus is presented after the target. It is assumed that the order in which the target and cue stimuli (i.e., the preview or review stimuli) are presented, will not affect the execution of the strategy. If so participants will use the same information to generate a report under conditions of previewing and reviewing. If this simplifying assumption is true then the preview-report strategy account predicts that participants would be equally likely to use the preview or review information to help complete their response. Therefore, the conjunction preview effect and post-target intrusion effect should have roughly the same magnitude.

The temporal illusory conjunction account of the conjunction preview effect holds that feature conjunctions migrate from the preview display and become incorporated in the representation of the target display. In the congruent conjunction preview condition, the migration of the preview object migration would result in a correct report. In the incongruent conjunction preview condition, the migration of the preview object would result in a conjunction error.

Temporal illusory conjunctions are thought to cause both pre-target intrusions and post-target intrusions (McLean et al., 1983). A *pre-target intrusion* will occur if a feature or object migrates from an earlier display to a later display. A *post-target intrusion* will occur if a feature or object migrates from an later display to an earlier display. Some studies have found pre-target and post-target intrusions to be equally frequent (Gathercole & Broadbent, 1984; McLean et al., 1983, Experiment 2). Other studies have found post-target intrusions to be more common than pre-target intrusions (Gathercole & Broadbent, 1984, Experiment 1; Lawrence, 1971; McLean et al., 1983, Experiment 1). Therefore, the temporal conjunction preview effect predicts that if conjunction preview displays are presented after the target displays then the post-target intrusion effect should be the same magnitude as the conjunction preview effect, if not greater.

The preview-report strategy and the temporal illusory conjunction accounts of the conjunction preview effect can both account for a post-target intrusion effect, however the priming of feature integration hypothesis cannot. For bottom-up or top-down priming to occur the preview stimulus must appear before the target stimulus. If the "preview" is presented after the probe it cannot activate object tokens and expectations cannot be generated prior to the processing the probe display. Therefore, the priming of feature integration hypothesis predicts there will be a greater conjunction preview effect than conjunction review effect. Furthermore, finding evidence of this interaction would be contrary to the temporal illusory conjunction and preview-report strategy accounts of the conjunction preview effect. Therefore, one way, potentially, of falsifying the temporal illusory conjunction and preview-report strategy explanations is to conduct an experiment in which participants are presented with the same stimuli as in Experiment 4 but for the target stimuli to precede the "preview" stimuli.

The present experiment was designed to discover whether the conjunction preview effect is greater the conjunction preview effect. Three displays were presented on each trial; a preview or pre-target display, a target display and a review or post-target display. On some trials the pre-target display contained a conjunction *preview* object. These trials enabled the effect of conjunction previewing to be determined. On other trials the review display contained a conjunction *review* object. These trials enabled the post-target intrusion effect to be analysed.

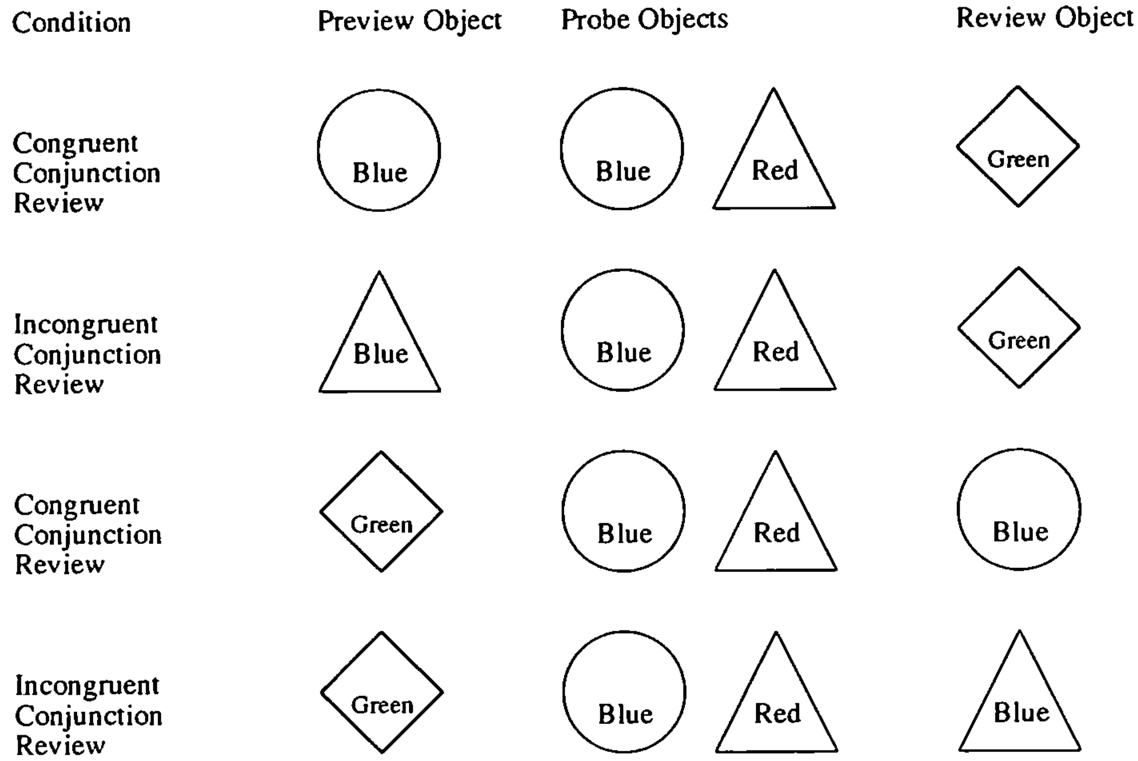

Figure 5.1. Examples of conjunction preview and review displays in Experiment 9 for a probe display consisting of a blue circle and a red triangle. Note that in the preview conditions all the preview displays contain a colour and a shape that is also present in the probe display. This is not the case in the review conditions.

Participants

Sixteen psychology undergraduates at the University of Plymouth participated as part of the course requirements or for a nominal fee. They had either normal or corrected-to-normal vision and reported having no major visual deficits.

Design

A two-way fully repeated-measures design was used. One independent variable was whether the conjunction cue object appeared before or after the probe display[28]. In the preview condition the pre-target display contained a congruent or incongruent conjunction preview object. In the review condition the post-target display contained a congruent or incongruent conjunction preview object. The other independent variable was the type of conjunction cue. In the congruent conjunction cue condition either the preview or review object was identical to one of the target objects In the incongruent conjunction cue condition the preview or review object was the same colour as one of the target objects and the same shape as the other target object. There were 50 trials in each cell of the two-by-two design.

Apparatus and Stimuli

The displays were generated by an Acorn Archimedes A5000 computer and displayed on an Acorn AKF18 60 Hz colour monitor. This was the same apparatus as was used as in Experiments 4 to 8.

The stimuli consisted of three displays; a preview or pre-target display, a target display and a review or post-target display. The dimensions of preview objects, target objects and the fixation square were the same as in Experiment 4 and others. The review objects were the same size as the preview objects. All the displays had a black background.

[28] The term *cue* is used here to denote a preview or review display.

The preview display consisted of a centrally located white square fixation point overlaid upon a preview object. On preview trials the colour and shape of the preview object were determined by colours and shapes of the target objects (see Figure 5.1). On the congruent conjunction preview trials, the preview object was the same colour and shape as one of the target objects. On the incongruent conjunction preview trials, the preview object was the same colour as one target object and the same shape as the other target object. On review trials the colour and shape of the preview object was randomly selected from the colours and shapes that did not appear in the target display on that trial.

The layout of the probe displays was similar to the previous experiments. The probe display consisted of two probe objects (see Figure 2.4 in Chapter 3). The probe objects were colour-filled geometric shapes. The two probe colours were randomly selected without replacement from a pool of five colours: blue, green, magenta, orange and red. The two probe shapes were randomly selected without replacement from a pool of five shapes: circle, cross, diamond, five-pointed star and triangle. Consequently, the two objects in a probe display had different colours and different shapes. The height and width of each probe item was approximately 1.68° of visual angle. The probe objects were located so that their centres were at either end of an unseen line approximately 8.4° in length. The midpoint of this line coincided with the centre of the display. Consequently, the retinal eccentricities (i.e., the distance from the point of fixation) of the two probe objects were 4.2°. The angle between the unseen line and the horizontal meridian was randomly determined on each trial to ensure that the participants equally attended to the two probe objects.

The post-target display contained two feature masks at the same locations as the probe items. The masks were generated in the same way as in the previous experiments. Each mask was a 10 by 10 block of feature chunks randomly selected from the possible shapes and colours. Each feature chunk was approximately 0.05° of visual angle in size and the whole mask had the same height and width as the probe items. The post-target display also contained a centrally located colour-filled geometric object. On review trials the colour and shape of this review object were determined by colours and shapes of the target objects (see Figure 5.1). On the congruent conjunction review trials, the review object was the same colour and shape as one of the target objects. On the incongruent conjunction review trials, the review object was the same colour as one target object and the same shape as the other target object. On preview trials the colour and shape of the review object was randomly selected from the colours and shapes that did not appear in the target display on that trial.

The response displays were the same as in Experiments 4 to 8. They comprised of a palette of shape icons, a palette of colour icons, two response boxes, one for each probe object, and the response complete button (see Figure 2.4 in Chapter 3). Each palette consisted of a row of five colour or shape icons superimposed on a larger black square. The black squares were set against a grey background. Colour icons were squares of the five feature colours. Shape icons were rendered in the same grey as the screen background. The location of feature icons within the palette was randomized on each trial. The palette of colours was presented at the top of the display and the palette of shapes was presented at the bottom of the display. Along the horizontal median was a row of three black squares. The flanking squares were the *object response boxes* into which participants composed their responses. The central square, the response complete button, contained the label *OK* rendered in white.

Procedure

Each participant undertook a single experimental session lasting about 45 minutes. The experiment consisted of 200 trials. The stimuli were viewed under dim lighting conditions from a distance of approximately 75 cm.

On each trial the following occurred. First, a tone was sounded and a preview display was presented for 0.5 secs. Next, a target display was presented for 140 msecs, followed by a post-target display, which was presented for 0.5 secs. In Experiments 4 to 8 the exposure duration of the target display had been 100 msecs. The participants in a pilot study of the present experiment had produced far fewer object correct report responses than in the previous experiments. It was thought that the presence of review objects in the post-target display may have caused a meta-contrast masking effect (Breitmeyer, 1984; Ramachandran & Cobb, 1995) that further degraded or inhibited perception of the target display. To enable comparison between this experiment and the others it was thought important that participants were approximately equally likely to make correct reports. Consequently, the target display was presented for longer in the present experiment.

Both the pre-target and post-target displays contained coloured geometric objects (see Figure 5.1). A pilot study had suggested that there was a backwards meta-contrast masking effect of the review object. In this study on preview condition trials there was a preview object but no review object and on review condition trials there was a review object but no preview object. There were many more feature errors in the review condition than the preview condition. The design of the present experiment was to ensure that the masking effects of the post-target displays were the same in the preview and review conditions.

After the three stimulus displays had appeared, a response screen was presented until the participant completed their response. The response displays were the same as used in Experiments 4 to 8. The response screen comprised of a palette of shape icons, a palette of colour icons, two object response boxes and a response complete button. The participants were instructed to compose the two coloured shapes they had seen in the probe display in the object response boxes. Participants dragged-and-dropped icons from the palettes into the response boxes using an on-screen pointer controlled by the computer mouse. When a colour icon and a shape icon were dropped into an object response box the composite coloured shape icon was displayed in the box. The participants were able to change the colour or shape in a response box by dragging-in the desired alternative feature icon.

Participants had to fill both response boxes with a composed coloured shape icon for them to be able to proceed to the next trial.

The colours and shapes of the two objects in a probe display were always different. Consequently, the response method precluded participants from reporting that the probe colours or shapes were the same. If a participant inadvertently dropped the same feature icon into both response boxes, then the computer would make an error tone and the second drag-and-drop would be unsuccessful. Participants had to fill both response boxes with a fully-composed coloured shape icon for them to be able to proceed to the next trial.

When participants thought that they had completed their report they would press the response complete button. If the report was complete then a blank display would be presented for one second followed by the next trial. The presentation of the blank display was to prevent participants' perception of the stimuli in the next trial from being primed by the previous response display. If the report was incomplete an error tone would be sounded. Participants were not informed about the accuracy of their reports during the experiment.

Prior to undertaking the full experiment the participants had a practise session of 30 trials to familiarise them with the stimuli and the task.

Table 5.1. *Mean proportions of conjunction errors and feature errors by condition in Experiment 9*

	Conjunction preview		Conjunction review	
	Congruent	Incongruent	Congruent	Incongruent
Conjunction errors	0.041	0.074	0.053	0.054
Feature errors	0.222	0.252	0.286	0.290

5.2.3 Results

Conjunction errors and feature errors were scored and transformed to proportions in the same way as in Experiments 4 to 8. Table 5.1 displays the mean proportions of conjunction errors and feature errors for each cell of the experimental design.

A two-by-two fully repeated-measures design ANOVA was performed on the conjunction error data. The arcsine transformation was applied to the data because the raw data were in the form of proportions and violated the sphericity assumption (Howell, 1997).

The conjunction congruence main effect was significant, $F\ (1,15) = 8.68$, $p < 0.01$. The mean conjunction error score was higher in the incongruent conjunction cue condition (0.064) than in the congruent conjunction cue condition (0.047). However, the difference in mean conjunction error scores between congruent and incongruent conjunction cue conditions was greater in the preview condition than in the review condition (see Table 5.1). Nevertheless, the conjunction congruence by preview-target presentation order interaction was not significant, $F\ (1, 15) = 2.33$, $p > 0.05$. Therefore, there is no evidence that conjunction congruence effect is affected by the order of stimulus presentation. The preview-target presentation order main effect was not significant, $F < 1$.

An analysis of the feature error data was undertaken to determine whether the effects upon conjunction errors were mediated not by illusory conjunctions but by the same processes that cause feature errors; i.e., illusory features or guessing. Table 5.1 shows that there was little difference in mean feature error scores between congruent and incongruent conjunction conditions in either the preview condition or the review condition.

A two-by-two fully repeated-measures design ANOVA was performed on the feature error data. The conjunction congruence main effect and the conjunction congruence by stimuli presentation order interaction were not significant, $F < 1$. Therefore, the effect of conjunction previewing upon conjunction error scores does not appear to be mediated by the processes that cause feature errors. Table 5.1 also shows that mean feature error scores were higher in the review condition than the preview condition. The preview-target presentation order main effect was significant, $F(1,15) = 14.92, p < 0.01$.

Analyses were performed to determine whether participants were more likely to report the target colour and target shape that were identical to the cue object than the other target colour and target shape. In the incongruent conjunction cue condition, cued and non-cued conjunction errors were compared. If the cue object was a blue triangle and the target objects were a blue circle and a red triangle then the report of a blue triangle would be a cued conjunction error and the report of a red circle would be a non-cued conjunction error.

A two-way repeated-measures ANOVA of the conjunction error data from the incongruent conjunction cue condition was undertaken. One factor was whether the conjunction error was cued or non-cued, the other factor was preview-target presentation order. The difference between the mean proportion of cued conjunction errors (0.067) and the mean proportion of non-cued conjunction errors (0.061) was not significant, $F < 1$. However, the two-way interaction was significant, $F(1,15) = 5.79, p < 0.05$. Under previewing there were more cued conjunction errors (mean proportion = 0.087) than non-cued conjunction errors (mean proportion = 0.060), but under reviewing there were fewer cued conjunction errors (mean proportion = 0.046) than non-cued conjunction errors (mean proportion = 0.062).

In the congruent conjunction cue condition, cued and non-cued correct reports were compared. If the cue object was a blue circle and the target objects were a blue circle and a red triangle then the report of a blue circle would be a cued correct report and the report of a red triangle would be a non-cued correct report.

A two-way repeated-measures ANOVA of the correct report data from the congruent conjunction cue condition was undertaken. One factor was whether the correct report was cued or non-cued, the other factor was was preview-target presentation order. The difference between the mean proportion of cued correct reports (0.600) and the mean proportion of non-cued correct reports (0.576) was not significant, $F < 1$. The two-way interaction was not significant either, $F(1,15) = 1.38$, $p > 0.05$.

5.2.4 Discussion

The experiment was performed to discover whether the conjunction preview effect (or pre-target intrusion effect) is greater than the conjunction review effect (or post-target intrusion effect). It was earlier claimed that if such an interaction were to be found it would be evidence against the temporal illusory conjunction and preview strategy explanations of the conjunction preview effect.

The cost-plus-benefit preview effect upon conjunction error scores found in Experiment 4 and other experiments was replicated. The main effect of conjunction cueing was significant; i.e., there were significantly fewer conjunction errors in the congruent conjunction cue condition than in the incongruent conjunction cue condition irrespective of the order of presentation of the cue and target displays. However, the difference in mean conjunction error scores between congruent and incongruent conjunction cue conditions was greater in the preview condition than in the review condition. Nevertheless, the conjunction congruence by preview-target presentation order interaction was not significant. Therefore there is little evidence that the post-target effect on conjunction errors differs from the pre-target effect. This finding is consistent with the preview-report strategy and the temporal illusory conjunction accounts of the conjunction preview effect on conjunction errors.

In the feature errors data, the conjunction congruence main effect and the conjunction congruence by stimuli presentation order interaction were not significant. Therefore, there was little evidence that effects found in the conjunction errors data were mediated by whatever processes that cause feature errors; e.g., feature guessing (Prinzmetal, 1981) or illusory features (Treisman & Schmidt, 1982). Therefore, it is possible that conjunction previewing could have influenced the production of illusory conjunctions.

It was also found that mean feature error scores were significantly higher in the review condition than the preview condition. Nevertheless, the mean conjunction error score was lower in the review condition than in the preview condition although the difference was not significant. In other words an effect upon feature errors occurred in the absence of an effect on conjunction errors. This further supports the contention made in Section 3.3.4 that feature errors scores are a poor predictor of conjunction error scores in the present series of experiments.

This preview-target main effect on feature errors may be related to a finding of Experiment 1, that feature previewing can affect the reporting of target features. In the preview condition the preview displays contained only congruent features, i.e., features that were also present in the target display were previewed. In the review condition, the congruent features appeared in the post-target displays and the preview displays contained only incongruent features, i.e., features that were not present in the target display were previewed. Perhaps, the pre-target displays in the conjunction preview condition caused fewer feature misidentifications or feature guesses than the pre-target displays in the conjunction review condition.

Another explanation of the preview-target presentation order main effect on feature errors is that it is a consequence of processes that cause pre-target intrusions. These intrusions may be caused by participants adopting a strategy of reporting the previewed features or because of feature migrations from the preview display. The finding could not be caused by intrusions of whole preview objects. In the conjunction preview condition, if the preview was a blue circle or a red circle and the target objects were a blue circle and a red triangle then a pre-target intrusion of a whole object would result in either a correct report or a conjunction error. In the conjunction review condition, if the preview was a green diamond and the target objects were a blue circle and a red triangle then a pre-target intrusion of a whole object would result in a double feature error (see Section 3.3.3). Therefore, whole object intrusions would not affect feature error scores. However, the finding could have been caused by pre-target intrusions of separate features. In the conjunction preview condition, if the preview was a blue circle or a red circle and the target objects were a blue circle and a red triangle then a pre-target intrusion of a feature would result in either a correct report or a conjunction error. In the conjunction review condition, if the preview was a green diamond and the target objects were a blue circle and a red triangle then a pre-target intrusion of a whole object would result in a feature error. Therefore, this finding does not support any account that argues that the conjunction preview effect is in fact a pre-target intrusion effect involving whole preview objects. The finding can only support the intrusion of features from the preview objects.

On incongruent conjunction cue trials participants were not significantly more likely to make a conjunction error that was identical to the preview object than a conjunction error of the non-cued probe colour and shape, although the effect was in the same direction as in previous experiments. However, there was evidence of an interaction. Under previewing there were more cued conjunction errors than non-cued conjunction errors, but under reviewing there were fewer cued conjunction errors than non-cued conjunction errors. On congruent conjunction preview trials participants were not significantly more likely to correctly report the probe object that was identical to the preview object than correctly report the non-previewed probe object, although the effect was in the same direction as in previous experiments.

The data from the present experiment suggest that a more powerful experiment may find that the conjunction preview effect is greater than the conjunction review effect. It was claimed in Section 5.2 that such a finding would not be consistent with either the preview-report strategy and temporal illusory conjunction explanations of the conjunction preview effect. However, even so it may not be possible to reject these explanations of the conjunction preview effect.

It was earlier assumed that the preview-report strategy account predicts that participants would be equally likely to use the preview or review information to help complete their response. Therefore, equal numbers of pre-target and post-target intrusions are predicted. However, this simplifying assumption may be false for several reasons. First, it is possible that participants are better able to remember the preview display than the review display due to the interplay of primacy and recency effects upon memory. Second, participants may have been better able to identify the preview objects than review objects due to meta-contrast masking by the target object masks which were also in the review display. Third, perhaps participants were biased to attend to pre-target displays rather than post-target displays. Consequently, the finding of a significant interaction between cue congruence and preview-target presentation order would not decisively rule out the involvement of a preview-report strategy. To completely rule out the preview-report strategy account further experimentation will be necessary, therefore. Given the possibility of different masking effects in the pre- and post-target displays, any future replication of the present experiment should incorporate feature masks in the pre-target displays.

It was earlier assumed that the temporal conjunction preview effect predicts that if conjunction preview displays are presented after the target displays then the post-target intrusion effect should be the same magnitude as the conjunction preview effect, if not greater. However, one study by Intraub (1985) has found pre-target intrusions to be more common than post-target intrusions. Intraub found that complex visual objects, i.e., colour photographs and monochromatic frames, can dissociate and migrate between displays, when displays are exposed for 111 msecs. Furthermore, Botella & Villar (1989; described in Botella & Eriksen, 1992) performed a Monte Carlo simulation of the parallel model of temporal illusory conjunctions (Gathercole & Broadbent, 1984; McLean et al., 1983). Their simulations predict that pre-target intrusions will be more frequent than post-target intrusions when the time needed to identify the cue feature, i.e., the feature which identifies the object to be reported, is shorter than the time needed to identify the response feature, i.e., the attribute of the cued object which is to be reported. However, there are obvious differences between the task which Botella & Villar (1989) simulated and the task in the present experiment. Given this difference it is unclear whether the parallel model of temporal illusory conjunctions would predict more pre-target intrusions than post-target intrusions in the present experiment. Given the findings of Intraub (1985) and Botella & Villar (1989) it may be possible for temporal illusory conjunctions to produce more pre-target intrusions than post-target intrusions.

In summary, the results of this experiment do not permit the rejection of the temporal illusory conjunction or the preview-strategy explanations of the conjunction preview effect because the relevant interaction was not significant. However, even if this interaction were to be substantiated in the future, there are versions of both explanations that would not be rejected because they can account for a predominance of pre-target intrusions over post-target intrusions.

5.3 Experiment 10: Lexical Previewing and the Conjunction Preview Effect

5.3.1 Introduction

The priming of feature integration hypothesis holds that the conjunction preview effect is mediated by the priming of a representation of visual objects which encodes which features belong to which objects; i.e., the object token domain is primed. The experiments reported so far are in partial support of the hypothesis. The experiments reported in Chapter 3 do not establish the exact locus of the preview process, i.e., they do not tell us what kind of representation is activated by the preview display to bring about the preview effect. Perhaps the conjunction preview effect is mediated by the priming of some other description of the target stimuli than object tokens.

Posner & Snyder's (1975a, b) account of preview effects proposes that the presentation of a stimulus will automatically activate many different representations. Each of these representational domains will encode different properties of the stimulus. One domain encodes the stimulus' physical form. There may be several distinct physical level representations; for example, a featural domain (e.g., Treisman & Gelade, 1980) and an object token domain (Kahneman & Treisman, 1984). Posner & Snyder (op. cit.) also suggested that there is a word level representation of the lexical entry corresponding to the stimulus. If the stimulus is a picture of a cat then the word level representation will describe the word *cat*. Finally, Posner & Snyder also proposed that there is a semantic level domain which encodes the meanings of the words described at the word level. It may be that the conjunction preview effect is mediated by the activation of lexical or semantic representations of the preview and target stimuli rather than object token representations.

However, the physical representations of the visual object and its lexical description will be very different. The object token representation of a visual object preview will encode that a certain colour and shape are conjoined. The object token representation of a lexical preview will encode which features belong to which letters and which letters belong to which words. If priming of feature integration were to occur then those letters and letter features would be recombined. In this experiment that could possibly result in feature errors but would not cause conjunction errors. Therefore, if the conjunction preview effect is caused by the bottom-up priming of object tokens then the effect will not occur under lexical previewing.

The present experiment was undertaken to determine whether the conjunction preview effect can occur with lexical prime as well as visual object primes. The methodology used was to compare the effects of previewing visual objects, i.e., *visual object previewing*, with the effects of previewing verbal descriptions of such objects; i.e., *lexical previewing*. Lexical previewing is a methodology widely-used in the study of visual word recognition (e.g., Carr et al., 1982; Gordon & Irwin, 1996; Meyer & Schvaneveldt, 1971; Neely, 1977). This involves the visual presentation of a word or words prior to the presentation of a to-be-reported target. Often the target and preview items share some semantic relationship.

The logic of the experiment is as follows. Lexical and visual object preview displays will activate the same word level and semantic level descriptions but different physical level descriptions. If the conjunction preview effect is caused by the activation of the word or semantic levels then the effect will occur under lexical and visual object previewing. It will not matter that the original source of the activation came from a coloured geometric shape or a two word description of a coloured geometric shape. The finding of a significant lexical conjunction preview effect upon conjunction errors might also be explained as being due to the top-down priming of the object token domain by the lexical or semantic domains.

The present experiment also tests whether the conjunction preview effect is mediated by temporal illusory conjunctions. Experiment 9 failed to rule out this possibility so long as these migrations can result in more pre-target intrusions than post-target intrusions. However, in the present experiment temporal illusory conjunctions can only occur with visual object previews. We would not expect the preview word *red* to migrate to the target display and conjoin with a circle causing the participant to report having seen a red circle. Therefore, if a lexical conjunction preview effect exists then it is also evidence against the temporal illusory conjunction account.

The present experiment also provides another test of whether the effect of conjunction previewing is mediated by a preview-report strategy. It is not expected that the form in which the preview information is conveyed to the participant will affect the execution of the strategy. It would not matter if the preview was a coloured shape or the verbal description of a coloured shape. Therefore, the preview-report strategy account predicts that there will be a preview effect under lexical conjunction previewing.

In summary, the finding of a larger preview effect with visual object conjunction previews than with lexical conjunction previews would not be compatible with the preview-report strategy explanation. On the other hand, the finding of approximately equivalent preview effects with visual object conjunction previews and lexical previews would suggest that neither temporal illusory conjunctions nor bottom-up priming are plausible.

5.3.2 Method

Participants

Sixteen psychology undergraduates at the University of Plymouth participated as part of the course requirements or for a nominal fee. They had either normal or corrected-to-normal vision and reported having no major visual deficits.

Design

The experiment was a two-way fully repeated-measures design. The independent variables were preview type and object versus lexical preview. Preview type had two levels. In the congruent conjunction preview condition one of the target objects was previewed by pre-presentation of either an identical object or the name of the object. In the incongruent conjunction preview condition the colour of one of the target objects and the shape of the other target object was previewed by the presentation of either an object comprised of these features or the names of these features. The object versus lexical preview variable had two levels. In the object preview condition the preview displays contained icons of coloured geometric shapes. In the lexical preview condition the preview displays contained a colour name and a shape name. There were 50 trials in each cell of the design.

Stimuli and Apparatus

The same apparatus was used as in the other experiments described in this chapter. As in Experiment 4 the stimuli consisted of three displays; a preview or pre-target display, a target display and a post-target mask display.

In the object preview condition the preview displays were the same as used in Experiments 4 and 5. In the lexical preview condition the preview displays consisted of two words; a colour name and a shape name. A white square fixation point was presented at the centre of the screen. The colour name was located above and the shape name was located below the fixation point with a gap of approximately 0.27° of visual angle. The words were rendered in lower-case white letters roughly 0.27° of visual angle high and 0.19° wide, centre-justified to the vertical midline. On congruent conjunction lexical preview trials the preview display contained the names of the colour and shape of the target objects. On incongruent conjunction lexical preview trials the preview display contained the name of the colour of one of the target objects and the name of the shape of the other target object. The preview object was approximately 1.68° of visual angle in height and width in all conditions. The target, mask and response displays were the same as in Experiment 6.

Procedure

Each participant undertook a single experimental session lasting about 45 minutes. The experiment consisted of 200 trials. The stimuli were viewed under dim lighting conditions from a distance of approximately 75 cm. The presentation of stimuli and the response method followed the same procedure as Experiments 5 and 6.

Table 5.2. *Mean proportions of conjunction errors and feature errors by condition in Experiment 10*

	Visual object preview		Lexical preview	
	Congruent	Incongruent	Congruent	Incongruent
Conjunction errors	0.059	0.078	0.040	0.063
Feature errors	0.267	0.266	0.264	0.287

5.3.3 Results

Conjunction errors and feature errors were scored and transformed to proportions in the same way as in Experiments 4 to 9. Table 5.2 displays the mean proportions of these response types for each condition. The results suggest that the preview effect occurs with either type of preview.

Table 5.2 shows that the mean proportion of responses classified as conjunction errors was lower in the congruent visual object conjunction preview condition than in the incongruent visual object conjunction preview condition, i.e., the observed effect is in the same direction as the conjunction preview effect. Similarly, Table 5.2 also shows that the mean proportion of responses classified as conjunction errors was lower in the congruent lexical conjunction preview condition than in the incongruent lexical conjunction preview condition; i.e., there was a cost-plus-benefit preview effect.

A two-by-two fully repeated-measures design ANOVA was performed on the conjunction error data to discover whether a preview effect occurs with lexical conjunction previews as well as with visual object conjunction previews. The conjunction congruence main effect was significant, $F\ (1,15) = 5.74$, $p < 0.05$. The interaction between conjunction congruence and the type of preview (visual object or lexical) was not significant, $F < 1$. Consequently, there is no evidence to support the hypothesis that the conjunction previewing effect occurs only with visual object previews.

The visual object preview versus lexical preview main effect was almost significant, $F\ (1,15) = 4.52$, $0.06 > p > 0.05$. Mean conjunction error scores were higher in the visual object preview condition than in the lexical preview condition (See Table 5.2).

A two-by-two fully repeated-measures design ANOVA was performed on the feature error data to determine whether the effects found with the conjunction error data were mediated by illusory features or guessing rather than illusory conjunctions. The two main effects and the interaction were not significant. Therefore, there is no evidence that the effect of conjunction previewing effect upon conjunction error scores is mediated by either feature guessing or illusory features.

Analyses were performed to determine whether participants were more likely to report the target colour and target shape that were identical to the preview object than the other target colour and target shape. In the incongruent conjunction preview condition, previewed and non-previewed conjunction errors were compared. If the preview object was a blue triangle and the target objects were a blue circle and a red triangle then the report of a blue triangle would be a previewed conjunction error and the report of a red circle would be a non-previewed conjunction error.

A two-way repeated-measures ANOVA of the conjunction error data from the incongruent conjunction preview condition was undertaken. One factor was whether the conjunction error was previewed or non-previewed, the other factor was the type of preview; visual object or lexical. The difference between the mean proportion of previewed conjunction errors (0.079) and the mean proportion of non-previewed conjunction errors (0.062) was not significant, $F\ (1,15) = 3.65$, $p > 0.05$. The two-way interaction was not significant either, $F\ (1,15) = 3.52$, $p > 0.05$.

In the congruent conjunction preview condition, previewed and non-previewed correct reports were compared. If the preview object was a blue circle and the target objects were a blue circle and a red triangle then the report of a blue circle would be a previewed correct report and the report of a red triangle would be a non-previewed correct report.

A two-way repeated-measures ANOVA of the correct report data from the congruent conjunction preview condition was undertaken. One factor was whether the correct report was previewed or non-previewed, the other factor was the type of preview; visual object or lexical. The difference between the mean proportion of previewed correct reports (0.693) and the mean proportion of non-previewed correct reports (0.699) was significant, F (1,15) = 27.34, $p < 0.001$. The two-way interaction was not significant, $F < 1$.

Baseline analyses were undertaken for each experimental condition. the same method was used as in Experiment 4. One sample t tests were undertaken to compare the observed conjunction error scores with the expected score determined from the baseline model. In the congruent visual object conjunction preview condition the observed mean conjunction error score (0.059) was significantly lower than the expected score (0.073), t (15) = 3.61, $p < 0.01$. In the incongruent visual object conjunction preview condition the observed mean conjunction error score (0.078) was lower than the expected score (0.089) but the difference was not significant, t (15) = 1.10, $p > 0.05$. In the congruent lexical conjunction preview condition the observed mean conjunction error score (0.040) was significantly lower than the expected score (0.088), t (15) = 6.28, $p < 0.001$. In the incongruent lexical conjunction preview condition the observed mean conjunction error score (0.063) was significantly lower than the expected score (0.096), t (15) = 3.68, $p < 0.01$.

5.3.4 Discussion

The experiment was performed to discover whether the conjunction preview effect occurs with lexical previews as well as visual object previews. The mean proportion of responses classified as conjunction errors was lower in the congruent visual object conjunction preview condition than in the incongruent visual object conjunction preview condition. Also, the mean proportion of responses classified as conjunction errors was lower in the congruent lexical conjunction preview condition than in the incongruent lexical conjunction preview condition. The conjunction congruence main effect was significant but the interaction with preview type (i.e., visual object or lexical) was not. Consequently, it appears that the conjunction previewing effect occurs with both visual object previews and lexical previews. There is no evidence that there is a larger preview effect with visual object conjunction previews than with lexical previews. Therefore, the preview-report strategy explanation is still plausible.

Lexical conjunction previewing could be due to top-down priming but could not be due to bottom-up priming. The physical properties of lexical previews cannot cause the bottom-up activation of object tokens that encode coloured geometric shapes. This is because the physical properties of the words *blue circle* and a blue circle visual object are quite different. However, it is possible that the lexical preview can cause the top-down activation of object tokens in the same way that visual objects might.

The lexical conjunction previewing effect could not be due to temporal illusory conjunctions. If the features of lexical previews, i.e., white letters or letter parts, migrated into the perception of target stimuli it would not result in conjunction errors. There is evidence that conjunctions errors can occur which incorporate word identities and the physical attributes of the word (Lawrence, 1971; Virzi & Egeth, 1984). However, these effects are attributed to propositional illusory conjunctions rather than perceptual illusory conjunctions (Virzi & Egeth, 1984).

The mean conjunction error score was higher in the object preview condition than in the lexical preview condition, but the difference was not significant. Nevertheless, the p value was very close to the 5% significance level. It appears that previewing of physical features may cause more conjunction errors than previewing the names of those features.

The analysis of the feature error data provides little evidence that any of the effects upon conjunction errors could have been mediated by feature misidentification or feature guessing. There were fewer conjunction errors than predicted by the baseline model in all four conditions, although the difference in incongruent visual object conjunction preview condition was not significant. The baseline level is the minimum number of conjunction errors expected to occur by chance for a given number of feature errors. If the observed level is less than the expected level then the model must be overestimating the expected conjunction error score. Consequently, these findings suggest that the baseline model of one third of the feature errors score is not appropriate for these data.

On incongruent conjunction preview trials participants were not significantly more likely to make a conjunction error that was identical to the preview object than a conjunction error of the non-previewed probe colour and shape, although the effect was in the same direction. On congruent conjunction preview trials participants were significantly more likely to correctly report the probe object that was identical to the preview object than correctly report the non-previewed probe object.

In summary, a cost-plus-benefit conjunction preview effect upon conjunction errors was found with visual object previews and lexical previews. There was no evidence that the lexical conjunction preview effect differed in magnitude to the visual object conjunction preview effect. This finding supports the preview-report strategy account and top-down priming of object tokens account of the conjunction preview effect at the expense of the bottom-up priming of object tokens account and the temporal illusory conjunction accounts.

5.4 General Discussion

The two experiments reported in this chapter were undertaken to determine whether the effect of conjunction previewing on conjunction error scores established in Chapter 3 is mediated by a priming effect upon visual feature integration or by one of several alternative explanations. In both experiments the participants reported the colour and shape of two objects in a briefly presented target display. In the main conditions, the congruent and incongruent conjunction preview displays were presented before the probe displays. The effects of conjunction previewing upon conjunction errors and feature errors were observed.

In Experiment 9, preview and review displays were presented before and after the target display. On each trial a congruent or an incongruent feature conjunction was presented in either the preview or the review display. The effect of conjunction cueing upon conjunction error scores was replicated. There was no evidence that this preview effect was mediated by the same processes that cause feature errors. However, there was little evidence of an interaction between conjunction congruence and preview target presentation order that would have allowed the rejection of the temporal illusory conjunction or the preview-strategy explanations of the conjunction preview effect. However, even if this interaction were to be substantiated in the future, there are versions of both explanations that would not be rejected because they can account for a predominance of pre-target intrusions over post-target intrusions.

In Experiment 10, two types conjunction preview displays were presented before the target display. Visual object preview displays each contained a coloured geometric shape. Lexical preview displays contained a verbal description of a coloured geometric shape. A conjunction preview effect upon conjunction errors was found with both visual object previews and lexical previews. The finding of a preview effect with lexical conjunction previews supports the preview-report strategy account and top-down priming of object tokens account of the conjunction preview effect at the expense of the bottom-up priming of object tokens account and the temporal illusory conjunction accounts. There was no evidence of an interaction between preview conjunction congruence and preview type (i.e., visual object or lexical). Consequently, the preview-report strategy explanation remains a plausible alternative.

CHAPTER 6: DISCUSSION AND CONCLUSIONS

6.1 Introduction

The experiments described in this thesis investigated the effects of visual previewing upon the formation of illusory conjunctions to determine the validity of the priming of feature integration hypothesis. This work was inspired by two previously separate avenues of research; i.e., the study of conjunction errors (e.g., Treisman & Schmidt, 1982) and the (non-spatial) previewing paradigm (e.g., Posner & Snyder, 1975a). This chapter discusses the findings of this experimental program and their implications for theories of visual feature integration. Finally, some possibilities for future research are examined.

In Chapter 1, it was proposed that previewing might affect the integration of visual features; a proposition called the priming of feature integration hypothesis. The hypothesis arises from bringing together several widely accepted ideas. The first idea is that previewing affects the accuracy and speed of reporting of target stimuli because it facilitates or inhibits the activation of many different internal representations of the stimuli (Keele, 1973; Posner & Snyder, 1975b; Warren, 1972). It is widely believed that facilitation or inhibition is caused by two priming mechanisms, bottom-up priming and top-down priming (Neely, 1977; Posner & Snyder, 1975b). The second idea is that the visual system explicitly represents information about objects in the form of object tokens (Fox, 1977; Kahneman & Treisman, 1984; Marr, 1976; Treisman, 1990). Bringing these two ideas together suggests the possibility that previewing may facilitate or inhibit the activation of object tokens. This suggestion is supported by the findings of several studies of visual previewing that may have been caused by the priming of object tokens (e.g., Marangolo et al., 1993; Humphreys & Quinlan, 1988).

Object tokens are the output representation of the process of visual feature integration (Kahneman & Treisman, 1986; Marr, 1982). Consequently, previewing that activates object tokens may affect integration. Illusory conjunctions are object tokens that stand for non-existent objects comprised of features that actually belong to two or more true objects.

They are thought to occur when the normal process of feature integration is interrupted or interfered with (Ashby et al., 1996; Green, 1991; Treisman & Schmidt, 1982). It follows that one effect of priming object tokens may be to vary the number of illusory conjunctions that occur. If so, we should expect that when previewing activates an object token that subsequently represents a target object then the accuracy and speed of reporting the conjunctions of target features will be affected; i.e., the priming of feature integration hypothesis.

The priming of feature integration hypothesis leads to several empirical questions. First, can either or both feature previewing and conjunction previewing vary the numbers of illusory conjunctions that occur during an integration task? Second, if such preview effects occur then do top-down priming processes, bottom-up priming processes or both mediate them. Third, are there plausible accounts of these preview effects that do not involve the priming of object tokens and if so can they be rejected. The experiments reported in Chapters 2 to 5 were undertaken to address these questions. The effect of non-spatial previewing upon the generation of illusory conjunctions had not been studied prior to the experiments reported in this thesis.

6.2 Experimental Summary

The following section outlines the method used in the experiments reported in this thesis. This method is a synthesis of methods used in the illusory conjunction (e.g., Treisman & Schmidt, 1982) and visual previewing programs (e.g., Posner & Snyder, 1975a).

On each trial of these experiments, two displays were presented; a preview display and a target display. The target displays contained two colour-filled geometric shapes. The participants' task was either a partial-report or a whole-report of the target objects. In Experiments 1 and 3 the target colours were reported. In Experiment 2 the target shapes were reported. In Experiments 4 to 10 the colours and shapes of the target objects were reported. The participants' reports were coded. A conjunction error is the report of a non-existent object whose colour and shape were actually in separate objects. A feature error is the report of a non-existent object possessing a feature that was not in the target display on that trial. To determine whether an effect upon conjunction error scores was attributable to illusory conjunctions it is necessary to discover whether the same processes that bring about feature errors could have caused the effect.

The effects of two types of non-spatial previewing were investigated; feature previewing and conjunction previewing. Feature previewing was used in Experiments 1, 2 and 3. In feature previewing the preview stimulus is either congruent or incongruent with the target stimulus on a single stimulus dimension. In Experiments 1 and 2 the previewed stimulus dimension was colour. The congruent preview stimulus was the same colour as one of the target objects and the incongruent preview stimulus was a different colour to both of the target objects. In Experiment 3 the previewed stimulus dimension was shape. The congruent preview stimulus was the same shape as one of the target objects and the incongruent preview stimulus was a different shape to both of the target objects.

The effects of conjunction previewing were studied in Experiment 4 to 10. In conjunction previewing the preview display contains an object composed of two features that also appear in the subsequent target display. On a *congruent* conjunction preview trial, the preview display contains an object that is identical to one of the objects in the target display of that trial. On an *incongruent* conjunction preview trial, the preview display contains an object composed of two features that appear in different target objects.

6.2.1 The effect of feature previewing upon visual feature integration

Experiments 1, 2 and 3 investigated whether feature previewing can affect feature integration. Overall, the experimental results do not suggest that feature previewing can affect the number of illusory conjunctions that occur.

In Experiment 1, task-relevant colour features were previewed and the participants reported the colours of the target items. Typically, congruent previews produce better performance of a visual task than incongruent previews. However, a *negative* cost-plus-benefit preview effect on conjunction errors was observed; i.e., congruent previews caused more conjunction errors than incongruent previews did. This preview effect was not attributable to the processes that bring about feature errors (Prinzmetal, 1981; Treisman & Schmidt, 1982) because congruent previews caused fewer feature errors than incongruent previews did. Therefore, the affect may have involved the production of illusory conjunctions. In other words the findings of Experiment 1 are consistent with the priming of feature integration hypothesis.

However, it is also plausible that the participants deliberately reported the task-relevant preview colour instead of probe colours; i.e., a preview-report strategy caused the conjunction preview effect. The results of two subsequent experiments support this interpretation. In Experiments 2 and 3 it was not possible for participants to report the task-relevant preview feature. In Experiment 2, colour features were previewed and the participants reported the shapes of the target items. Feature previewing did not appear to affect conjunction error scores or feature error scores. In Experiment 3 shape features were previewed and the participants reported the colours of the target items. Again feature previewing did not appear to affect conjunction error scores or feature error scores. In light of these findings it was concluded that the preview effect found in Experiment 1 was due to the use of a preview-report strategy by participants.

Together, the evidence from Experiments 1, 2 and 3 suggests that neither colour nor shape feature previewing can affect the production of illusory conjunctions. Therefore, it appears that even if feature previewing does affect the activation of object tokens, this does not appear to affect the process of visual feature integration; i.e., feature previewing studies do not support the priming of feature integration hypothesis.

Perhaps feature previews do not affect integration because they only convey to the viewer what features may appear in the target display. They do not convey what target features are conjoined together. Imagine a trial in which the target items were a blue circle and a red triangle. A congruent colour preview will activate an object token that describes an object comprised of a target feature and a task-neutral feature (i.e., a feature that is not a target feature on any trial); e.g., a blue square. An incongruent colour preview will activate an object token that describes an object comprised of a task-relevant feature (i.e., a feature that is a target feature on other trials but not on the present trial) and a task-neutral feature; e.g., a green square. Feature previewing may cause bottom-up activation of object tokens, which in turn facilitates the integration of blue squares or green squares. However, it will not cause participants to expect blue circles and red triangles rather than red circles and blue triangles.

6.2.2 The effect of conjunction previewing on visual feature integration

Unlike feature previews, conjunction previews can convey to the viewer what target features are conjoined together. Experiments 4, 5 and 6 investigated whether conjunction previewing can affect feature integration. Overall, the results from these experiments support the priming of feature integration hypothesis. Conjunction previewing may cause top-down priming of the production of illusory conjunctions. It is also possible that conjunction previewing also causes bottom-up priming of illusory conjunction generation.

Experiment 4 investigated the effect of conjunction previewing upon the whole-report of two probe objects. The congruent conjunction preview stimulus was the same colour and shape as one of the probe objects and the incongruent conjunction preview stimulus was the same colour as one of the probe objects and the same shape as the other probe object. A cost-plus-benefit preview effect on conjunction error scores was found; i.e., more errors occurred in the incongruent conjunction prime condition than in the congruent conjunction prime condition. Feature error scores did not appear to exhibit the same effect, therefore, the preview effect upon conjunction errors may not be attributable to the processes that cause feature errors; i.e., the guessing of features (Prinzmetal, 1981) and non-veridical feature identification (Treisman & Schmidt, 1982). It was concluded that the cost-plus-benefit effect of conjunction previewing on conjunction errors may have occurred because incongruent conjunction previews caused more illusory conjunctions than congruent conjunction previews did. This is a novel finding and is potentially important for theories of visual integration and illusory conjunctions.

Experiment 5 investigated how preview-probe stimulus-onset asynchrony (SOA) interacts with conjunction previewing upon the whole-report of two probe objects. The experiment was undertaken to determine whether the conjunction preview effect of Experiment 4 was mediated by bottom-up or top-down priming processes (Posner & Snyder, 1975b). It was reasoned that a long prime-probe SOA would interfere with bottom-up priming but not top-down priming. There were two SOA conditions. In one condition SOA was 0.5 secs and the onset of the target display coincided with the offset of the preview display. The method in this condition was very similar to that of Experiment 1. In the other condition SOA was 2 secs and there was a delay of 1.5 secs between the offset of the preview display and the onset of the target display.

The conjunction errors data displayed a significant main effect of conjunction previewing. The magnitude of the conjunction previewing effect was greater when preview-target SOA was 0.5 sec than when preview-target SOA was 2 sec, however, the interaction between conjunction previewing and preview-target SOA that was short of the prescribed significance level. If top down priming alone caused the conjunction preview effect then this interaction would not be expected. However, if this interaction were substantiated by future experiments it could be argued that conjunction preview effect is caused by the top-down and bottom-up priming mechanisms together.

Experiment 6 investigated how predictive validity interacts with conjunction previewing upon the whole-report of two probe objects. Predictive validity was operationalized as the ratio of congruent conjunction preview trials to incongruent conjunction preview trials.

The experiment was undertaken to determine whether the conjunction preview effect was mediated by bottom-up priming, top-down priming or both. There were three predictive validity conditions. In the high predictive validity condition there were three congruent trials to each incongruent trial. In the medium predictive validity condition there were equal numbers of congruent and incongruent trials. In the low predictive validity condition there was one congruent trials to every three incongruent trials. It was reasoned that top-down priming would occur under high predictive validity but not under medium or low predictive validity. It was also reasoned that bottom-up priming would occur to the same degree with high, medium and low predictive validity.

Predictive validity was found to interact with conjunction previewing. A significant conjunction preview effect was found in the high predictive validity condition but not the medium and low predictive validity conditions. However, the conjunction preview effect in the medium predictive validity condition was close to significant. Furthermore, the method in this condition was very similar to that of Experiment 4 and the 0.5 sec SOA condition of Experiment 5 where significant conjunction preview effects were found. The conjunction preview effect in the low predictive validity condition was far from significant. Bottom-up priming of feature integration alone cannot account for these findings,

One explanation of the above-mentioned results is that top-down priming alone affects feature integration. This explanation is supported by the conjunction preview effect occurring under high predictive validity but not under low predictive validity. However, the evidence of a conjunction preview effect in the medium predictive validity condition suggests that, contrary to Posner & Snyder's (1975a, b) claims, top-down priming can occur when there are equal numbers of congruent and incongruent trials. Perhaps top-down priming occurred in this condition because the availability (Tversky & Kahneman, 1973) of congruent conjunction previews was greater than that of incongruent conjunction previews. This may have affected participants' judgements regarding the probability of congruence and therefore biased their expectations. If this explanation is true then the failure to find a conjunction preview effect in the 2 sec SOA condition of Experiment 5 cannot have been a result of the decay of the bottom-up priming effects of the preview. Perhaps, contrary to Posner & Snyder (1975a, b) long inter-stimulus intervals can interfere with top-down priming as well as bottom-up priming. How this may occur is not clear. Furthermore, it is unclear why the source of priming activity (top-down or bottom-up) should have a bearing on whether it can affect integration or not.

Another explanation of the findings is that both bottom-up priming and top-down priming affect integration. This explanation is supported by the conjunction preview effect occurring in the high and medium predictive validity conditions and the failure to find a conjunction preview effect in the 2 sec SOA condition of Experiment 5. However, if this explanation is true then the absence of a conjunction preview effect in the low predictive validity condition suggests that bottom-up and top-down priming may have cancelled each other out. This might occur if participants in this condition expected the preview features to be in separate target objects. Bottom-up priming could activate a veridical object token whereas the expectation of an incongruent trial could cause top-down priming of an object token containing an illusory conjunction. Activating object tokens for a veridical object and an illusory conjunction may cause neither to be primed as they are mutually exclusive.

The findings of Experiments 4, 5 and 6 support both of the two above explanations. Either way the experiments support the existence of top-down priming effects upon the generation of illusory conjunctions. Therefore, these experiments support the priming of feature integration hypothesis.

The findings suggest that although both feature previewing and conjunction previewing may affect the activation of object tokens only conjunction previewing affects the integration of visual features. Why might this occur? Perhaps conjunction previews affect the feature integration because they can convey information to the participants about the possible conjunction of features in the target display.

Imagine a trial in which the target objects were a blue circle and a red triangle. A congruent conjunction preview will activate an object token that describes an object that is the same as one of the target objects; e.g., a blue circle. This may initiate two priming mechanisms; one bottom-up and one top-down. The bottom-up mechanism is simply that the preview object (i.e., a blue circle) activates the object token that stands for it. This object token for the preview object is easily reactivated or its evidence threshold is reduced. When the target objects appear, the primed object token will facilitate the integration of the target object that is the same as the preview object. The top-down priming mechanism is initiated when participants expect the preview object (i.e., a blue circle) to also appear in the target. This expectation will also activate an object token for the preview object, which will facilitate its later reactivation by a target object.

An incongruent conjunction preview will activate an object token that describes an illusory conjunction of target features; e.g., a red circle. The bottom-up priming mechanism will activate an object token for the preview object. The activated object token will be an illusory conjunction of the target features. This will interfere with the integration of the target features. The target display may disappear before veridical object tokens have been formed. The top-down priming mechanism will be to cause participants to expect a blue circles to appear in the target.

It appears that previewing may affect the integration of visual features so long as the previews convey to the viewer what target features may be conjoined together. Further experiments are necessary to determine whether it is also possible for bottom-up priming to affect illusory conjunction production.

6.2.3 Cost-benefit analysis of the conjunction preview effect

A cost-plus-benefit effect of conjunction previewing upon the production of illusory conjunctions was found in Experiments 4, 5 and 6. Cost-benefit analyses were performed upon the data from Experiments 4 & 5, but significant benefits or costs were not found.

Therefore, it is not possible to say whether congruent conjunction previews facilitate integration, incongruent conjunction previews interfere with integration or both happen. A valid cost-benefit analysis of the conjunction preview effect is needed to determine which of these effects exist.

In Experiments 7 and 8, cost-benefit analysis of the conjunction preview effect upon conjunction errors was performed. The benefit effect was determined by comparing the scores from the congruent preview condition with those from a control condition. The cost effect was determined by comparing the scores from the incongruent preview condition with those from the control condition.

The preview stimuli used in control conditions must be carefully considered for cost-benefit analysis to be meaningful (Jonides & Mack, 1984). It was suggested that conjunction previews affect feature integration because they can convey to the viewer what target features are conjoined together. For the cost-benefit analysis of conjunction previewing, the control previews should prime the same features as the conjunction previews but should not prime an object token of a veridical conjunction or an illusory conjunction. In Experiments 7 and 8, the control preview displays and the conjunction preview displays contained two preview objects. One preview colour and one preview shape were considered to be task-relevant because these features were also present in the target display. The other preview colour and other preview shape were considered to be task-neutral because they never appeared in the target display.

The congruent conjunction previews contained one preview object that was same colour and shape as one of the target objects. The incongruent conjunction previews contained one preview object that was the same colour as one target object and the same shape as the other target object. In both conjunction preview conditions the colour and shape of the second preview object were task-neutral. In the control previews the task-relevant features were present in separate preview objects; i.e., these features were not physically conjoined.

Therefore, they did not prime an object token of a veridical conjunction or an illusory conjunction. One preview object had the same colour as a target object and had a shape that never appeared in the target display. The other preview object had the same shape as a target object and had a colour that never appeared in the target display.

In Experiment 7 the preview objects were located peripherally and indicated the locations of the forthcoming probe objects to the participants. There was no evidence of a cost-plus-benefit preview effect upon conjunction error scores. It was suggested that the conjunction preview effect did not occur because of the location of the preview objects. Consequently, Experiment 8 was undertaken, in which the preview objects were located centrally and their locations did not indicate the locations of the forthcoming probe objects. However, the magnitude of cost-plus-benefit conjunction preview effect upon conjunction error scores was not significant.

Why was the conjunction preview effect not significant in Experiment 8? The retinal eccentricity of target items is known to affect the numbers of illusory conjunctions (e.g., Ashby et al., 1996). Retinal eccentricity may also affect the magnitude of the conjunction preview effect upon illusory conjunctions. In Experiment 8 the probe objects were 4.2 degrees of visual angle from the centre of the display. In Experiments 4 and 5 this distance was 2.1 degrees. Perhaps the magnitude of the conjunction preview effect is reduced when target items are located further away from the point of fixation. In Experiment 6 the probe objects, like Experiment 8, were 4.2 degrees of visual angle from the centre of the display. The effect of conjunction previewing was not significant in this experiment in the condition where there were equal numbers of congruent and incongruent conjunction preview trials.

Another possibility is that there was a common cause for the absence of significant conjunction preview effects in Experiments 7 and 8. There was only one way in which both of these experiments were different from Experiments 4, 5 & 6. In Experiments 7 and

8 the preview displays contained two preview objects. Perhaps when two object tokens are primed, by a task-relevant object and a task-neutral object, there is interference between the two active object tokens that drastically reduces the magnitude of the conjunction preview effect. If so, a more powerful experiment will be required for cost-benefit analysis of conjunction previewing to be performed.

A new experiment is needed to decide between the competing explanations of the lack of conjunction preview effect in Experiment 8. In this experiment the preview displays should be the same as used in Experiment 8 and the target objects should be 2.1 degrees from the centre of the display as in Experiments 4 and 5.

Although a cost-plus-benefit effect of conjunction previewing upon the production illusory conjunctions was established in Experiments 4, 5 and 6, separate cost and benefit effects were not found in Experiments 7 or 8. Strictly speaking, it is not possible to say whether congruent conjunction previews facilitate integration, incongruent conjunction previews interfere with integration or that both happen. A valid and powerful cost-benefit analysis of the conjunction preview effect is needed to determine which of these effects exist. Until this is achieved it can only be said that conjunction previewing affects the integration of features. However, for a cost-plus benefit effect to occur one or both of the composite effects must also occur. In Experiment 8 the cost effect was larger than the benefit effect, but the difference was not significant. In other words there is more support for a cost effect than a benefit effect. Bottom-up priming effects are normally associated with the absence of a cost effect (Posner & Snyder, 1975a). Therefore, on the face of it Experiment 8 supports the existence of top-down priming of integration but not bottom-up priming of integration.

6.2.4 The priming of feature integration hypothesis and the conjunction preview effect

The priming of feature integration is not the only possible explanation of the conjunction preview effect upon conjunction errors. Several other explanations of the findings of

Experiments 4 to 8 were proposed that do not involve the priming of object tokens affecting the occurrence of illusory conjunctions. Several alternative explanations involve priming mechanisms that are thought not to affect the integration of visual features.

One putative explanation can be easily dismissed. It might be argued that conjunction previewing causes the activation of motor action plans. The priming of response plans has been proposed to explain various preview effects (e.g., Di Pace et al., 1997; La Berge et al., 1970; Simon, 1988). However, this is not a plausible explanation of the conjunction preview effect because the participants did not know in advance what mouse-movements they would need to make in order to report the target stimuli. This was because the arrangement of the response screen was randomly determined on each trial.

The other alternative explanations are not so easily rejected. It was suggested that conjunction previewing may affect the processes that cause feature errors, i.e., the incorrect abstraction (Treisman & Schmidt, 1982) or guessing (Prinzmetal, 1981) of features. These processes may also cause conjunction errors. In Experiment 4 and the conditions in Experiments 5, 9 and 10 that were similar to Experiment 4, the incongruent conjunction previews did not cause significantly more feature errors than congruent conjunction previews did. However, in most of these experiments feature errors were most frequent in the incongruent condition, the exception was in the visual object preview condition of Experiment 10. Furthermore, in Experiment 6 there was a significant main effect of conjunction previewing upon feature errors. Taken together the series of experiments suggest that conjunction previewing may indeed affect feature errors.

However, it does not follow from the above that the conjunction preview effect is caused by feature guessing, feature misidentification or both. Two findings suggest the contrary. First, in Experiment 4 there was no evidence of even a monotonic relationship between feature errors and conjunction error scores. If the same process were to cause most feature errors and conjunction errors one would expect a positive relationship between the two variables. Second, in Experiment 9, reviewing caused significantly more feature errors than previewing did, but there was no evidence of the same effect upon conjunction errors. Therefore, whilst there is some evidence to support the feature guessing and misidentification account of the conjunction preview effect, the evidence is incomplete. It seems that feature error and conjunction error scores may be largely independent of each other and therefore do not appear to have a common cause.

Two more explanations of the findings of Experiments 4, 5 and 6 suggest that it would be better to refer to the conjunction preview effect as a pre-target intrusion effect. This is because these explanations suggest that the effect upon conjunction error scores is caused by intrusions from the preview (pre-target) display and is nothing to do with illusory conjunctions. One account is that participants deliberately reported the preview object rather than one of the target objects; i.e., a preview-report strategy took place. The other account is that participants inadvertently reported the preview object rather than one of the target objects because it had temporally migrated from the preview display to the target display (Keele et al., 1988).

It was also suggested that conjunction previewing activates a representation in the form of a proposition that describes the stimuli; i.e., Posner & Snyder's (1975b) name level of representation. It may even be that illusory conjunctions occur with this type of representation as well as with representations of the stimuli's physical appearance (Virzi & Egeth, 1984). If this is all true then perhaps the priming of a representation of the names of the stimuli causes the conjunction preview effect.

Chapter 5 describes two experiments that were conducted to investigate whether the priming of feature integration, the priming of propositional illusory conjunctions, the preview object strategy or the temporal illusory conjunctions explanations were best able to account for the conjunction preview effect.

Experiment 9 investigated the effects of reversing the presentation order of the preview and target stimulus displays on the whole report of the target objects. In the preview condition a task-relevant preview object appeared before the target display and a task-neutral object appeared after the target display; i.e., the method in this condition was similar to that of Experiment 4. In the review condition a task-relevant preview object appeared after the target display and a task-neutral object appeared before the target display. It was reasoned that if the priming of feature integration hypothesis was true then presenting the target objects before the task-relevant "preview" object would interfere with the conjunction preview effect. It was also reasoned that if the preview-report strategy or temporal illusory conjunction accounts of the conjunction preview effect were true then presenting the target objects before the task-relevant "preview" object would not interfere with the conjunction preview effect.

The effect of conjunction previewing upon conjunction error scores was replicated. It did not appear that this preview effect was mediated by the same processes that cause feature errors. However, there was little evidence that order of presenting the preview and target displays can affect the conjunction preview effect upon conjunction error scores; i.e.. there was no evidence that there were fewer post-target intrusions than pre-target intrusions. The preview-report strategy and temporal illusory conjunction accounts of the conjunction previewing effect were supported by this finding.

Experiment 10 compared the effects of lexical and visual object previewing upon conjunction errors during the whole-report of two target objects. The lexical previews contained a verbal description of a coloured geometric shape, Visual object preview displays contained a coloured geometric shape. It was reasoned that if the conjunction preview effect is mediated by a preview-report strategy or by the priming of a propositional representation of the stimuli then lexical previews would be have the same effects as visual object previews.

It was found that incongruent conjunction previews caused more conjunction error scores than congruent conjunction previews did. There was no evidence that the effect of lexical conjunction previewing differed in magnitude from the effect of visual object conjunction previewing. Consequently, it was concluded that it is possible that conjunction preview effect is caused by a preview-report strategy or the priming of a propositional representation of the stimuli.

It does not appear that the temporal illusory conjunctions can account for the conjunction preview effect. In Experiment 10 there was evidence of a conjunction previewing effect with lexical previews. It seems unlikely that the name of a coloured object could migrate from the preview display to the target display and then be reported as if it were a target object. Also in Experiment 6 it was found that the conjunction preview effect is affected by predictive validity. There is no reason why predictive validity should affect the occurrence of temporal illusory conjunctions.

It is possible that the conjunction preview effect is caused by participants reporting the preview object as if it were one of the target objects. This alternative explanation was not conclusively ruled out by any of the experiments. However, some explanation of why the strategy is affected by preview-target SOA may be necessary if a near significant finding of Experiment 5 is replicated.

6.3 Theoretical Summary

The experiments described in this thesis support the following conclusions: (a) conjunction previewing may affect the integration of visual features but feature previewing appears not to; (b) although the cost-plus-benefits conjunction preview effect was established, separate benefit and cost effects were not found; (c) conjunction previewing may affect the production of illusory conjunctions by means of a top-down priming mechanism but the possibility of a bottom-up priming mechanism is not ruled out. A major outcome of this work is that a new method of investigating visual feature integration is now available; the non-spatial previewing of integration tasks. Studies using this method may shed light on how visual objects are segmented and encoded by the visual system.

Feature integration theory (FIT; Treisman, 1990; Treisman & Gelade, 1980) location uncertainty theory (LUT; Ashby et al., 1996; Prinzmetal & Keysar, 1989) and the recurrent architecture network (RAN) model (Green, 1991) are current theories of visual feature integration and the generation of illusory conjunctions. These theories make different claims regarding the process of feature integration and the representation of visual objects. The conditions under which the priming of feature integration occurs has consequences for these theories. It appears that conjunction previewing causes the top-down priming of an object-centred description of the stimuli and thereby affects the production of illusory conjunctions. Conjunction previewing may also cause the bottom-up priming of visual integration. As described below, these conclusions are compatible with FIT but they are incompatible with LUT and the RAN model.

In Chapter 3, an explanation of the effect of conjunction previewing upon the numbers of illusory conjunctions was proposed that incorporates a bottom-up priming mechanism compatible with FIT. This explanation involves the process that updates object files over time (Kahneman et al., 1992). Perhaps the object reviewing process causes the object file that denotes the preview object to be used later on to denote one of the target objects. For an object file to be re-used in this way, the preview object and one of the target objects must be linked in some way. However, the conjunction preview effect occurred even though there were no moving frames and the presentation conditions did not cause apparent motion between the preview and target objects. Kahneman et al. (1992) do not accept that correspondence can be determined by reference to the contents of the object file. Either, Kahneman et al.'s (1992) claim is wrong or object reviewing cannot account for the conjunction preview effect. Furthermore, viewers did not report experiencing the preview and target stimuli as successive states of the same object. Consequently, there is little evidence supporting this explanation of the bottom-up priming of visual integration.

Top-down priming of object files may affect visual integration and thereby cause conjunction previewing to affect conjunction error scores. A participant's expectations regarding the forthcoming probe objects causes top-down activity to affect the thresholds for activation of features within the object file. Adjusting these thresholds will either facilitate or inhibit feature detection. For priming to occur it is thought that the same resources must be activated by the preview and the probe (Posner & Snyder, 1975a). According to FIT, object files contain an object-centred structural description of an object (Treisman, 1992 & 1993). In the experiments described in this thesis the conjunction preview objects and the target objects were in different locations. Consequently, if conjunction previewing does affect integration by top-down activation of object tokens then the descriptions of the preview and target objects must be object-centred, otherwise they will not overlap and priming will not occur.

LUT, and possibly also the RAN model, hold that objects are explicitly encoded by a set of topographically organized feature maps (Ashby et al., 1996; Green, 1991; Prinzmetal & Keysar, 1989). Each detector in a map encodes the conjunction of a particular feature with a particular location. However, the conjunction preview effect occurred even though the preview object and the probe objects appeared in different locations. Therefore, the topographic feature map descriptions of the preview and target objects do not overlap. Consequently, bottom-up and top-down priming of topographic feature maps cannot account for the conjunction preview effect. LUT and the RAN model do not appear to provide an adequate account of how objects are explicitly encoded.

LUT and the RAN model fail to account for the effect of conjunction previewing upon visual integration because they maintain that object tokens are encoded by a set of feature detectors that encode the conjunctions of feature identities and feature locations. Therefore, it is not possible to activate a feature or an object independently of its location. It is inadequacies of the scheme for representing object tokens that cause problems for LUT.

This does not mean that visual integration is not performed in parallel by a network of simple processors. This mechanism can easily incorporate top-down and bottom-up constraints on processing. In the current climate biological plausibility is considered important for cognitive theories. Yet the FIT account of object files and object reviewing theory (Kahneman et al., 1992) are largely unconstrained by neuroscientific data. Treisman (1992) has suggested that object files may be implemented by a neural network in which the correlated firing of units signals the various features of an object (Crick & Koch, 1990; Gray et al., 1989; König & Engel, 1995; von der Malsburg, 1995). However, it is not obvious how a network that employs a temporal code could mediate the various sub-processes of object reviewing or top-down priming effects.

What is needed is a representational scheme by which object-centred object tokens can be encoded in a connectionist network. The main obstacle limiting the development of this theory is that it is not known how object-centred descriptions can be encoded by neural networks. It appears that a solution to the integration problem requires a solution to the binding problem (Crick, 1994; Treisman, 1996). The scope of these two problems overlap over the question of how visual objects are encoded. Advances in the binding problem may inform a more powerful connectionist theory of visual feature integration.

6.4 Proposals for Further Study

Several questions regarding the effect that conjunction previewing has upon conjunction error scores remain unanswered. Further experimentation is needed to address these questions.

Can conjunction previewing cause bottom-up priming of visual integration? One way to address this question is to perform a cost-benefit analysis of the conjunction preview effect. The dual-process theory of priming maintains that bottom-up priming does not cause a significant cost effect (Posner & Snyder, 1975b). The results of the cost-benefit-analyses undertaken in Experiments 4, 5, 7 and 8 were inconclusive. It is not known whether congruent conjunction previews facilitate integration, incongruent conjunction previews interfere with integration or both of these processes take place. Consequently, the method used in Experiment 8 needs to be improved upon. Perhaps, the experiment was inconclusive because the high retinal eccentricity of the target objects decreased the magnitude of the conjunction previewing effect. In Experiment 8 the target items were 4.2 degrees from the centre of the display. In other experiments significant conjunction preview effects were found when the target items were 2.1 degrees from centre. Perhaps, increasing target object eccentricity causes more feature guesses and feature misidentifications. An experiment should be undertaken that is similar to Experiment 8 but, in which the target objects are closer to the centre of the screen.

Another way of addressing whether conjunction previewing can cause bottom-up priming of visual integration is to undertake experiments in which the preview-probe SOA is brief. It is possible that the effects of top-down priming may obscure the effects of bottom-up priming when preview-probe SOA is 500 msecs or more. Top-down priming is thought to occur only when the SOA is long enough to permit participants to produce specific expectations about the forthcoming probe. A preview-probe SOA of 250 msecs or less is thought not to cause top-down priming of physical representations of stimuli (e.g., Marangolo et al., 1993; Taylor, 1977). In the present experiments the onset of the probe coincided with the offset of the preview. Therefore, reduction of preview-probe SOA will also reduce the exposure duration of the preview display. Ideally one would wish to study how preview-probe SOA and predictive validity interact with conjunction previewing in a single experiment in which cost-benefit analysis of the data is performed. However, it would be prudent first to discover under what conditions conjunction previewing affects illusory conjunctions when preview-probe SOA is less than 250 msecs, or whether it does at all. A future series of experiments might be undertaken similar to those described in this thesis but in which the preview-probe SOA is 250 msecs or less.

Is the conjunction preview effect replicated with different integration tasks? The conjunction previewing experiments described in this thesis employed the same task throughout, the whole-report of two probe objects. It is possible that the conjunction preview effect only occurs with this task. If the effect is caused by the priming of visual integration then it should not be task-specific. The whole-report task may cause memory errors (Treisman & Schmidt, 1982) or propositional illusory conjunctions (Virzi & Egeth, 1984) rather than illusory conjunctions. If so, then the priming of feature integration hypothesis would not be supported. Whole-report tasks place a greater demand on memory than partial-report tasks, which may result in more memory errors. Also the drag-and-drop response method in itself may have caused memory errors because participants appear to have taken a long time to report the targets. Also it was observed during the practise sessions that participants almost always composed a complete object in one response box before completing the other object. The object colour was usually dragged in before the object shape was. Therefore, it will be necessary to replicate the conjunction preview effect with different report tasks. Participants might be required to make a partial-report of the stimuli (see Cohen & Ivry, 1989; Prinzmetal et al., 1995).

Does conjunction previewing affect shape-shape illusory conjunctions? The conjunction previewing experiments described in this thesis employed the same stimuli throughout. These stimuli allowed incorrect conjunctions of shape and colour features to occur. If the conjunction preview effect is caused by the priming of visual integration then it may also affect the production of shape-shape illusory conjunctions (see Maddox et al., 1994; Prinzmetal, 1981; Prinzmetal & Keysar, 1989). This possibility should be investigated.

6.5 Concluding Remarks

A new method for studying visual feature integration has been proposed, in which the effect of non-spatial previewing upon the production of conjunction errors and feature errors is observed. Previewing a single task-relevant feature (i.e., feature previewing) does not appear to affect the integration of visual features. However, feature previewing can cause a preview effect upon conjunction errors that does not appear to be mediated by the priming of visual feature integration. This effect may be the result of participants performing a preview-report strategy. Also it seems that previewing a combination of two task relevant features (i.e., conjunction previewing) may affect the production of illusory conjunctions. This phenomenon has not been reported prior to this thesis. The effect of conjunction previewing upon conjunction errors appears not to be caused by temporal illusory conjunctions but it may be caused by a preview-report strategy. However, it is argued that the top-down priming of feature integration causes the conjunction preview effect. It is unclear whether a bottom-up priming process upon affect feature integration is also involved in the effect.

7. APPENDIX 1: STATISTICAL ANALYSES OF EXPERIMENTS REPORTED IN CHAPTER 2

7.1 Statistical Analyses for Experiment 1

7.1.1 Table of mean proportions by condition for each type of report in Experiment 1

		Colour preview		
	No object	Congruent	Incongruent	Mean
Correct reports	0.716	0.755	0.672	0.714
Conjunction errors	0.107	0.128	0.097	0.111
Colour feature errors	0.177	0.117	0.231	0.175

7.1.2 Analysis of variance of conjunction error scores for Experiment 1

Source	Sum of squares (SS)	d.f.	Mean square (MS)	*F*	*p*
Preview (A)	1.391×10^{-2}	2	6.954×10^{-3}	3.742	< 0.05
Trial block (B)	1.056×10^{-2}	1	1.056×10^{-2}	2.861	> 0.05
Subject (S)	8.514×10^{-1}	13	6.550×10^{-2}		
A x B	1.589×10^{-3}	2	7.945×10^{-4}	0.499	> 0.05
A x S	4.832×10^{-2}	26	1.858×10^{-3}		
B x S	4.797×10^{-2}	13	3.690×10^{-3}		
Residual	4.138×10^{-2}	26	1.592×10^{-3}		
Total	1.015	83			

7.1.3 Analysis of variance of feature error scores for Experiment 1

Source	SS	d.f.	MS	F	p
Preview (A)	1.815×10^{-1}	2	9.073×10^{-2}	34.952	< 0.01
Trial block (B)	1.200×10^{-2}	1	1.200×10^{-2}	3.292	> 0.05
Subject (S)	6.346×10^{-1}	13	4.881×10^{-2}		
A x B	5.609×10^{-3}	2	2.804×10^{-3}	1.338	> 0.05
A x S	6.749×10^{-2}	26	2.596×10^{-3}		
B x S	4.737×10^{-2}	13	3.643×10^{-3}		
Residual	5.451×10^{-2}	26	2.097×10^{-3}		
Total	1.003	83			

7.2 Statistical Analyses for Experiment 2

7.2.1 Table of mean proportions by condition for each type of report in Experiment 2

		Colour Preview			
	No object	Neutral	Congruent	Incongruent	Mean
Correct reports	0.621	0.628	0.607	0.623	0.620
Conjunction errors	0.157	0.180	0.183	0.165	0.171
Shape feature errors	0.222	0.193	0.210	0.213	0.209

7.2.2 Analysis of variance of conjunction error scores for Experiment 2

Source	SS	d.f.	MS	*F*	*p*
Preview	6.935×10^{-3}	3	2.312×10^{-3}	0.523	> 0.05
Subject	4.816×10^{-1}	14	3.440×10^{-2}		
Residual	1.857×10^{-1}	42	4.420×10^{-3}		
Total	6.742×10^{-1}	59			

7.2.3 Analysis of variance of feature error scores for Experiment 2

Source	SS	d.f.	MS	*F*	*p*
Preview	6.297×10^{-3}	3	2.099×10^{-3}	1.734	> 0.05
Subject	5.862×10^{-1}	14	4.188×10^{-2}		
Residual	5.084×10^{-2}	42	1.210×10^{-3}		
Total	6.434×10^{-1}	59			

7.3 Statistical Analyses for Experiment 3

7.3.1 Table of mean proportions by condition for each type of report in Experiment 3

		Shape Preview			
	No object	Neutral	Congruent	Incongruent	Mean
Correct Reports	0.622	0.635	0.617	0.627	0.625
Conjunction Errors	0.140	0.130	0.130	0.122	0.130
Colour Feature Errors	0.238	0.236	0.252	0.252	0.245

7.3.2 Analysis of variance of conjunction error scores for Experiment 3

Source	SS	d.f.	MS	*F*	*p*
Preview	2.535×10^{-3}	3	8.449×10^{-4}	0.278	> 0.05
Subject	2.003×10^{-1}	14	1.431×10^{-2}		
Residual	1.274×10^{-1}	42	3.034×10^{-3}		
Total	3.303×10^{-1}	59			

7.3.3 Analysis of variance of feature error scores for Experiment 3

Source	SS	d.f.	MS	*F*	*p*
Preview	3.434×10^{-3}	3	1.145×10^{-3}	0.724	> 0.05
Subject	1.685	14	1.203×10^{-1}		
Residual	6.643×10^{-2}	42	1.582×10^{-3}		
Total	1.755	59			

8. APPENDIX 2: STATISTICAL ANALYSES OF EXPERIMENTS REPORTED IN CHAPTER 3

8.1 Statistical Analyses for Experiment 4

8.1.1 Table of mean proportions by condition for each type of report in Experiment 4

	No object	Conjunction preview: Congruent	Conjunction preview: Incongruent	Mean
Correct reports	0.575	0.648	0.550	0.591
Conjunction errors	0.089	0.071	0.128	0.096
Colour feature errors	0.071	0.054	0.071	0.065
Shape feature errors	0.198	0.170	0.203	0.190
Double feature errors	0.068	0.057	0.047	0.057

8.1.2 Analysis of variance of conjunction error scores for Experiment 4

The data did not satisfy the sphericity assumption of ANOVA and was in the form of proportions. Therefore, the arcsine transformation was applied to the data before the ANOVA was performed; i.e., $f(p) = \text{arcsine}\sqrt{p}$, where p is a raw score. The means of the transformed data were as follows; no preview object condition, M = 0.256, congruent conjunction preview condition, M = 0.230, and incongruent conjunction preview, M = 0.339.

Source	Sum of squares (SS)	d.f.	Mean square (MS)	*F*	*p*
Preview	1.159×10^{-1}	2	5.794×10^{-2}	4.313	< 0.05
Subject	8.691×10^{-1}	17	5.112×10^{-2}		
Residual	4.568×10^{-1}	34	1.344×10^{-2}		
Total	1.442	53			

8.1.3 Analysis of variance of feature error scores for Experiment 4

Source	SS	d.f.	MS	*F*	*p*
Preview	2.760×10^{-2}	2	1.380×10^{-2}	2.586	> 0.05
Subject	3.009×10^{-1}	17	1.770×10^{-2}		
Residual	1.814×10^{-1}	34	5.335×10^{-3}		
Total	5.099×10^{-1}	53			

8.1.4 Table of mean proportions of paired object reports by condition in Experiment 4

	Preview display		
		Conjunction preview	
	No object	Congruent	Incongruent
Correct & Correct	0.330	0.424	0.323
CE & Correct	0.024	0.017	0.038
CE & CE	0.049	0.035	0.056
CE & Colour FE	0.010	0.007	0.014
CE & Shape FE	0.028	0.045	0.087
CE & Double FE	0.017	0.003	0.007
Colour FE & Correct	0.090	0.087	0.094
Shape FE & Correct	0.278	0.243	0.257
Colour FE & Colour FE	0.003	0.000	0.003
Shape FE & Shape FE	0.021	0.014	0.010
Colour FE & Shape FE	0.031	0.014	0.024
Colour FE & Double FE	0.003	0.000	0.003
Shape FE & Double FE	0.017	0.010	0.017
Double FE & Correct	0.097	0.101	0.066
Double FE & Double FE	0.000	0.000	0.000

8.2 Statistical Analyses for Experiment 5

8.2.1 Table of mean proportions by condition for each type of report in Experiment 5

Preview-probe SOA	0.5 secs			2 secs			
Preview type	Congr.	Neutral	Incongr.	Congr.	Neutral	Incongr.	Mean
Correct reports	0.585	0.604	0.541	0.553	0.592	0.594	0.578
Conjunction errors	0.050	0.071	0.094	0.066	0.064	0.057	0.067
Colour feature errors	0.102	0.081	0.091	0.100	0.102	0.092	0.095
Shape feature errors	0.178	0.175	0.193	0.191	0.163	0.166	0.177
Double feature errors	0.084	0.069	0.082	0.091	0.080	0.092	0.083

8.2.2 Analysis of variance of conjunction error scores for Experiment 5

Source	SS	d.f.	MS	*F*	*p*
Stimulus-onset asynchrony (SOA)	2.109×10^{-3}	1	2.109×10^{-3}	3.035	0.102
SOA x subjects	1.043×10^{-2}	15	6.951×10^{-4}		
Preview	5.018×10^{-3}	2	2.509×10^{-3}	3.702	0.037
Preview x subjects	2.034×10^{-2}	30	6.779×10^{-4}		
Preview x SOA	1.090×10^{-4}	2	5.450×10^{-4}	2.971	0.066
Residual	5.502×10^{-2}	30	1.834×10^{-3}		
Subjects	4.641×10^{-1}	15	3.094×10^{-2}		
Total	5.679×10^{-1}	95			

The variance was also partitioned so that the significance of the two simple effects of preview type could be determined (Howell, 1997).

Source	SS	d.f.	MS	*F*	*p*
Stimulus-onset asynchrony (SOA)	2.109×10^{-3}	1	2.109×10^{-3}	3.035	0.102
SOA x subjects	1.043×10^{-2}	15	6.951×10^{-4}		
Preview (SOA = 0.5 secs)	1.532×10^{-2}	2	7.658×10^{-3}	5.164	0.012
Residual (SOA = 0.5 secs)	4.449×10^{-2}	30	1.483×10^{-3}		
Preview (SOA = 2 secs)	6.029×10^{-4}	2	3.014×10^{-4}	0.293	0.748
Residual (SOA = 2 secs)	3.087×10^{-2}	30	1.029×10^{-3}		
Subjects	4.641×10^{-1}	15	3.094×10^{-2}		
Total	5.679×10^{-1}	95			

8.2.3 Analysis of variance of feature error scores for Experiment 5

Source	SS	d.f.	MS	F	p
Stimulus-onset asynchrony (SOA)	1.419×10^{-4}	1	1.419×10^{-4}	0.036	> 0.05
SOA x subjects	5.864×10^{-2}	15	3.909×10^{-3}		
Preview	1.015×10^{-2}	2	5.075×10^{-3}	1.704	> 0.05
Preview x subjects	8.932×10^{-2}	30	2.977×10^{-3}		
Preview x SOA	6.704×10^{-3}	2	3.352×10^{-3}	1.333	> 0.05
Residual	7.545×10^{-2}	30	2.515×10^{-3}		
Subjects	8.144×10^{-1}	15	5.429×10^{-2}		
Total	1.055	95			

The variance was also partitioned so that the significance of the two simple effects of preview type could be determined (Howell, 1997).

Source	SS	d.f.	MS	F	p
Stimulus-onset asynchrony (SOA)	1.419×10^{-4}	1	1.419×10^{-4}	0.036	> 0.05
SOA x subjects	5.864×10^{-2}	15	3.909×10^{-3}		
Preview (SOA = 0.5 secs)	7.028×10^{-3}	2	3.514×10^{-3}	1.127	> 0.05
Residual (SOA = 0.5 secs)	9.350×10^{-2}	30	3.117×10^{-3}		
Preview (SOA = 2 secs)	9.825×10^{-3}	2	4.912×10^{-3}	2.068	> 0.05
Residual (SOA = 2 secs)	7.127×10^{-2}	30	2.376×10^{-3}		
Subjects	8.144×10^{-1}	15	5.429×10^{-2}		
Total	1.055	95			

8.2.4 Analysis of variance of cued and non-cued correct reports for Experiment 5

Source	SS	d.f.	MS	*F*	*p*
Previewed/Non-previewed (P/NP)	1.111×10^{-1}	1	1.111×10^{-1}	9.740	< 0.01
P/NP x subjects	1.711×10^{-1}	15	1.140×10^{-2}		
Stimulus-onset asynchrony (SOA)	2.500×10^{-3}	1	2.500×10^{-3}	0.294	> 0.05
SOA x subjects	1.275×10^{-1}	15	8.500×10^{-3}		
P/NP x SOA	0.000	1	0.000	0.000	> 0.05
Residual	1.944×10^{-1}	15	1.296×10^{-2}		
Subjects	2.333	15	1.555×10^{-1}		
Total	2.940	63			

8.2.5 Analysis of variance of cued and non-cued conjunction errors for Experiment 5

Source	SS	d.f.	MS	*F*	*p*
Previewed/Non-previewed (P/NP)	1.563×10^{-4}	1	1.563×10^{-4}	0.190	> 0.05
P/NP x subjects	1.234×10^{-2}	15	8.229×10^{-4}		
Stimulus-onset asynchrony (SOA)	2.127×10^{-3}	1	2.127×10^{-3}	9.535	< 0.01
SOA x subjects	3.345×10^{-2}	15	2.230×10^{-3}		
P/NP x SOA	8.509×10^{-4}	1	8.509×10^{-4}	0.535	> 0.05
Residual	2.387×10^{-2}	15	1.591×10^{-3}		
Subjects	3.730×10^{-1}	15	2.487×10^{-2}		
Total	4.650×10^{-1}	63			

8.3 Statistical Analyses for Experiment 6

8.3.1 Table of mean proportions by condition for each type of report in Experiment 6

	Predictive validity						
	High (3:1)		Medium (1:1)		Low (1:3)		
	Congr.	Incongr.	Congr.	Incongr.	Congr.	Incongr.	Mean
Correct reports	0.688	0.605	0.703	0.654	0.611	0.583	0.641
Conjunction errors	0.045	0.095	0.065	0.082	0.060	0.058	0.068
Colour feature errors	0.064	0.076	0.037	0.043	0.079	0.090	0.065
Shape feature errors	0.155	0.180	0.170	0.186	0.150	0.165	0.168
Double feature errors	0.048	0.044	0.025	0.036	0.100	0.103	0.059

8.3.2 Analysis of variance of conjunction error scores for Experiment 6

Source	SS	d.f.	MS	F	p
Predictive validity (PV)	1.854×10^{-3}	2	9.270×10^{-4}	0.216	> 0.05
Subjects within groups	9.009×10^{-1}	21	4.290×10^{-3}		
Preview	5.701×10^{-3}	1	5.701×10^{-3}	11.63	0.003
Preview x PV interaction	5.368×10^{-3}	2	2.684×10^{-3}	5.474	0.012
Residual (Within Subjects)	1.030×10^{-2}	21	4.903×10^{-4}		
Total	9.240×10^{-1}	47			

In the following ANOVA summary table the variance is partitioned so that the significance of the three repeated-measures simple effects can be determined (Howell, 1997).

Source	SS	d.f.	MS	F	p
Between-subjects	9.027×10^{-1}	23			
Predictive validity (PV)	1.854×10^{-3}	2	9.270×10^{-4}	0.216	> 0.05
Subjects within groups	9.009×10^{-1}	21	4.290×10^{-3}		
Within-subjects	2.134×10^{-2}	24			
Preview (PV = 3:1)	9.836×10^{-3}	1	9.836×10^{-3}	16.03	0.005
Residual (PV = 3:1)	4.295×10^{-3}	7	6.135×10^{-4}		
Preview (PV = 1:1)	1.222×10^{-3}	1	1.222×10^{-3}	1.973	0.202
Residual (PV = 1:1)	4.334×10^{-3}	7	6.191×10^{-4}		
Preview (PV = 1:3)	1.122×10^{-5}	1	1.122×10^{-5}	0.047	0.834
Residual (PV = 1:3)	1.668×10^{-3}	7	2.383×10^{-4}		
Total	9.240×10^{-1}	47			

8.3.3 Analysis of variance of feature error scores for Experiment 6

Source	SS	d.f.	MS	F	p
Predictive validity (PV)	5.568×10^{-3}	2	2.784×10^{-3}	0.245	> 0.05
Subjects within groups	2.380×10^{-1}	21	1.135×10^{-2}		
Preview	9.728×10^{-3}	1	9.728×10^{-3}	8.130	0.01
Preview x PV interaction	5.179×10^{-4}	2	2.589×10^{-4}	0.216	> 0.05
Residual (Within Subjects)	2.517×10^{-2}	21	1.199×10^{-3}		
Total	2.791×10^{-1}	47			

In the following ANOVA summary table the variance is partitioned so that the significance of the three repeated-measures simple effects can be determined (Howell, 1997).

Source	SS	d.f.	MS	F	p
Between-subjects	2.437×10^{-1}	23			
Predictive validity (PV)	5.568×10^{-3}	2	2.784×10^{-3}	0.245	> 0.05
Subjects within groups	2.380×10^{-1}	21	1.135×10^{-2}		
Within-subjects	3.538×10^{-2}	24			
Preview (PV = 3:1)	5.517×10^{-3}	1	5.517×10^{-3}	2.657	> 0.05
Residual (PV = 3:1)	1.453×10^{-2}	7	2.076×10^{-3}		
Preview (PV = 1:1)	1.804×10^{-3}	1	1.804×10^{-3}	2.785	> 0.05
Residual (PV = 1:1)	4.534×10^{-3}	7	6.477×10^{-4}		
Preview (PV = 1:3)	2.925×10^{-3}	1	2.925×10^{-3}	3.378	> 0.05
Residual (PV = 1:3)	6.061×10^{-3}	7	8.659×10^{-4}		
Total	2.791×10^{-1}	47			

8.3.4 Analysis of variance of previewed and non-previewed correct reports for Experiment 6

Source	SS	d.f.	MS	F	p
Predictive validity (PV)	7.760×10^{-2}	2	3.880×10^{-2}	0.916	> 0.05
Subjects within groups	8.890×10^{-1}	21	4.234×10^{-2}		
Previewed/non-previewed (P/NP)	7.868×10^{-2}	1	7.868×10^{-2}	17.479	< 0.01
P/NP x PV interaction	2.816×10^{-2}	2	1.408×10^{-2}	3.128	< 0.10
Residual (Within Subjects)	9.453×10^{-1}	21	4.501×10^{-2}		
Total	2.019	47			

8.3.5 Analysis of variance of previewed and non-previewed conjunction errors for Experiment 6

Source	SS	d.f.	MS	F	p
Predictive validity (PV)	1.112×10^{-2}	2	5.559×10^{-2}	1.202	> 0.05
Subjects within groups	9.713×10^{-2}	21	4.625×10^{-3}		
Previewed/non-previewed (P/NP)	2.133×10^{-3}	1	2.133×10^{-3}	2.515	> 0.05
P/NP x PV interaction	4.668×10^{-4}	2	2.334×10^{-4}	0.275	> 0.05
Residual (Within Subjects)	1.781×10^{-2}	21	8.481×10^{-4}		
Total	1.287×10^{-1}	47			

9. APPENDIX 3: STATISTICAL ANALYSES OF EXPERIMENTS REPORTED IN CHAPTER 4

9.1 Statistical Analyses for Experiment 7

9.1.1 Table of mean proportions by condition for each type of report in Experiment 7

	Controls		Temporal preview		Conjunct. preview	
	No object	Neutral	Congr.	Incongr.	Congr.	Incongr.
Correct reports	0.618	0.617	0.619	0.610	0.650	0.586
Conjunction errors	0.050	0.067	0.050	0.070	0.061	0.103
Feature errors	0.260	0.238	0.259	0.238	0.225	0.233
Double feature errors	0.071	0.077	0.071	0.082	0.064	0.078

9.1.2 Analysis of variance of conjunction error scores for Experiment 7

The data did not satisfy the homogeneity of variance and sphericity assumptions of ANOVA and was in the form of proportions. Therefore, the arcsine transformation (Howell, 1997) was applied to the data before the ANOVA was performed. After transformation the data still did not satisfy the sphericity assumption, nevertheless the main effect was not significant.

Source	Sum of squares (SS)	d.f.	Mean square (MS)	F	p
Preview	1.161×10^{-1}	5	2.322×10^{-2}	1.639	0.158
Subjects	1.048	20	5.242×10^{-2}		
Residual	1.417	100	1.417×10^{-2}		
Total	2.581	125			

9.1.3 Analysis of variance of feature error scores for Experiment 7

Source	SS	d.f.	MS	F	p
Preview	2.136×10^{-2}	5	4.271×10^{-3}	1.366	> 0.05
Subjects	6.332×10^{-1}	20	3.166×10^{-2}		
Residual	3.128×10^{-1}	100	3.128×10^{-3}		
Total	9.674×10^{-1}	125			

9.2 Statistical Analyses for Experiment 8

9.2.1 Table of mean proportions by condition for each type of report in Experiment 8

	Conjunction preview		Temporal preview	
	Congruent	Incongruent	Congruent	Incongruent
Correct reports	0.674	0.612	0.653	0.619
Conjunction errors	0.059	0.096	0.063	0.074
Feature errors	0.208	0.224	0.216	0.249
Double feature errors	0.059	0.068	0.068	0.058

9.2.2 Analysis of variance of conjunction error scores for Experiment 8

The data did not satisfy the homogeneity of variance assumption of ANOVA and was in the form of proportions. Therefore, the arcsine transformation (Howell, 1997) was applied to the data before the ANOVA was performed.

Source	SS	d.f.	MS	*F*	*p*
Preview	3.255×10^{-2}	3	1.085×10^{-2}	1.855	> 0.05
Subjects	8.858×10^{-1}	15	5.905×10^{-2}		
Residual	2.6312×10^{-1}	45	5.848×10^{-3}		
Total	1.181	63			

9.2.3 Analysis of variance of feature error scores for Experiment 8

Source	SS	d.f.	MS	*F*	*p*
Preview	1.578×10^{-2}	3	5.260×10^{-3}	2.429	< 0.10
Subjects	3.124×10^{-1}	15	2.083×10^{-2}		
Residual	9.744×10^{-2}	45	2.165×10^{-3}		
Total	4.256×10^{-1}	63			

10. APPENDIX 4: STATISTICAL ANALYSES OF EXPERIMENTS REPORTED IN CHAPTER 5

10.1 Statistical Analyses for Experiment 9

10.1.1 Table of mean proportions by condition for each type of report in Experiment 9

	Preview		Review	
	Congruent	Incongruent	Congruent	Incongruent
Correct reports	0.638	0.594	0.539	0.533
Conjunction errors	0.041	0.074	0.053	0.054
Feature errors	0.222	0.252	0.286	0.290
Double feature errors	0.079	0.080	0.123	0.123

10.1.2 Analysis of variance of conjunction error scores for Experiment 9

The conjunction error data did not satisfy the sphericity assumption of ANOVA and was in the form of proportions. Therefore, the arcsine transformation was applied to the data before the ANOVA was performed.

Source	Sum of squares (SS)	d.f.	Mean square (MS)	*F*	*p*
Preview/review (P/R)	1.063×10^{-3}	1	1.063×10^{-3}	0.137	> 0.05
P/R x subject	1.160×10^{-1}	15	7.735×10^{-3}		
Conj. congruence (CC)	3.373×10^{-2}	1	3.373×10^{-2}	8.684	< 0.01
CC x subject	5.826×10^{-2}	15	3.884×10^{-3}		
P/R x CC	9.859×10^{-3}	1	9.859×10^{-3}	2.326	> 0.05
Residual	6.359×10^{-2}	15	4.239×10^{-3}		
Subject	5.010×10^{-1}	15	1.063×10^{-3}		
Total	7.835×10^{-1}	63			

In the following ANOVA summary table the variance is partitioned so that the significance of the two conjunction congruence simple effects can be determined (Howell, 1997).

Source	SS	d.f.	MS	F	p
Preview/review	1.063×10^{-3}	1	1.063×10^{-3}	0.137	> 0.05
Preview/review x subject	1.160×10^{-1}	15	7.735×10^{-3}		
Conj. congruence (preview)	4.002×10^{-2}	1	4.002×10^{-2}	10.753	< 0.01
Residual (preview)	5.584×10^{-2}	15	3.722×10^{-3}		
Conj. congruence (review)	3.559×10^{-3}	1	3.559×10^{-3}	0.809	> 0.05
Residual (review)	6.602×10^{-2}	15	4.401×10^{-3}		
Subject	5.010×10^{-1}	15	3.340×10^{-2}		
Total	7.835×10^{-1}	63			

10.1.3 Analysis of variance of feature error scores for Experiment 9

Source	SS	d.f.	MS	*F*	*p*
Preview/review (P/R)	2.681×10^{-2}	1	2.681×10^{-2}	14.917	< 0.01
P/R x subject	2.696×10^{-2}	15	1.797×10^{-3}		
Conjunction congruence (CC)	8.294×10^{-4}	1	8.294×10^{-4}	0.261	> 0.05
CC x subject	4.768×10^{-2}	15	3.179×10^{-3}		
P/R x CC	1.260×10^{-4}	1	1.260×10^{-4}	0.044	> 0.05
Residual	4.316×10^{-2}	15	2.877×10^{-3}		
Subject	2.719×10^{-1}	15	1.813×10^{-2}		
Total	4.175×10^{-1}	63			

In the following ANOVA summary table the variance is partitioned so that the significance of the two conjunction congruence simple effects can be determined (Howell, 1997).

Source	SS	d.f.	MS	*F*	*p*
Preview/review	2.681×10^{-2}	1	2.681×10^{-2}	14.917	< 0.01
Preview/review x subject	2.696×10^{-2}	15	1.797×10^{-3}		
Conj. congruence (preview)	8.010×10^{-4}	1	8.010×10^{-4}	0.368	> 0.05
Residual (preview)	3.261×10^{-2}	15	2.174×10^{-3}		
Conj. congruence (review)	1.544×10^{-4}	1	1.544×10^{-4}	0.040	> 0.05
Residual (review)	5.823×10^{-2}	15	3.882×10^{-3}		
Subject	2.719×10^{-1}	15	1.813×10^{-2}		
Total	4.175×10^{-1}	63			

10.1.4 Analysis of variance of cued and non-cued correct reports for Experiment 9

Source	SS	d.f.	MS	*F*	*p*
Cued/non-cued (C/NC)	9.026×10^{-3}	1	9.026×10^{-3}	0.952	> 0.05
C/NC	1.422×10^{-1}	15	9.478×10^{-3}		
Preview/review (P/R)	1.560×10^{-1}	1	1.560×10^{-1}	35.474	< 0.001
P/R x subject	6.598×10^{-2}	15	4.398×10^{-3}		
C/NC x P/R	1.102×10^{-2}	1	1.102×10^{-2}	1.376	> 0.05
Residual	1.202×10^{-1}	15	8.012×10^{-3}		
Subjects	1.195	15	7.964×10^{-2}		
Total	1.699	63			

10.1.5 Analysis of variance of cued and non-cued conjunction errors for Experiment 9

Source	SS	d.f.	MS	*F*	*p*
Previewed/non-previewed (C/NC)	5.064×10^{-4}	1	5.064×10^{-4}	0.481	> 0.05
C/NC x subjects	1.579×10^{-2}	15	1.053×10^{-3}		
Preview/review (P/R)	6.007×10^{-3}	1	6.007×10^{-3}	2.111	> 0.05
P/R x subject	4.269×10^{-2}	15	2.846×10^{-3}		
C/NC x P/R	7.656×10^{-3}	1	7.656×10^{-3}	5.788	< 0.05
Residual	1.984×10^{-2}	15	1.323×10^{-3}		
Subjects	1.316×10^{-1}	15	8.776×10^{-3}		
Total	2.241×10^{-1}	63			

10.2 Statistical Analyses for Experiment 10

10.2.1 Table of mean proportions by condition for each type of report in Experiment 10

	Physical object preview		Lexical preview	
	Congruent	Incongruent	Congruent	Incongruent
Correct reports	0.601	0.579	0.608	0.570
Conjunction errors	0.059	0.078	0.040	0.063
Feature errors	0.267	0.266	0.264	0.287
Double feature errors	0.074	0.078	0.088	0.079

10.2.2 Analysis of variance of conjunction error scores for Experiment 10

Source	SS	d.f.	MS	F	p
Conjunction congruence (CC)	7.012×10^{-3}	1	7.012×10^{-3}	5.742	0.030
CC x subjects	1.832×10^{-2}	15	1.221×10^{-3}		
Preview (visual object v. lexical)	4.387×10^{-3}	1	4.387×10^{-3}	4.520	0.051
Preview x subjects	1.456×10^{-2}	15	9.706×10^{-4}		
CC x preview	7.634×10^{-5}	1	7.634×10^{-5}	0.114	0.740
Residual	1.004×10^{-2}	15	6.693×10^{-4}		
Subjects	3.293×10^{-2}	15	2.195×10^{-3}		
Total	8.732×10^{-2}	63			

In the following ANOVA summary table the variance is partitioned so that the significance of the two simple effects of conjunction congruence can be determined (Howell, 1997).

Source	SS	d.f.	MS	F	p
Preview (visual object v. lexical)	4.387×10^{-3}	1	4.387×10^{-3}	4.520	0.051
Preview x subject	1.456×10^{-2}	15	9.706×10^{-4}		
Conjunction congruence (visual object)	2.813×10^{-3}	1	2.813×10^{-3}	3.150	0.096
Residual (visual object)	1.340×10^{-2}	15	8.930×10^{-4}		
Conjunction congruence (lexical)	4.276×10^{-3}	1	4.276×10^{-3}	4.286	0.056
Residual (lexical)	1.497×10^{-2}	15	9.980×10^{-4}		
Subject	3.293×10^{-2}	15	2.195×10^{-3}		
Total	8.732×10^{-2}	63			

10.2.3 Analysis of variance of feature error scores for Experiment 10

Source	SS	d.f	MS	F	p
Conjunction congruence (CC)	2.145×10^{-3}	1	2.145×10^{-3}	1.041	> 0.05
CC x subjects	3.089×10^{-2}	15	2.060×10^{-3}		
Preview (visual object v. lexical)	1.313×10^{-3}	1	1.313×10^{-3}	0.775	> 0.05
Preview x subjects	2.541×10^{-2}	15	1.694×10^{-3}		
CC x preview	2.378×10^{-3}	1	2.378×10^{-3}	1.141	> 0.05
Residual	3.126×10^{-2}	15	2.084×10^{-3}		
Subjects	2.800×10^{-1}	15	1.867×10^{-2}		
Total	3.734×10^{-1}	63			

In the following ANOVA summary table the variance is partitioned so that the significance of the two simple effects of conjunction congruence can be determined (Howell, 1997).

Source	SS	d.f.	MS	F	p
Preview (Visual object v. lexical)	1.313×10^{-3}	1	1.313×10^{-3}	0.775	> 0.05
Preview x subject	2.541×10^{-2}	15	1.694×10^{-3}		
Conjunction congruence (visual object)	2.999×10^{-6}	1	2.999×10^{-6}	0.001	> 0.05
Residual (visual object)	4.185×10^{-2}	15	2.790×10^{-3}		
Conjunction congruence (lexical)	4.520×10^{-3}	1	4.520×10^{-3}	3.339	< 0.10
Residual (lexical)	2.030×10^{-2}	15	1.354×10^{-3}		
Subject	2.800×10^{-1}	15	1.867×10^{-2}		
Total	3.734×10^{-1}	63			

10.2.4 Analysis of variance of cued and non-cued correct reports for Experiment 10

Source	SS	d.f.	MS	*F*	*p*
Cued/Non-Cued (C/NC)	5.776×10^{-1}	1	5.776×10^{-1}	27.348	< 0.001
C/NC x subjects	3.168×10^{-1}	15	2.112×10^{-2}		
Visual Object/Lexical (VO/L)	9.001×10^{-4}	1	9.001×10^{-4}	0.200	> 0.05
VO/L x subjects	6.750×10^{-2}	15	4.500×10^{-3}		
C/NC x VO/L	2.250×10^{-4}	1	2.250×10^{-4}	0.018	> 0.05
Residual	1.902×10^{-1}	15	1.268×10^{-2}		
Subjects	8.568×10^{-1}	15	5.712×10^{-2}		
Total	2.010	63			

10.2.5 Analysis of variance of cued and non-cued conjunction errors for Experiment 10

Source	SS	d.f.	MS	*F*	*p*
Cued/Non-Cued (C/NC)	4.557×10^{-3}	1	4.557×10^{-3}	3.647	> 0.05
C/NC x subjects	1.874×10^{-2}	15	1.251×10^{-3}		
Visual Object/Lexical (VO/L)	3.307×10^{-3}	1	3.307×10^{-3}	1.570	> 0.05
VO/L x subjects	3.160×10^{-2}	15	2.106×10^{-3}		
C/NC x VO/L	2.755×10^{-3}	1	2.755×10^{-3}	3.520	> 0.05
Residual	1.175×10^{-2}	15	7.830×10^{-4}		
Subjects	5.849×10^{-2}	15	3.900×10^{-3}		
Total	1.312×10^{-1}	63			

11. REFERENCES

Ahmad, S. & Omohundro, S. (1991) Efficient visual search: a connectionist solution. In *The Proceedings of the Thirteenth Annual Conference of the Cognitive Science Society* (pp. 293-298). Hillsdale, NJ: Erlbaum.

Arguin, M., & Bub, D. (1995). Priming and response selection processes in letter classification and identification tasks. *Journal of Experimental Psychology: Human Perception and Performance*, 21 (5), 1199-1219.

Ashby, F. G., Prinzmetal, W., Ivry, R. (B.), & Maddox, W. T. (1996). A formal theory of illusory conjunctions. *Psychological Review*, 103 (1), 165-192.

Atkinson, J., & Braddick, O. (1989). "Where" and "what" in visual search. *Perception*, 18, 181-189.

Attneave, F. (1971). Multistability in perception. *Scientific American*, 225, 63-71.

Attneave, F. (1974). Apparent motion and the what-where connection. *Psychologica*, 17, 198-120.

Barnden, J. A., & Pollack, J. B. (1991). Introduction: Problems for high-level connectionism. In J. A. Barnden & J. B. Pollack (Eds.) *Advances in Connectionist and Neural Computation Theory: Vol. 1. High-Level Connectionist Models*. Norwood, NJ: Ablex.

Bechtel, W., & Abrahamsen, A. (1990). *Connectionism and the Mind: An Introduction to Parallel Processing in Networks*. Oxford, England: Blackwell.

Beck, J. (1982). Textural segregation. In J. Beck (Ed.) *Organization and Representation in Perception*. Hillsdale, NJ: Erlbaum.

Beller, H. K. (1971). Priming: the effects of advanced information of letter matching. *Journal of Experimental Psychology*, 87, 176-182.

Botella, J., & Eriksen, C. W. (1992). Filtering versus parallel processing in RSVP tasks. *Perception and Psychophysics*, 51 (4), 334-343.

Botella, J., & Villar, M. V. (1989). Modelos de procesamiento en tareas de presentacion rapida de series visuales. *Psicólogica*, 10, 179-203.

Botella, J., Garcia, M.L., & Barriopedro, M. (1992). Intrusion patterns in rapid serial visual presentation tasks with two response dimensions. *Perception and Psychophysics*, 52 (5), 547-552.

Briand, K. A., & Klein, R. M. (1987). Is Posner's "beam" the same as Treisman's "glue"? On the relationship between visual orienting and feature integration theory. *Journal of Experimental Psychology: Human Perception and Performance*, 13, 228-241.

Breitmeyer, B. G. (1984). *Visual Masking: An Integrative Approach.* Oxford, England: Oxford Press.

Broadbent, D.E., & Broadbent, M.H.P. (1987). From detection to identification: Response to multiple targets in rapid serial visual presentation. *Perception and Psychophysics*, 42 (2), 105-113.

Butler, B. E., & Morrison, I. R. (1984). Do letter features migrate? A note of caution. *Psychological Research*, 46, 223-236.

Butler, B. E., Mewhort, D. J. K., & Browse, R. A. (1991). When do letter features migrate? A boundary condition for feature-integration theory. *Perception and Psychophysics*, 49 (1), 91-99.

Carr, T. H., McCauley, C., Sperber, R. D., & Parmelee, C. M. (1982). Words, pictures, and priming: On semantic activation, conscious identification, and the automaticity of information processing. *Journal of Experimental Psychology: Human Perception and Performance*, 8 (6), 757-777

Cave, K. R., & Wolfe, J. M. (1990). Modelling the role of parallel processing in visual search. *Cognitive Psychology*, 22, 225-271.

Chastain, G. (1982). Feature mislocalizations and misjudgements of intercharacter distance. *Psychological Research*, 44, 51-66.

Cohen, A., & Ivry, R. B. (1989). Illusory conjunctions inside and outside the focus of attention. *Journal of Experimental Psychology: Human Perception and Performance*, 15 (4), 650-663.

Cohen, A., & Ivry, R. B. (1990). Illusory conjunctions as a function of distance between objects inside and outside the focus of attention. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 317-331.

Cohen, A., & Rafal, R. B. (1991). Attention and feature integration: Illusory conjunctions in a patient with parietal lobe lesions. *Psychological Science*, 2, 106-110.

Coren, S., & Girus, J. S. (1980). Principles of perceptual organization and spatial distortion: the Gestalt illusions. *Journal of Experimental Psychology: Human Perception and Performance*, 6 (3), 404-412.

Crick, F. (1994). *The Astonishing Hypothesis.* London: Simon and Schuster.

Crick, F., & Koch, C. (1990). Towards a neurobiological theory of consciousness. *Seminars in Neurosciences*, 2, 263-275.

D'Agostino, P. R. (1982). Plasticity of mental color codes. *American Journal of Psychology*, 95 (1), 3-12.

Di Pace, E., Marangolo, P., & Pizzamiglio, L. (1997). Response bias in color priming. *Acta*

Psychologica, 95, 3-14.

Duncan, J., & Humphreys, G. W. (1989). Visual search and visual similarity. *Psychological Review*, 96, 433-458.

Duncan, J., & Humphreys, G. W. (1992). Beyond the search surface: Visual search and attentional engagement. *Journal of Experimental Psychology: Human Perception and Performance*, 18 (2), 578-588.

Duncan, J., Humphreys, G. W., & Ward, R. (1997). competitive brain activity in visual attention. *Current Opinion in Neurobiology*, 7, 255-261.

Eglin, M. (1987). The effects of different attentional loads on feature integration in the cerebral hemispheres. *Perception and Psychophysics*, 42 (1), 81-86.

Eriksen, C. W., & Yeh, Y-Y. (1985). Allocation of attention in the visual field. *Journal of Experimental Psychology: Human Perception and Performance*, 11, 583-587.

Evans, J. St. B. T. (1989). *Bias in Human Reasoning: Causes and Consequences.* London: Erlbaum.

Fang, S. P., & Wu, P. (1989). Illusory conjunctions in the perception of Chinese characters. *Journal of Experimental Psychology: Human Perception and Performance*, 15 (3), 434-447.

Fahle, M., & Koch, C. (1995). Spatial displacement, but not temporal asynchrony, destroys figural binding. *Vision Research*, 35, 491-494.

Feldman, J. A. (1985) Four frames suffice: A provisional model of vision and space. *behavioral and Brain Sciences*, 8, 265-289.

Felleman, D. J., & Van Essen, D. C. (1991). Distributed hierarchical processing in the primate cerebral cortex. *Cerebral Cortex*, 1, 1-47.

Fox, J. (1977). Continuity, concealment, and visual attention. In G. Underwood (Ed.), *Strategies of information-processing*. New York: Academic Press.

Freidman-Hill, S. R., Robertson, L. C., & Treisman, A. (1995). Parietal contributions to visual feature binding: Evidence from a patient with bilateral lesions. Science, 269, 853-855.

Gallant, J. L., & Garner, W. R. (1988). Some effects of distance and structure on conjunction errors. *Bulletin of the Psychonomic Society*, 26 (4), 323-326.

Gibson, J. J. (1950). *The perception of the Visual World.* Boston, MA: Houghton Mifflin.

Gibson, J. J. (1979). *The Ecological Approach to Visual Perception.* Boston, MA: Houghton Mifflin.

Gordon, R. D., & Irwin, D. E. (1996). What's in an object file? Evidence from priming studies. *Perception and Psychophysics*, 58 (8), 1260-1277.

Gray, C. M., König, P., Engel, A.K., & Singer, W. (1989). Oscillatory responses in cat visual cortex exhibit inter-columnar synchronization which reflects global stimulus properties. *Nature*, 338, 334-337.

Green, M. (1989). Color correspondence in apparent motion. *Perception and Psychophysics*, 45 (1), 15-20.

Green, M. (1991). Visual search, visual streams and visual architecture. *Perception and Psychophysics*, 50 (4), 388-403.

Grossberg, S., & Somers, D. (1991). Synchronized oscillations during co-operative feature linking in a cortical model of visual perception. *Neural Networks*, 4, 453-466.

Hazeltine, R. E., Prinzmetal, W., & Elliott, K. (1997). If it's not there, where is it? Locating illusory conjunctions. *Journal of Experimental Psychology: Human Perception and Performance*, 23 (1), 263-277.

Hebb, D. O. (1949). *The Organization of Behavior*. New York: Wiley.

Henderson, J. M. (1994). Two representational systems in dynamic visual identification. *Journal of Experimental Psychology: General*, 123, 410-426.

Henderson, J. M. & Anes, M. D. (1994). Roles of object-file review and type priming in visual identification within and across eye fixations. *Journal of Experimental Psychology: Human Perception and Performance*, 20, 826-839.

Hinton, G. E., McClelland, J. L., & Rumelhart, D. E. (1986) Distributed representations. In Rumelhart, McClelland and the Parallel Distributed Processing Research Group. *Parallel distributed processing: Explorations in the microstructure of cognition: Vol. 1. Foundations.* Cambridge MA: MIT Press.

Horn, D., Sagi, D., & Usher, M. (1991). Segmentation, binding and illusory conjunctions. *Neural Computation*, 3, 510-525.

Houck, M. R., & Hoffman, J. E. (1986). Conjunction of color and form without attention: Evidence from an orientation-contingent color aftereffect. *Journal of Experimental Psychology: Human Perception and Performance*, 12 (2), 186-199.

Howell, D. C. (1997). *Statistical Methods for Psychology (Fourth Edition)*. Belmont CA: Wadsworth.

Hubel, D. H., & Wiesel, T. N. (1962). Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *Journal of Physiology*, 166, 106-154.

Hummel, J. E., & Biederman, I. (1992). Dynamic binding in a neural network for shape recognition. *Psychological Review*, 99, 480-517.

Humphreys, G. W., Riddoch, M. J., & Boucart, M. (1992). The breakdown approach to visual perception: Neurophysiological studies of object recognition. In G. W. Humphreys (Ed.) *Understanding vision: An interdisciplinary perspective. Readings in mind and language 1*. Oxford, England: Blackwell.

Humphreys, G. W., & Quinlan, P. T. (1988). Priming effects between two-dimensional shapes. *Journal of Experimental Psychology: Human Perception and Performance*, 14 (2), 203-220.

Intraub, H. (1985). Visual Dissociation: An illusory conjunction of pictures and forms. *Journal of Experimental Psychology: Human Perception and Performance*, 11 (4), 431-442.

Intraub, H. (1989). Illusory conjunctions of forms, objects, and scenes during RSVP search. *Journal of Experimental Psychology: Human Perception and Performance*, 11, 431-442.

Ivry, R. B., & Prinzmetal, W. (1991). Effect of feature similarity on illusory conjunctions. *Perception and Psychophysics*, 49, 105-116.

Jacobs, A. M., & Grainger, J. (1991). Automatic letter priming in an alphabetic decision task. *Perception and Psychophysics*, 49 (1), 43-52.

James, W. (1890). *The Principles of Psychology*. New York: Holt.

Jonides, J. (1983). Further towards a model of the mind's eye's movement. *Bulletin of the Psychonomic Society*. 21, 247-250.

Jonides, J., & Mack, R. (1984). On the cost and benefit of cost and benefit. *Psychological Bulletin*, 96 (1), 29-44.

Julesz, B. (1981). Textons, the elements of texture perception, and their interactions. *Nature*, 290, 91-7.

Kahneman, D. (1968). Method, findings, and theory in studies of visual masking. *Psychological Bulletin*, 70, 404-25.

Kahneman, D., & Treisman, A. (1984). Changing views of attention and automaticity. In R. Parsuraman & D.R. Davies (Eds.), *Varieties of Attention*. Orlando, FL: Academic Press.

Kahneman, D., Treisman, A., & Gibbs, B. (1992). The reviewing of object files: Object-specific integration of information. *Cognitive Psychology*, 24, 175-219.

Kanwisher, N. (1991). Repetition blindness and illusory conjunctions: Errors in biding visual types with visual tokens. *Journal of Experimental Psychology: Human Perception and Performance*, 17 (2), 404-421.

Keele, S. W. (1973). *Attention and Human Performance*. Pacific Palisades, CA: Goodyear.

Keele, S. W., Cohen, A., Ivry, R. (B.), Liotti, M., & Yee, P. (1988). Tests of a temporal theory of attentional binding. *Journal of Experimental Psychology: Human Perception and Performance*, 14, 444-452.

Klein, S. A., & Levi, D. M. (1987). Position sense of the peripheral retina. *Journal of the Optical Society of America, Part A*, 4, 1544-1553.

Kleiss, J. A., & Lane, D. M. (1986). Locus and persistence of capacity limitations in visual information processing. *Journal of Experimental Psychology: Human Perception and Performance*, 12 (2), 200-210.

Kolers, P. A., & Green, M. (1984). Color logic of apparent motion. *Perception*, 13, 249-254.

König, P. & Engel, A. K. (1995). Correlated firing in sensory-motor systems. *Current Opinion in Neurobiology*, 5, 511-519.

La Berge, D. P., van Gelder, P., & Yellott, J. (1970). A cueing technique in choice reaction time. *Perception and Psychophysics*, 7, 57-62.

Lasaga, M. I., & Hecht, H. (1991). Integration of local features as a function of global goodness and spacing. *Perception and Psychophysics*, 49 (3), 201-211.

Lavie, N. (1997). Visual feature integration and focused attention: Response competition from multiple distractor features. *Perception and Psychophysics*, 59 (4), 543-556.

Lawrence, D. H. (1971). Two studies of visual search for word targets with controlled rates of presentation, *Perception and Psychophysics*, 10, 85-89.

Lesch, M. F., & Pollatsek, A. (1993). Automatic access of semantic information by phonological codes in visual word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 19, 285-294.

Levi, D. M., & Klein, S. A. (1989). Both separation and eccentricity can limit precise position judgments: A reply to Morgan & Watt. *Vision Research*, 29, 1463-1469.

Livingstone, M., & Hubel, D. (1988). Segregation of form, color, movement, and depth: anatomy, physiology, and perception. *Science*, 240, 740-749.

Lumer, E. D., & Huberman, B. A. (1992). Binding hierarchies: A basis fro dynamic perceptual grouping. *Neural Computation*, 4, 341-355.

Maddox, W. T., Prinzmetal, W., Ivry, R. B., & Ashby, F. G. (1994). A probabilistic multidimensional model of location information. *Psychological Research*, 55, 66-77.

Maljkovic, V., & Nakayama, K. (1994). Priming of pop-out: I. Role of features. *Memory and Cognition*, 22 (6), 657-672.

Marangolo, P., Di Pace, E., & Pizzamiglio, L. (1993). Priming effect in a color discrimination task. *Perceptual and Motor Skills*, 77, 259-269.

Marr, D. (1976). Early processing of visual information. *Philosophical Transactions of the Royal Society of London*, B207, 187-217.

Marr, D. (1982). *Vision*. San Francisco, CA: Freeman.

Marr, D., & Nishihara, H. K. (1978). Representation and recognition of the spatial organization of three-dimensional shapes. *Proceedings of the Royal Society of London* (Series B), 200, 269-294.

McCullough, C. (1965). Colour adaption of edge detectors in the human visual system. *Science*, 149, 1115-1116.

McLean, J. P., Broadbent, D. E., & Broadbent, M. H. P. (1983). Combining attributes in rapid serial visual presentations. Quarterly Journal of Experimental Psychology, 35A, 171-186.

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognising pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, 90, 227-234.

Mishkin, M., Ungerleider, L. G., & Macko, K. A. (1983). Object vision and spatial vision: Two cortical pathways. *Trends in Neurosciences*, 6, 414-417.

Modigliani, V., Wright, R. D., & Loverock, D. S. (1996). Inattention and the perception of visual feature conjunctions. *Acta Psychologica*, 91, 121-129.

Moran, J. C., & Desimone, R. (1985). Selective attention gates visual processing in the extrastriate cortex. *Science*, 229, 782-784.

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review*, 76, 165-178.

Mozer, M. C. (1991). *The Perception of Multiple Objects: A Connectionist Approach*. Cambridge, MA: MIT Press.

Mozer, M. C., Zemel, R. S., & Behrmann, M. (1991). *Learning to segment images using dynamic feature binding*. Technical Report, CU-CS-540-91. Department of Computer Science, University of Colorado, Boulder.

Müller, H. J., & Rabbitt, P. M. A. (1989). Spatial cueing and the relation between the accuracy of "where" and "what" decisions in visual search. *Quarterly Journal of Experimental Psychology*, 41A, 747-773.

Navon, D. (1990a). Does attention serve to integrate features? *Psychological Review*, 97 (3), 453-459.

Navon, D. (1990b). Treisman's search model does not require feature integration:

Rejoinder to Treisman (1990). *Psychological Review*, 97 (3), 464-465.

Navon, D., & Ehrlich, B. (1995). Illusory conjunctions: Does inattention really matter? *Cognitive Psychology*, 29, 59-83.

Neely, J. (1977). Semantic priming and retrieval from lexical memory: The roles of inhibitionless spreading activation and limited capacity attention. *Journal of Experimental Psychology: General*, 106, 226-254.

Neisser, U. (1967). *Cognitive Psychology*. New York: Freeman.

Neumann, K. N., & D'Agostino, P. R. (1981). Specificity of mental color codes. *American Journal of Psychology*, 94 (3), 451-459.

Poggio, T., Gamble, E., & Little, J. (1988). Parallel integration of visual modules. *Science*, 242, 436-439.

Posner, M. I. (1978). chronometric Explorations of Mind. Hillsdale, NJ: Erlbaum.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, 3-25.

Posner, M. I., & Boies, S. J. (1971). Components of attention. *Psychological Review*, 78, 391-408.

Posner, M. I., & Snyder, C. R. R. (1975a). Facilitation and inhibition in the processing of signals. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and Performance: Vol. 5*. London: Academic Press.

Posner, M. I., & Snyder, C. R. R. (1975b). Attention and cognitive control. In R. L. Solso (Ed.), *Information Processing and Cognition: The Loyola Symposium*. Hillsdale, NJ: Erlbaum.

Posner, M. I., Snyder, C. R. R., & Davidson, B. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General*, 109, 160-174.

Prinzmetal, W. (1981). Principles of feature integration in visual perception. *Perception and Psychophysics*, 30, 330-340.

Prinzmetal, W. (1995). Visual feature integration in a world of objects. *Current Directions in Psychological Science*, 4, 90-94.

Prinzmetal, W., Henderson, D., & Ivry, R. (B.) (1995). Loosening the constraints on illusory conjunctions: Assessing the roles of exposure duration and attention. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 1362-1375.

Prinzmetal, W., Hoffman, H., & Vest, K. (1991). Automatic processes in word perception: An analysis from illusory conjunctions. *Journal of Experimental Psychology: Human Perception and Performance*, 17, 902-923.

Prinzmetal, W., & Keysar, B. (1989). A functional theory of illusory conjunctions and neon colours. *Journal of Experimental Psychology: General*, 118 (2), 165-190.

Prinzmetal, W., & Millis-Wright, M. (1984). Cognitive and linguistic factors affect visual feature integration. *Cognitive Psychology*, 16, 305-340.

Prinzmetal, W., Presti, D. E., & Posner, M. I. (1986). Does attention affect visual feature integration? *Journal of Experimental Psychology: Human Perception and Performance*, 12, 361-369.

Prinzmetal, W., Treiman, R., & Rho, S. H. (1986). How to see a reading unit. *Journal of Memory and Language*, 25, 461-475.

Quinlan, P. T. (1991). Differing approaches to two-dimensional shape recognition. *Psychological Bulletin*, 109 (2), 224-241.

Ramachandran, V. S., & Cobb, S. (1995). Visual attention modulates metacontrast masking. *Nature*, 373, 66-67.

Rapp, B. C. (1992). The nature of sub-lexical orthographic organization: The bigram trough hypothesis examined. *Journal of Memory and Language*, 31, 33-35.

Rayner, K., & Pollatsek, A. (1983). Is visual information integrated across saccades? *Perception and Psychophysics*, 34(1), 39-48.

Rayner, K., & Pollatsek, A. (1992). Eye movements and scene perception. *Canadian Journal of Psychology*, 46, 342-376.

Rock, I., & Palmer, S. (1990). The legacy of Gestalt psychology. *Scientific American*, December, 84-90.

Rumelhart, D. E., McClelland, J. L., & The Parallel Distributed Processing Research Group (1986). *Parallel distributed processing: Explorations in the microstructure of cognition: Vol. 1. Foundations.* Cambridge MA: MIT Press.

Sagi, D., & Julesz, B. (1985). "Where" and "what" in vision. *Science*, 228, 1217-1219.

Sanocki, T. (1993). Time course of object identification: Evidence for a global-to-local contingency. *Journal of Experimental Psychology: Human Perception and Performance*, 19 (4), 878-898.

Seidenberg, M. (1987). Sublexical structures in visual word recognition: Access units or orthographic redundancy? In M. Coltheart (Ed.), *Attention and Performance XII*. Hillsdale, NJ: Erlbaum.

Sejnowski, T. J. (1986). Open questions about computation in the cerebral cortex. In McClelland, Rumelhart and the Parallel Distributed Processing Research Group. *Parallel distributed processing: Explorations in the microstructure of cognition: Vol. 2. Psychological and Biological Models.* Cambridge MA: MIT Press.

Selfridge, O. G. (1959). *Pandemonium: A paradigm for learning*. London: Her Majesty's Stationary Office.

Shastri, L., & Aajanagadde, V. (1993). From simple associations to systematic reasoning: A connectionist representation of rules, variables and dynamic bindings using temporal synchrony. *behavioral and Brain Sciences*, 16 (3), 417-451.

Shechter, S., Hochstein, S., & Hillman, P. (1988). Shape similarity and distance disparity as apparent motion correspondence cues. *Vision Research*, 28, 1013-1021.

Simon, W. E. (1971). Number and colour responses of some college students: Preliminary evidence of the blue and seven phenomena. *Perception and Motor Skills*, 33, 373-374.

Simon, J. R. (1988). A 'priming' effect in a choice reaction time task. *Acta Psychologica*, 69, 45-60.

Smolensky, P. (1987). *On variable binding and the representation of symbolic structures in connectionist systems*. Technical Report, CU-CS-355-87. Department of Computer Science, University of Colorado, Boulder.

Smolensky. P. (1990). Tensor product variable binding and the representation of symbolic structures in connectionist systems. *Artificial Intelligence*, 46, 159-216.

Snyder, C. R. R. (1972). Selection, inspection and naming in visual search. *Journal of Experimental Psychology*, 92 (3), 428-431.

Sperling, G. (1960) The information available in brief visual presentations. *Psychological Monographs*, 74 (Whole No. 498).

Spoehr, K. T., & Lehmkuhle, S. W. (1982). *Visual Information Processing*. San Francisco, CA: Freeman.

Stefurak, D. L., & Boynton, R. M. (1986). Independence of memory for categorically different colors and shapes. *Perception and Psychophysics*, 39 (3), 164-174.

Styles, E. A. (1997). *The Psychology of Attention*. Hove, England: Psychology Press.

Taylor, D. A. (1977). Time course of context effects. *Journal of Experimental Psychology: General*, 106 (4), 404-426.

Ternus, J. (1938). The problem of phenomenal identity. In W. D. Ellis (Ed.) *A Source Book of Gestalt Psychology*. New York: Harcourt, Brace and Co.

Treisman, A. (1986). Features and objects in visual processing. *Scientific American*, November, 106-115.

Treisman, A. (1988). features and objects: The fourteenth Bartlett memorial lecture. *Quarterly Journal of Experimental Psychology*, 40A, 201-237.

Treisman A. (1990). Variations on a theme of feature integration: Reply to Navon (1990). *Psychological Review*, 97 (3), 460-463.

Treisman, A. (1992). Perceiving and re-perceiving objects. *American Psychologist*, 47 (7), 862-875.

Treisman, A. (1993). Representing visual objects. *Attention and Performance XIV: Synergies in experimental psychology, artificial intelligence, and cognitive neuroscience*, (Ed.) D. E. Meyer & S. Kornblum. Cambridge, MA: MIT Press.

Treisman, A. (1995). Modularity and attention: Is the binding problem real? *Visual Cognition*, 2 (2/3), 303-311.

Treisman, A. (1996). The binding problem. *Current Opinion in Neurobiology*, 6, 171-178.

Treisman, A., & Gelade, (1980). A feature-integration theory of attention. *Cognitive Psychology*, 12, 97-136.

Treisman, A., & Gormican, S. (1988). feature analysis in early vision: Evidence from search asymmetries. *Psychological Review*, 95, 15-48.

Treisman, A., & Paterson, R. (1984). Emergent features, attention and object perception. *Journal of Experimental Psychology: Human Perception and Performance*, 10, 12-21.

Treisman, A., & Schmidt, H. (1982). Illusory conjunctions in the perception of objects. *Cognitive Psychology*, 14, 107-141.

Treisman, A., Sykes, M., & Gelade, G. (1977). Selective attention and stimulus integration. In S. Dornic (Ed.), *Attention and Performance VI*. Hillsdale, NJ: Erlbaum.

Tsal, Y. (1989a). Do illusory conjunctions support the feature integration theory? A critical review of theory and findings. *Journal of Experimental Psychology: Human Perception and Performance*, 15 (2), 394-400.

Tsal Y. (1989b). Further comments on feature integration: A reply to Briand and Klein. *Journal of Experimental Psychology: Human Perception and Performance*, 15 (2), 407-410.

Tsal, Y., Meiran, N., & Lavie, N. (1994). The role of attention in illusory conjunctions. *Perception and Psychophysics*, 55, 350-358.

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, 5, 207-232.

Ullman, S. (1979). The Interpretation of Visual Motion. Cambridge, MA: MIT Press.

Ungerleider, L. G., & Mishkin, M. (1982). Two cortical visual systems. In M. A. Goodale & R. J. W. Mansfield (Eds.) *Analysis of Visual Behaviour*.

Virzi, R. A., & Egeth, H. E. (1984). Is meaning implicated in illusory conjunctions? *Journal of Experimental Psychology: Human Perception and Performance*. 10 (4), 573-580.

von der Malsburg, C. (1986). Am I thinking assemblies? In G. Palm & A. Aertson (Eds.), *Brain Theory*. Berlin: Springer.

von der Malsburg, C. (1995). Binding in models of perception and brain function. *Current Opinion in Neurobiology*, 5, 520-526.

von der Malsburg, C., & Buhmann, J. (1992). Sensory segmentation with coupled oscillators. *Biological Cybernetics*, 67, 233-242.

van Gelder, T. (1991). What is the "D" in "PDP"? A survey of the concept of distribution. In W. Ramsey, S. Stich & D. Rumelhart (Eds.) *Philosophy and Connectionist Theory*. Hillsdale, NJ: Erlbaum.

Warren, R. E. (1972). Stimulus encoding and memory. *Journal of Experimental Psychology*, 94, 90-100.

Wertheimer, M. (Max) (1958). Principles of perceptual organization. In D.C. Beardslee & M. (Michael) Wertheimer (Eds.) *Readings in Perception*, Princeton, NJ: van Nostrand. Abridged translation by M. (Michael) Wertheimer of Wertheimer, M. (Max) (1923) Untersuchungen zur Lehre der Gestalt, II. *Psychology Forschung* 4, 302-350.

Wertheimer, M. (Michael) (1974). The problem of perceptual structure. In E. C. Carterette & M. P. Friedman (Eds.), *Handbook of Perception: Vol. 1. Historical and Philosophical Roots of Perception*. London: Academic Press.

Wolfe, J. M,, Cave, K. R., & Franzel, S. L. (1989). Guided search: An alternative to the feature integration model for visual search. *Journal of Experimental Psychology: Human Perception and Performance*, 15, 419-433.

Wolford, G. (1975). Perturbation model for letter identification. *Psychological Review*, 82, 184-199.

Wolford, G., & Shum, K. H. (1980). Evidence of feature perturbations. *Perception and Psychophysics*, 27, 409-420.

Zeki, S., & Shipp, S. (1988). The functional logic of cortical connections. *Nature*. 335. 311-317.