

Demands on Attention and the Role of Response Priming in Visual Discrimination of Feature Conjunctions

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This study examined how response mapping of features within single- and multiple-feature targets affects decision-based processing and attentional capacity demands. Observers judged the presence or absence of 1 or 2 target features within an object either presented alone or with distractors. Judging the presence of 2 features relative to the less discriminable of these features alone was faster (conjunction benefits) when the task-relevant features differed in discriminability and were consistently mapped to responses. Conjunction benefits were attributed to asynchronous decision priming across attended, task-relevant dimensions. A failure to find conjunction benefits for disjunctive conjunctions was attributed to increased memory demands and variable feature–response mapping for 2- versus single-feature targets. Further, attentional demands were similar between single- and 2-feature targets when response mapping, memory demands, and discriminability of the task-relevant features were equated between targets. Implications of the findings for recent attention models are discussed.

Comparing decisions based on target stimuli defined by multiple features and those based on target stimuli defined by single features has played an essential role in the development of most attention models, especially feature integration models (e.g., Cave, 1999; Treisman & Gelade, 1980; Treisman & Sato, 1990; Wolfe, 1994). Evidence indicating differences in selection time and attentional capacity demands between multiple- and single-feature targets are typically based on reaction time (RT) and accuracy measures (e.g., Cohen & Shoup, 2000; Lavie, 1995; Treisman & Gelade, 1980; Treisman & Schmidt, 1982). However, how responses are selected for multiple- and single-feature targets and how response mapping of features within these targets might influence discrimination time and accuracy for these targets have been generally ignored. The present study examines how response mapping of features within multiple- and single-feature targets affects decision-based processing as well as capacity demands on selective attention.

Most feature integration models assume that targets defined by two or more features must first be integrated by focal attention and that only the integrated object can activate its associated decision–response (e.g., Cave, 1999; Treisman & Gelade, 1980; Treisman & Sato, 1990; Wolfe, 1994). Consistent with this assumption, determining the presence of an object defined by two features is often assumed or shown to take more time or to be time limited by the more difficult feature comparison (Duncan, 1980; Hawkins, 1969; Wickens, 1984; Woods, Alain, & Ogawa, 1998). Furthermore, research findings suggesting that attentional capacity demands increase due to a feature integration process required to perceive two features (conjunctions) versus single features are often cited as

evidence for these models (Lavie, 1995; Treisman, 1991; Treisman & Paterson, 1984; Treisman & Schmidt, 1982). For example, Lavie (1995) showed that determining the presence of a stimulus defined by two features (a conjunction) takes longer and requires more attentional capacity than does determining the presence of a stimulus defined by a single feature.

Lavie (1995) presented task-relevant items in known locations and equated visual displays between the single-feature and two-feature discriminations.¹ A two-choice discrimination response to a target letter was executed or withheld on the basis of perceptual characteristics of a colored, geometric object (blue or red, circle or square) located next to the target letter. In the *single-feature* condition, a response to the target letter was made when the object was blue and withheld when it was red. In the *two-feature* condition, a response to the target letter was made when either a blue square or a red circle was present; otherwise, the response was withheld. Attentional capacity demands between these two conditions were compared by measuring how much a response-incompatible distractor letter interfered with response to the target relative to a neutral distractor (cf. B. A. Eriksen & Eriksen, 1974). It was assumed that increasing attentional demands of the geometric object would reduce the attentional capacity available to process a distractor letter and should, therefore, reduce interference by an incompatible distractor. Results showed that the incompatible distractor interfered with the target more than the neutral distractor in the single-feature condition only. Also, target discrimination took longer and was less accurate in the two-feature condition. Thus, it was concluded that discrimination of two-feature conjunctions, as opposed to single-feature targets, increases attentional capacity demand due to a feature integration process. The advan-

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¹ Lavie (1997) found similar results, but unlike in Lavie (1995), perceptual factors between targets and distractors were not constant across the single- and two-feature target displays and, hence, the differences in performance between these two target conditions can be attributed to difficulties in target segregation or localization (e.g., Duncan & Humphreys, 1992).

tage of Lavie's (1995) paradigm over visual search (e.g., Treisman & Gelade, 1980) and illusory conjunction paradigms (e.g., Treisman & Schmidt, 1982) is that her findings cannot be attributed to differences in localization time (Duncan & Humphreys, 1989; Wolfe, 1994) or memory recall difficulty (Tsal, 1989; Virzi & Egeth, 1984).

However, there are factors other than feature integration that could have delayed RTs and increased attentional capacity demands associated with the two-feature condition in Lavie's (1995) study. First, memory demands were likely greater in the two-feature condition because *disjunctive conjunctions* were used, requiring two different sets of feature combinations (blue square and red circle) to be held in memory and compared with the geometric object, in contrast to only one feature (blue) in the single-feature condition. An increase in memory demand has been shown to increase attentional demand (Schneider & Shiffrin, 1977). Second, attentional load was likely greater for the two-feature condition due to the failure to equate the discriminability between the color and shape dimensions. Only the two-feature condition required the shape dimension to be discriminated, and if the shape dimension was less discriminable than color, this may have increased the attentional load in this condition (e.g., B. A. Eriksen & Eriksen, 1974; C. W. Eriksen, Webb, & Fournier, 1990). Third, for the disjunctive conjunction *red circle or blue square*, the response mapping (present or absent) of a single feature (red) was variable and depended on the feature (circle or square) that it was paired with. In contrast, for the single-feature judgment of *red*, the feature red was consistently mapped to a *present* response. Discrimination time and attentional load have been shown to increase for stimuli with variable versus consistent response mappings (Farell, 1984; Schneider & Shiffrin, 1977; Strayer & Kramer, 1990). Fourth, Fournier, Bowd, and Herbert (2000) found that distractors containing a feature that was response incompatible with the target object interfered equally with the target object, independent of whether observers were discriminating the presence of one or two features within the target object. This suggests that resource demands may not differ between these two types of discriminations.

Furthermore, Fournier, Eriksen, and Bowd (1998), Fournier, Bowd, and Herbert (2000), and Fournier, Scheffers, Coles, Adamson, and Vila (2000) showed that determining the presence of an object defined by two features does not necessarily take longer and is not necessarily time limited by the more difficult feature comparison if all task-relevant features to be compared are response compatible with the correct response. They had observers judge the presence or absence of one or two target features within an object. The object was a letter that varied in color (red or green) and shape (*H* or *K*), and color was easier to discriminate than shape. The authors found that judgment of the presence of the color–shape conjunction was faster and more accurate than judgment of the presence of the less discriminable target feature of shape alone. Faster (and more accurate) *present* responses for conjunctions relative to the less discriminable feature were referred to as *conjunction benefits*. Also, *absent* responses, required when one or both target features were not present within an object, showed similar response patterns for single- and two-feature judgments, but only when all task-relevant features were absent. *Absent* responses for two-feature judgments were slower and less accurate when one of the target features was absent and the other was present, especially when the target feature that was present was more discriminable. Slower *absent* responses for conjunctions

when a target feature was present were referred to as *conjunction costs*. The fact that conjunction benefits and costs were determined by the discriminability of features mapped to the correct and incorrect responses suggests that responses may be influenced and coded by individual, task-relevant dimensions.

Conjunction benefits and costs have been shown for both two-feature and three-feature targets (e.g., color, shape, size). They have been observed for objects present among distractors in both response-compatibility flanker tasks and cuing tasks as well as for objects presented alone (Fournier, Bowd, & Herbert, 2000; Fournier et al., 1998; Fournier, Scheffers, et al., 2000). In all of these cases, displays were physically identical between the multiple-feature and single-feature targets and, in contrast to Lavie (1995), only one specific feature or feature conjunction had to be identified on any one trial. It is important to note that conjunction benefits were shown not to be accounted for by differential presentation frequency of the task-relevant (target) features, strategic weighting of decisions on the basis of the more discriminable target feature(s), or contingencies related to target-feature expectancies across target-feature judgments (Fournier et al., 1998). The phenomena of conjunction benefits and costs are important because they not only suggest that comparing more information is not time limited by the more difficult comparison, they suggest that discrimination RTs may be influenced by response mapping of individual features composing the target. That is, response priming and competition may occur across different dimensions within the same object, not just within the same dimensions across different objects, as suggested by Cohen and Shoup (2000).

An asynchronous priming (AP) model has been proposed to account for conjunction benefits and costs (Fournier, Bowd, & Herbert, 2000; Fournier, Scheffers, et al., 2000). This model is similar to the asynchronous discrete model discussed by Miller (1982) and has been modified since its original introduction (see Fournier, Bowd, & Herbert, 2000; Fournier, Scheffers, et al., 2000). The AP model assumes that each attended, task-relevant dimension can partially activate its task-relevant decision (e.g., *present* or *absent*) independently and in parallel. Also, easily discriminated dimensions can partially activate decisions earlier than can less discriminable dimensions, and partial decision activations by different dimensions that are attended and occupy the same spatial location are combined to meet a single decision criterion (Grice, Canham, & Schafer, 1982). Thus, when all task-relevant dimensions within an attended location are mapped to the same response (e.g., *present*), conjunction benefits result from early decision activation by the more discriminable dimensions, which are combined with activation by the less discriminable dimensions. This allows a decision criterion to be met earlier than does decision activation by the less discriminable dimensions alone.² Conjunction costs result when one feature partially activates the incorrect response and another feature activates the

² The AP model has been amended from that originally discussed by Fournier, Eriksen, and Bowd (1998) on the basis of behavioral and psychophysiological research suggesting that decision activations from each task-relevant dimension that occupy the same attended spatial location are combined (Fournier, Bowd, & Herbert, 2000) to reach a decision criterion before a response is executed (Fournier, Scheffers, et al., 2000; Smid, Bocker, van Touw, Mulder, & Brunia, 1996; Smid, Jacob, & Heinze, 1997).

correct response. In this case, correct responses will be slowed due to the time required to override incorrect priming (C. W. Eriksen & Schultz, 1979). Costs will be greater if the more discriminable feature is mapped to the incorrect response, because more incorrect priming will accumulate and need to be overridden. Thus, the speed of response depends on the discriminability of features mapped to the correct or incorrect response. Furthermore, in contrast to the assumptions and findings of Lavie (1995), the AP model makes no assumption that only the integrated feature representation activates decisions, and hence it does not assume that extra attentional resources are needed to integrate features into objects. According to the AP model, attentional resource demands should not differ between decisions based on one or two target features as long as response mapping (i.e., decision-activation strength), memory demands, and discriminability of task-relevant dimensions are equated between these target comparisons.

It is possible, however, that conjunction benefits found by Fournier and colleagues (Fournier, Bowd, & Herbert, 2000; Fournier, Scheffers, et al., 2000) were not due to response priming but were instead due to decreased memory load for the two-feature relative to the single-feature targets. This is because the number of objects in the stimulus set that matched a two-feature target was less than the number that matched a single-feature target. For example, when determining the presence of red *H* within the four possible objects of red *H*, red *K*, green *H*, and green *K*, observers saw only one object matching this description (i.e., red *H*). In contrast, when judging the presence of *H*, they saw two objects that matched this description (i.e., red *H* and green *H*). If one generates memory representations based on the number of objects that constitute a match, memory load may be less for the two-feature targets (cf. Farrell, 1984; Hyman, 1953; Prinz & Scheerer-Neumann, 1974; Ratcliff, 1978; Sternberg, 1969). Such an account of conjunction benefits would not conflict with the assumptions and findings of Lavie (1995), and it is consistent with the memory comparison (MC) model proposed by Ratcliff. The MC model assumes that the number of alternative objects that match the target is equivalent to the number of memory representations that the target stimulus must be compared with before a decision (i.e., *target present*) can be made; fewer alternatives lead to faster decisions. Also, decision time is influenced by the discriminability of object dimensions (perceptual certainty); more discriminable dimensions are evaluated and compared with the stimulus alternatives held in memory faster than are less discriminable dimensions. Finally, this model assumes that the entire stimulus (both its task-relevant and task-irrelevant features) at a specific attended location is compared with the memory representation(s) to determine whether there is a match.

There are two important differences between the AP model and the MC model. First, the AP model assumes that decision-activation time is determined only by each task-relevant dimension, not also by the task-irrelevant dimensions. Second, the AP model assumes that conjunction benefits will occur only if each feature on the task-relevant dimension is consistently mapped to a response and varies in discriminability to allow asynchronous decision activation by individual dimensions. In contrast, the MC model assumes that conjunction benefits will occur due to the reduced number of stimulus alternatives, regardless of whether task-relevant dimensions are similar or dissimilar in discriminability and regardless of whether features on task-relevant dimensions are or are not consistently mapped to a response.

In the current study, four experiments examined whether conjunction benefits are due to asynchronous response priming by task-relevant features, as assumed by the AP model. Experiment 1 determined whether (a) consistent mapping as well as discriminability differences between task-relevant features are necessary for conjunction benefits, as predicted by the AP model, or (b) conjunction benefits are instead due to memory factors, as predicted by the MC model. Experiments 2 and 3 compared two-feature targets defined by a specific conjunction and those defined by disjunctive conjunctions to determine whether response mapping and memory-demand factors can account for differences in decision times found between these two target types, as predicted by the AP model. Experiment 4 used a selection task to determine whether single-feature targets and two-feature targets defined by a specific conjunction impose similar demands on selective attention, as predicted by the AP model. If conjunction benefits are due to response priming, as assumed by the AP model, this would suggest that response mapping of task-relevant features within multiple- and single-feature targets is an important factor in determining decision times for these targets. It would also suggest that two-feature targets—at least those with features that are consistently mapped—are not necessarily integrated into an object representation first before they activate a decision and do not impose more of an attentional demand due to a feature integration process than do single-feature targets.

General Method: Experiments 1–3

Participants

Different undergraduates from Washington State University participated in each experiment; 16 participated in Experiment 1, 8 participated in Experiment 2, and 8 participated in Experiment 3. They received optional extra credit in a psychology course. All had normal acuity as assessed by a Snellen chart.

Apparatus and Stimuli

Stimuli were presented on a computer screen and were viewed through a face mask to keep viewing distance constant. A white fixation cross (0.12° of visual angle) appeared in the center of the screen before the onset of a single probe object (rectangle or ellipse). All possible probe objects were white (unfilled) and were presented against a black background. Luminance of the stimuli ranged from 2.36 to 3.60 cd/m^2 .

Probe objects were selected from three possible stimulus sets (see Figure 1). Within each stimulus set (A, B, and C), the objects differed across the two dimensions of orientation (vertical–horizontal) and shape (ellipse–rectangle). Discriminability of the orientation and shape dimensions was manipulated by varying the aspect ratios (width–height) of the objects across these stimulus sets. In *Stimulus Set A*, the ellipses and rectangles had aspect ratios of 0.90 (vertical orientation) and 1.11 (horizontal orientation), and the sizes of the vertical and horizontal objects were $0.70^\circ \times 0.76^\circ$ and $0.76^\circ \times 0.70^\circ$ of visual angle, respectively. In *Stimulus Set B*, the ellipses and rectangles had aspect ratios of 0.5 (vertical orientation) and 2.0 (horizontal orientation), and the sizes of the vertical and horizontal objects were $0.51^\circ \times 0.95^\circ$ and $0.95^\circ \times 0.51^\circ$ of visual angle, respectively. Finally, in *Stimulus Set C*, the ellipses and rectangles had aspect ratios of 0.13 (vertical orientation) and 7.71 (horizontal orientation), and the sizes of the vertical and horizontal objects were $0.25^\circ \times 2.04^\circ$ and $2.04^\circ \times 0.25^\circ$ of visual angle, respectively. Thus, in Stimulus Set A, orientation was difficult, whereas shape was easy to discriminate; in Stimulus Set C, orientation was easy, whereas shape was difficult to discriminate; and in Stimulus Set B, orientation and shape were both intermediate in discrim-

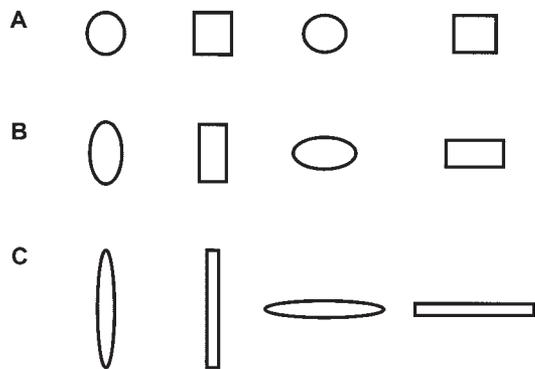


Figure 1. The different stimulus sets used in Experiments 1 (A, B, and C), 2 (A and C), and 3 (A and C). Target dimensions varied in discriminability as follows across stimulus sets: orientation difficult/shape easy (A), orientation/shape intermediate (B), and orientation easy/shape difficult (C).

inability compared with Stimulus Sets A and C. Discrimination difficulty was operationally defined by RT. Accuracy was measured to ensure that RTs were not accounted for by a speed–accuracy trade-off interpretation. It was assumed that features that are more discriminable (or salient) are responded to faster (with an equivalent or greater degree of accuracy) than are features that are less discriminable (Fournier, Bowd, & Herbert, 2000; Fournier et al., 1998; Fournier, Scheffers, et al., 2000). The difficulty of discriminating between the orientation and shape dimensions across Stimulus Sets A, B, and C was validated by RT and accuracy data from 2 pilot observers and from the experimental data, and it likely reflects differences in spatial frequency among the stimulus dimensions across the different stimulus sets.

Procedure

Observers judged whether one (e.g., vertical) or two target features (e.g., vertical ellipse) were present or absent within a probe object on each trial. Half of the observers moved a hand lever to the right when all target features were *present* and to the left when one or more target features were *absent*; the other half had the opposite response assignment. Observers were to respond as quickly and as accurately as possible.

The sequence of events was as follows. The four objects that corresponded to the stimulus set (A, B, or C) for a given block of trials appeared on the screen. After viewing these objects, the observer cleared the screen by pressing a hand button held in the left hand. Next, a message appeared indicating the one or two target features to be discriminated as *present* or *absent* in the probe object. After the observer cleared the screen with the hand button, a red fixation cross appeared for 500 ms and was then replaced by a white fixation cross. When the white cross was in focus, the observer pressed the hand button to initiate the onset of the probe object. The probe object replaced the cross and was presented for 200 ms. Observers determined whether the target features were present or absent in the probe object. A 2,000-ms interval was allowed for a response, and then accuracy feedback was provided. Next, a message appeared indicating the target feature(s) for the next trial, and the sequence of events was repeated.

The number of probe alternatives that matched the target feature or features (one alternative for the two-feature target, two alternatives for each single-feature target) was constant across the three stimulus sets (A, B, C), and the discriminability differences between the two dimensions (orientation and shape) within each stimulus set (A, B, C) differed. It is important to note that all comparisons concerning whether conjunction benefits were observed were made within a stimulus set, in which presumably similar perceptual channels were involved.

Analyses

For Experiment 1, a three-way, repeated measures analysis of variance (ANOVA)—Response (present, absent) \times Target Feature (orientation, shape, orientation–shape) \times Stimulus Set (A, B, C)—was conducted on both the mean correct RT and accuracy data. The analysis was identical for Experiments 2 and 3, except that the factor of stimulus set contained only two levels (A and C).

Experiment 1

Experiment 1 determined whether conjunction benefits are accounted for by the AP model or by the MC model. The MC model predicts that conjunction benefits should occur within each stimulus set (A, B, and C), independent of dimension-discriminability differences, because the number of stimulus alternatives that match a two-feature target is lower than the number for a single-feature target. In contrast, the AP model predicts that conjunction benefits should occur only when task-relevant dimensions within an object vary in discriminability (Stimulus Sets A and C), because only then can partial decision activation by the less discriminable dimension benefit from early partial activation by the more discriminable dimension. If the predictions of the AP model are supported and the predictions of the MC model are not, then conjunction benefits cannot be attributed to a decrease in memory demands resulting from a decrease in the number of stimulus alternatives. Furthermore, if each task-relevant dimension partially activates a decision asynchronously on the basis of feature discriminability, as assumed by the AP model, then conjunction costs (i.e., slower and less accurate *absent* responses relative to those for the less discriminable, single-feature targets) should be found when these dimensions are mapped to different responses (e.g., *present* and *absent*), particularly if the more discriminable dimension is mapped to the incorrect response.

Method

A verbal message indicated which target features to judge as *present* or *absent*. Each observer looked for one specific feature combination throughout the experiment. The specific feature combinations were these: vertical and ellipse, vertical and rectangle, horizontal and ellipse, or horizontal and rectangle. Thus, each observer always looked for one specific orientation (e.g., vertical), one specific shape (e.g., ellipse), and one specific orientation–shape feature combination (e.g., vertical ellipse) within each probe object from the three stimulus sets (see Figure 1). The single- and two-feature target judgments occurred randomly within each block of trials. A different stimulus set appeared across blocks in a counterbalanced order, and the four probe objects that corresponded to the stimulus set were presented in a random order within a block.

To ensure that conjunction benefits could not be attributed to a target-feature frequency confound (Fournier et al., 1998; Nickerson, 1972, 1973), each probe object within the stimulus sets (A, B, C) appeared equally often in each target-feature condition (see Table 1). That is, the vertical ellipse, horizontal ellipse, vertical rectangle, and horizontal rectangle each appeared 25% of the time within the orientation, shape, and orientation–shape target judgments. Note that this created an *absent* response bias for the two-feature targets because only one of the four probe objects in each stimulus set could match each two-feature target, whereas two of the four probe objects in each stimulus set could match each single-feature target (see Table 1). Thus, for the two-feature targets, a *present* response was required 25% of the time, and an *absent* response was required 75% of the time. Observers completed two sessions, each containing nine blocks of 48

Table 1
Target Feature and Response Frequencies in Experiment 1

Target feature and response	Probe object(s)	Frequency	
		Target feature	Response
Vertical-ellipse			
Present	○	Vertical: ½	Present: ¼
Absent	○ □ □	Ellipse: ½	Absent: ¾
Vertical			
Present	○ □	Vertical: ½	Present: ½
Absent	○ □	Ellipse: ½	Absent: ½
Ellipse			
Present	○ ○	Vertical: ½	Present: ½
Absent	□ □	Ellipse: ½	Absent: ½

trials. The first three blocks of trials in Session 1 were practice and were not included in the data analyses.

Results and Discussion

Figure 2 shows the correct *present* and *absent* RTs and percentages of error for each target feature across the three stimulus sets (A, B, C). Conjunction benefits occurred only when target features differed in discriminability (Stimulus Sets A and C). An ANOVA indicated that all main effects were significant for RT: response, $F(1, 15) = 33.19, p < .05$; target feature, $F(2, 30) = 5.91, p < .05$; and stimulus set, $F(2, 30) = 44.65, p < .05$. Moreover, the Target Feature \times Stimulus Set, $F(4, 60) = 70.44, p < .05$, and Re-

sponse \times Target Feature \times Stimulus Set, $F(4, 60) = 6.15, p < .05$, interactions were significant for RT. The ANOVA for accuracy showed a significant main effect of stimulus set, $F(2, 30) = 4.54, p < .05$, and a significant Target Feature \times Stimulus Set interaction, $F(4, 60) = 7.96, p < .05$. Our main focus concerns the three-way and two-way interactions found for RT and accuracy, respectively. All planned comparisons reported below are based on 1 and 15 degrees of freedom ($p < .05$).

As is evident in Figure 2, the *present* RT differences between the orientation and shape targets were greater in Stimulus Sets A and C than in Stimulus Set B. In Stimulus Set A (orientation difficult/shape easy), *present* and *absent* RTs were longer for the orientation than for the shape target. In Stimulus Set C (orientation easy/shape difficult), *present* and *absent* RTs were longer for the shape than for the orientation target. However, in Stimulus Set B (orientation/shape intermediate), *present* and *absent* RTs and accuracy were no different between the single-feature targets of orientation and shape ($p > .14$). These findings indicate that orientation was more difficult to discriminate than shape among the objects in Stimulus Set A, and shape was more difficult to discriminate than orientation among the objects in Stimulus Set C. Also, orientation and shape were no different in discriminability among the objects in Stimulus Set B. Percentage of error rates are consistent with these RT interpretations and do not indicate a speed-accuracy trade-off.

Two-feature present responses. Significant conjunction benefits were found only when target features clearly differed in discriminability. That is, *present* responses were faster for the

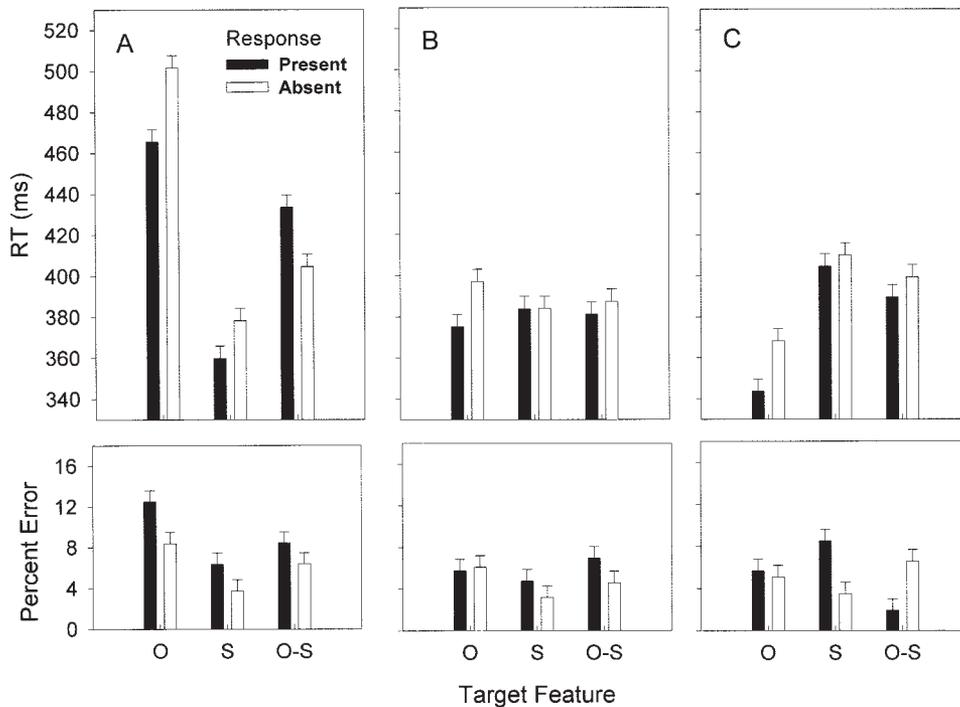


Figure 2. Mean correct reaction times (RTs) and percentages of error for *present* and *absent* responses for each target feature in each of the three stimulus sets in Experiment 1. Panel labels correspond to Stimulus Sets A (orientation difficult/shape easy), B (orientation/shape intermediate), and C (orientation easy/shape difficult). Error bars represent mean standard errors. O = orientation; S = shape; O-S = conjunction of orientation and shape.

Table 2
Reaction Times (RTs, in Milliseconds) and Percentages of Error Based on the Percentage of Total Correct Absent Responses for Two-Feature Target Judgments in Each Stimulus Set in Experiment 1

Stimulus set	Target feature mapped to incorrect, <i>present</i> response					
	Shape		Orientation		None	
	RT	% error	RT	% error	RT	% error
A: Orientation difficult/shape easy	454* _{a,b}	14.0* _{a,b}	387* _a	4.0* _a	378* _a	0.0* _b
B: Orientation/shape intermediate	387	4.4	405* _b	8.2* _b	370* _b	0.4* _b
C: Orientation easy/shape difficult	385* _a	3.0* _a	449* _{a,b}	14.1* _{a,b}	371* _b	1.0* _b

^a Significant difference between shape feature mapped to the incorrect, *present* response and orientation feature mapped to the incorrect, *present* response. ^b Significant difference when one feature (shape or orientation, compared with none) mapped to incorrect, *present* response.

* $p < .05$.

two-feature target than for the less discriminable, single-feature target in Stimulus Sets A and C only. In Stimulus Set A, *present* responses were faster (and more accurate) for the orientation–shape target than for the orientation target. Also, in Stimulus Set C, *present* responses were faster (and more accurate) for the orientation–shape target than for the shape target. Finally, in Stimulus Set B, *present* response latencies and accuracy for the orientation–shape target did not differ from those for the orientation or the shape targets ($ps > .19$). This indicates that eliminating discriminability differences between target features eliminates conjunction benefits, consistent with predictions of the AP model.³ Because we failed to find better performance for the two-feature target than for the single-feature targets when feature discriminability and target-feature frequency were similar between target dimensions (Stimulus Set B), we found no support for the MC model. We failed to support the MC model even though constructing a conjunction representation and, hence, using a memory-comparison strategy would likely have been easiest for Stimulus Set B, in which both task-relevant dimensions were easy to discriminate, as opposed to Stimulus Sets A and C, in which one dimension was difficult to discriminate. Thus, decreased memory load for the two-feature target cannot account for conjunction benefits. Consistent with these findings, Fournier et al. (1998) found equivalent conjunction benefits for two- and three-feature targets, independent of the number of matching stimulus alternatives (two alternatives for the two-feature target vs. one alternative for the three-feature target) when the target dimensions were the two most discriminable dimensions allowing similar rates of early, partial decision activation.

Two-feature absent responses. Recall that an *absent* response was required for the two-feature targets when one or both target features were absent from the probe. In the former case, one probe feature was mapped to the correct, *absent* response and the other to the incorrect, *present* response; in the latter case, both probe features were mapped to the correct, *absent* response. To determine whether each task-relevant dimension contributed to decision activation, we compared correct, *absent* responses for the two-feature targets on the basis of whether the probe feature on one of the target dimensions was mapped to the incorrect, *present* response or not (Fournier et al., 1998; Fournier, Scheffers, et al., 2000). Table 2 shows correct, *absent* response latencies and error rates for the two-feature targets on the basis of which feature was

mapped to the incorrect, *present* response (shape, orientation, none) within Stimulus Sets A, B, and C. Correct, *absent* RTs and accuracy for two-feature targets were evaluated in a repeated measures ANOVA with the factors of stimulus set (A, B, C) and feature mapped to the incorrect, *present* response (orientation, shape, none). It is important to note that the Stimulus Set \times Feature Mapped to the Incorrect, *Present* Response interaction was significant for both correct, *absent* RT, $F(4, 60) = 14.96, p < .001$, and error rate, $F(4, 60) = 7.77, p < .001$.

Correct, *absent* RTs and error rates (for Stimulus Sets A and C) were greater when the more discriminable feature was mapped to the incorrect, *present* response than when the less discriminable feature was mapped to the incorrect, *present* response. In Stimulus Set B, *absent* RTs and error rates did not differ when either orientation or shape was mapped to the incorrect, *present* response, which further indicates that these features were similar in discriminability. Trends (although not significant) also suggest that correct, *absent* RT was shortest (and error rate was lowest) when none of the features were mapped to the incorrect, *present* response. Response-based decision competition between features found for the two-feature *absent* responses, especially when the more discriminable feature was mapped to the competing, incorrect response, further supports the AP model's assumption that individual features contribute to response decisions when features within an object are consistently mapped to a response. The finding that response-based decision competition was significant only when the more discriminable feature was incompatible with the correct response indicates that more discriminable features can begin to activate decisions earlier than less discriminable features, and they can lead to a significant degree of decision interference. Fournier, Scheffers, et al. (2000) showed similar feature-based decision competition on the basis of electromyogram (EMG) and squeeze

³ Similar results were obtained in an experiment in which response frequency was controlled across the single- and two-feature targets (presented across blocks) with target-feature frequency confounded. The only difference was that a benefit in accuracy (not RT) was found for the two-feature targets compared with both single-feature targets in Stimulus Set B. However, this result can be attributed to the target-feature frequency confound for two-feature targets, especially because there was no indication of a conjunction benefit in Stimulus Set B in Experiment 1 when this confound was not present.

responses when evaluating correct, *absent* response delays for two-feature and three-feature targets when one or more features were mapped to the incorrect, *present* response.

Summary. Conjunction benefits were only found when task-relevant dimensions differed in discriminability, consistent with the AP model. Also, conjunction benefits found for *present* responses and conjunction costs found for *absent* responses indicate that each task-relevant dimension can partially activate a decision independently, and the more discriminable dimensions partially activate decisions earlier than do those that are less discriminable. The failure to find conjunction benefits when task-relevant features were similar in discriminability (Stimulus Set B) indicates that conjunction benefits cannot be accounted for by the MC model.

Experiment 2

Method

Unlike the methods used in Experiment 1, Lavie (1995) used disjunctive conjunctions in a nonsearch task and found slower (and less accurate) responses associated with determining the presence of two features compared with determining the presence of a single feature. Also, other researchers investigating object perception who have used disjunctive-conjunction targets have failed to find conjunction benefits (e.g., Farell, 1984; Lavie, 1997; for accuracy: Duncan, 1984; Müller & O'Grady, 2000). According to the AP model, task-relevant dimensions must independently and asynchronously contribute to a decision for conjunction benefits to occur. In Experiment 1 and previous research showing conjunction benefits (e.g., Fournier, Bowd, & Herbert, 2000; Fournier et al., 1998; Fournier, Scheffers, et al., 2000), observers judged the presence or absence of one specific feature conjunction (e.g., vertical ellipse) on any one trial. In this case, the value on each task-relevant dimension was consistently mapped to either a *present* or an *absent* response on any one trial (e.g., the individual features of vertical and ellipse were each mapped to the *present* response, and the features of horizontal and rectangle were each mapped to the *absent* response, regardless of which two features occurred together). Because the response associated with each feature is represented independently, as a feature is being resolved, its associated response can also be partially activated. Thus, resolving the feature on one dimension earlier than the feature on the other dimension will allow this "early" resolved feature to partially activate a (*present* or *absent*) decision first and lead to asynchronous decision activation.

In contrast, disjunctive-conjunction discriminations (e.g., Lavie, 1995) required observers to judge the presence or absence of two different feature conjunctions (e.g., vertical ellipse or horizontal rectangle) on any one trial. In this case, the value on each task-relevant dimension was not consistently mapped to a *present* or *absent* response on any one trial. The response mapping of each feature varied depending on the feature that it was paired with (e.g., the feature vertical was mapped to the *present* response when paired with ellipse but not when paired with rectangle). Hence, the response associated with one feature was contingent on the identity of the other. This contingency should prevent a feature (e.g., vertical) on one relevant dimension from partially activating a decision before the feature (e.g., ellipse) on the other relevant dimension. That is, even if one feature were resolved earlier than another, the former feature could not activate its associated response until the latter feature was also resolved, because the response of the former is defined by the latter. Moreover, because features on each dimension are not consistently mapped in the disjunctive-conjunction case but are consistently mapped in the single-feature case, the decision-activation strength of each task-relevant dimension (and, hence, the rate of decision activation) should be reduced for two-feature compared with single-feature targets. This assumption is consistent with previous findings of increased RTs and error rates for target stimuli that are not

consistently mapped relative to those that are (Farell, 1984; Schneider & Shiffrin, 1977). The lack of asynchronous decision activation and decreased decision-activation strength can lead to increased decision times and errors for two-feature targets, consistent with Lavie's (1995) findings.

Disjunctive-conjunction targets may also impose a higher demand on memory than do single-feature targets. Disjunctive-conjunction targets require two different sets of specific feature combinations (e.g., vertical ellipse and horizontal rectangle) to be retained in memory and compared with an object, whereas the single-feature target requires only one feature (e.g., vertical). This may lead to longer responses for the disjunctive-conjunction than for the single-feature targets. In contrast, two-feature targets defined by a specific conjunction require only one set of feature combinations (e.g., vertical ellipse) to be held in memory and compared with an object, which may be more similar to the memory demands for the single-feature targets. To support this latter assumption, we found that equating discriminability difficulty between target dimensions (Stimulus Set B, Experiment 1) led to equivalent *present* response performance (latency and accuracy) between the conjunction and single-feature targets.

The purpose of Experiment 2 was to determine whether differences in response mapping and memory demands between two-feature and single-feature targets could account for the lack of conjunction benefits and poorer discrimination performance found for disjunctive conjunctions. To test this, we used Stimulus Sets A and C from Experiment 1 and examined *present* response performance for the two- and single-feature targets when disjunctive-conjunction judgments were used. Note that the stimuli were physically identical to those in Experiment 1 (Stimulus Sets A and C), and only the type of two-feature target judgment differed. Thus, if it takes longer to judge the presence of a disjunctive conjunction than the less-discriminable single feature, this result can be accounted for by differences in response and/or memory factors that are imposed by the disjunctive-conjunction target. Such a result cannot be due to differences in low-level feature analyses or feature integration, because the physical aspects of the stimuli—including features required to identify targets—were the same as those in Experiment 1, in which conjunction benefits were found.

The procedure for Experiment 2 was similar to that for Experiment 1, except for the following. First, all observers judged the presence or absence of each possible single feature (vertical, horizontal, ellipse, and rectangle) and the two possible disjunctive conjunctions (*vertical ellipse or horizontal rectangle* and *vertical rectangle or horizontal ellipse*) on different trials within a block. Second, instead of a verbal message indicating the target features, two objects appeared on the screen (edges between objects separated by 1° of visual angle) for both the single- and two-feature targets, and observers determined whether the probe object matched one of these objects.⁴ For example, a vertical ellipse and a vertical rectangle were presented for the single-feature target of *vertical*. In addition, a vertical ellipse and a horizontal rectangle were presented for the disjunctive-conjunction target of *vertical ellipse or horizontal rectangle*. A *present* response was required when the probe object matched one of the two objects representing the single- or two-feature targets, and an *absent* response was required if it did not. Third, the presentation frequency of each probe object and response frequency (present or absent) was equated across the target features. Observers completed two 90-min sessions that

⁴ In a pilot study, verbal messages were used for single-feature and disjunctive-conjunction targets. RTs for disjunctive-conjunction targets were extremely long compared with those for single-feature targets. We originally believed that the extremely long RTs for disjunctive conjunctions were due to the difficulty of encoding these longer messages, as indicated by participants. Thus, we replaced the verbal messages with two objects that represented the single-feature and disjunctive-conjunction targets to try to reduce memory-demand differences between target messages. The data trends were the same with the verbal message and the two-object message, although the RTs were shorter for the disjunctive-conjunction targets in the latter case.

consisted of 10 blocks of 48 trials. The first session was practice and was not analyzed.

Results and Discussion

Figure 3 shows the *present* and *absent* RTs and percentages of error for each target feature across the two stimulus sets (A and C). Conjunction benefits were not found for disjunctive conjunctions even when target dimensions varied in discriminability (Stimulus Set A). An ANOVA indicated that all main effects were significant for RT: response, $F(1, 7) = 11.98, p < .05$; target feature, $F(2, 14) = 111.48, p < .05$; and stimulus set, $F(1, 7) = 61.27, p < .05$. Moreover, the Target Feature \times Stimulus Set interaction was significant, $F(2, 14) = 59.88, p < .01$. The ANOVA for accuracy showed significant main effects of response, $F(1, 7) = 13.64, p < .05$, and target feature, $F(2, 14) = 11.66, p < .05$, as well as a significant Response \times Target Feature interaction, $F(2, 14) = 5.57, p < .05$. Our main focus concerns the two-way interactions for RT and accuracy. All planned comparisons reported below are based on 1 and 7 degrees of freedom ($p < .05$).

As is evident in Figure 3, the orientation and shape dimensions differed in discriminability in Stimulus Set A (orientation difficult/shape easy) only; both *present* and *absent* RTs were longer for the orientation than for the shape target, with no significant differences in response errors. In Stimulus Set C (orientation easy/shape difficult), both *present* and *absent* RTs and response errors were not significantly different between the single-feature targets of

orientation and shape ($ps > .05$). Most important, in both Stimulus Sets A and C, *present* and *absent* RTs and response errors were greater for the disjunctive orientation–shape targets than for the single-feature targets of orientation and shape. Note that poorer target-discrimination performance for disjunctive-conjunction than for single-feature targets was found even though the number of objects in the stimulus set that matched each of these targets was identical.

The failure to find conjunction benefits for the disjunctive conjunctions even when task-relevant features differed in discriminability (Stimulus Set A) is consistent with the AP model, which predicts that conjunction benefits will not occur when individual target features are not consistently mapped to a response. Also, greater *present* responses for the disjunctive-conjunction target than for the less discriminable, single-feature target suggests that decision-activation strength was reduced and/or memory load was increased for disjunctive-conjunction targets compared with single-feature targets.

Experiment 3

However, it may be argued that the differences in *present* responses for two-feature targets between conjunction (Experiment 1) and disjunctive-conjunction (Experiment 2) judgments were due to the requirement that observers judge the presence of each possible single- and two-feature combination in Experiment 2 only. Experiment 3 was conducted to ensure that conjunction benefits would be observed for conjunction judgments of two-feature targets even though all possible single-feature and two-feature combinations must be discriminated within observers.

Method

The stimuli and procedure for Experiment 3 were identical to those for Experiment 2, with the following exceptions. First, conjunction discriminations, as opposed to disjunctive-conjunction discriminations, were required for two-feature targets. Second, a verbal message indicated the target feature(s) for each trial. Third, each probe object appeared equally often in each of the target-feature conditions (see Table 1) to prevent any target-feature frequency biases (similar to Experiment 1). Observers completed one 120-min session that consisted of 14 blocks of 64 trials. The first 4 blocks were practice and were not analyzed.

Results and Discussion

Figure 4 shows the *present* and *absent* RTs and percentages of error for each target feature across the two stimulus sets (A and C). The ANOVA conducted on correct RTs showed significant main effects of target feature, $F(2, 14) = 3.94, p < .05$, and stimulus set, $F(1, 7) = 25.78, p < .05$, as well as significant Target Feature \times Stimulus Set, $F(2, 14) = 42.55, p < .05$, and Response \times Target Feature \times Stimulus Set, $F(2, 14) = 5.15, p < .05$, interactions. The ANOVA for accuracy revealed no significant effects ($ps > .05$). All planned comparisons reported below are based on 1 and 7 degrees of freedom ($p < .05$).

The results are consistent with those of Experiment 1. *Present* and *absent* responses were greater for the orientation than for the shape target in Stimulus Set A (orientation difficult/shape easy), whereas *present* responses (although not *absent* responses) were greater for the shape than for the orientation target in Stimulus Set C (orientation difficult/shape easy). Moreover, conjunction bene-

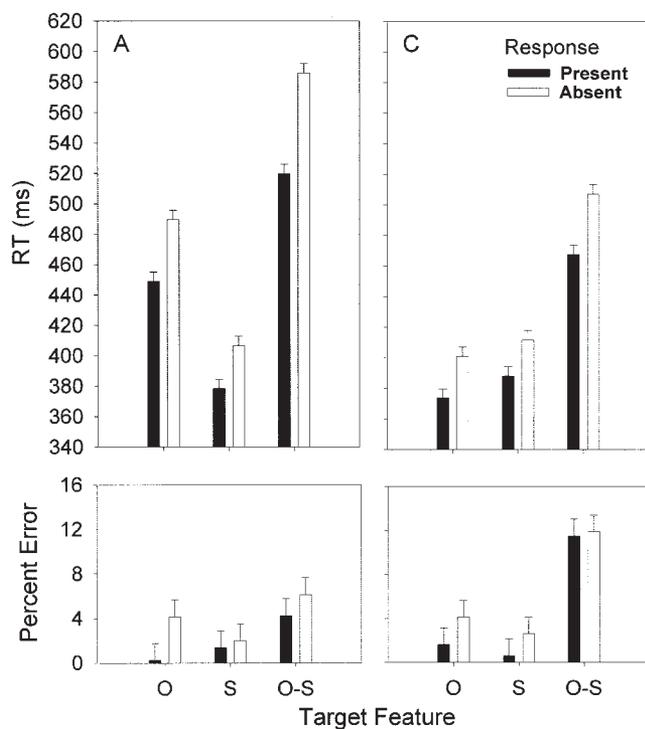


Figure 3. Mean correct reaction times (RTs) and percentages of error for *present* and *absent* responses for each target feature in each of the two stimulus sets in Experiment 2. Panel labels correspond to Stimulus Sets A (orientation difficult/shape easy) and C (orientation easy/shape difficult). Error bars represent mean standard errors. O = orientation; S = shape; O-S = disjunctive conjunction of orientation and shape.

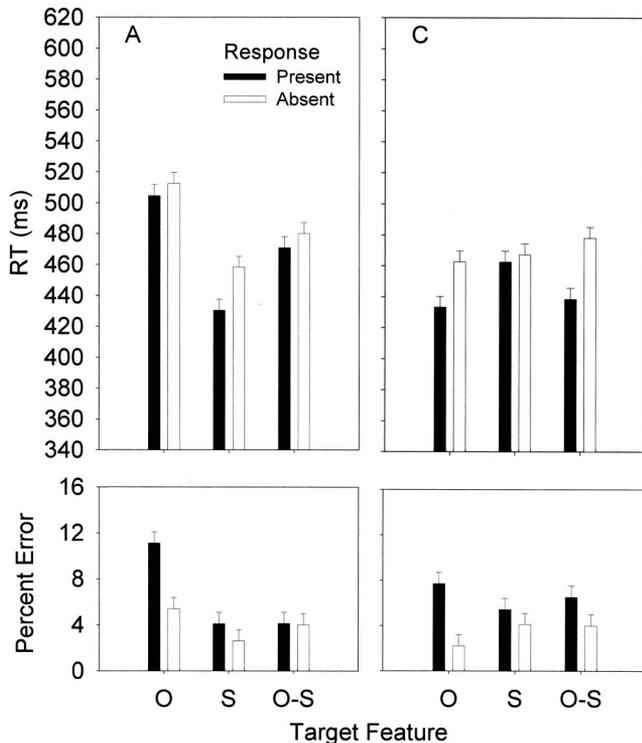


Figure 4. Mean correct reaction times (RTs) and percentages of error for *present* and *absent* responses for each target feature in each of the two stimulus sets in Experiment 3. Panel labels correspond to Stimulus Sets A (orientation difficult/shape easy) and C (orientation easy/shape difficult). Error bars represent mean standard errors. O = orientation; S = shape; O-S = conjunction of orientation and shape.

fits were found in both stimulus sets: *Present* responses in Stimulus Set A were faster for the orientation–shape target relative to the orientation target, and *present* responses in Stimulus Set C were faster for the orientation–shape target relative to the shape target.

The fact that conjunction benefits occurred when all possible features and feature combinations were judged as present or absent within observers (see also Fournier et al., 1998, Experiment 2) indicates that the failure to obtain conjunction benefits in Experiment 2 was not due to the increased variability of the target features. The longer *present* responses found for the disjunctive–conjunction targets relative to single-feature targets in Experiment 2 were likely due to decision-activation strength and/or memory-demand differences, because only feature–response mapping and memory factors differed between the disjunctive (Experiment 2) and conjunction targets (Experiment 3). It is important to note that results obtained in Experiments 2 and 3 indicate that response mapping and memory factors did not facilitate performance for conjunction targets but did hinder performance for disjunctive–conjunction targets. This is because feature–response mapping was more variable for the disjunctive–conjunction than it was for the single-feature targets, whereas feature–response mapping was similar in consistency for the conjunction and single-feature targets. Also, it was previously shown that memory demands were similar between conjunction and single-feature targets when feature discriminability was similar between these two target types (Stimulus

Set B, Experiment 1). Thus, Lavie’s (1995) findings of slower responses associated with disjunctive–conjunction judgments can be accounted for by differences in decision activation and/or memory demands.

Experiment 4

The purpose of Experiment 4 was to determine whether identifying the presence of a two-feature target, as opposed to a single-feature target, increases resource demands on selective attention due to a feature integration process. According to Lavie (1995), determining the presence of two features within an object, as opposed to one feature, will require additional attentional resources at an early, perceptual level of processing to integrate features in the two-feature case. In contrast, the AP model makes no assumption that extra attentional resources are used to integrate features into objects. According to the AP model, attentional resource demands should not differ between decisions based on one or two target features as long as response mapping (i.e., decision-activation strength), memory demands, and discriminability of task-relevant dimensions are equated between these targets. The AP model assumes that benefits found for conjunction targets are a result of asynchronous decision activation; conjunction benefits are not assumed to be due to an increase in attentional resource allocation.

We showed in Experiments 2 and 3 that Lavie’s (1995) use of disjunctive conjunctions likely reduced decision-activation strength and increased memory demands for the two-feature relative to the single-feature discriminations. These factors alone may have led to the increased attentional capacity demands that Lavie (1995) found. Previous research (e.g., Farrell, 1984; Schneider & Shiffrin, 1977) has shown that stimuli that contain variable response mapping (which is inherent in disjunctive–conjunction discriminations) are more attention demanding than are stimuli that contain consistent response mapping (which is representative of single-feature discriminations). Increased demands on memory have also been shown to increase demands on attention (de Fockert, Rees, Frith, & Lavie, 2001; Schneider & Shiffrin, 1977). Furthermore, we argued in the introduction that the discriminability between the features required for the two-feature (color and shape) and single-feature (color only) judgments were not equated in the Lavie (1995) study (i.e., the less discriminable feature of shape had to be identified in the two-feature case only). This factor could also partly account for Lavie’s results if features that are more difficult to discriminate demand more attention. Thus, a combination of these factors, not a feature-integration process, likely increased attentional demands for the two-feature judgments.

Experiment 4 used a response-competition paradigm (B. A. Eriksen & Eriksen, 1974) to determine whether identifying the presence of a two-feature target increased resource demands on selective attention due to a feature integration process. Similar to the logic of Lavie (1995), we determined whether incompatible distractors interfere less with a probe stimulus when observers judge the presence of a two-feature target (color and shape) as opposed to a less discriminable, single-feature target (shape). In contrast to Lavie (1995), decision-activation strength, memory demands, and target-feature discriminability were similar between these two target types. To better equate decision-activation strength and memory demands, we used conjunction and single-

feature judgments for which each feature on a task-relevant dimension was consistently mapped to a response, and only one specific feature conjunction or single feature was judged on each trial. To better equate target-feature discriminability and memory demands, we compared *present* responses for two-feature and single-feature targets that required the less discriminable feature of shape to be identified. If there is less interference from incompatible distractors when observers judge the presence of a two-feature target compared with the less discriminable, single-feature target, this would indicate that two-feature targets impose a higher demand on attention, possibly due to a feature integration process. This prediction was based on evidence that attentional resources are fixed in capacity, and whatever capacity is not used is automatically allocated to other local stimuli (e.g., Lavie & Tsai, 1994; Rees, Frith, & Lavie, 1997). Also, if two-feature targets are more attention demanding, then directing attention to the probe location with a visual cue (precue) before the onset of the probe and distractor stimuli should cause greater decreases in incompatible distractor interference for the two-feature than for single-feature targets. This prediction follows from the assumptions that (a) directing attention to a probe location in advance of stimulus presentation allows attentional resources to accumulate at this location, leaving fewer resources available to distractor locations, and (b) targets that demand more attentional resources may benefit more from the early accumulation of attentional resources than targets that do not (e.g., C. W. Eriksen & St. James, 1986). If more attentional resources are required for the two-feature targets, more attentional resources should accumulate at the precued location when observers discriminate two features as opposed to a single feature, leaving fewer attentional resources allocated to distractor locations in the two-feature case.

Method

Participants. Fourteen undergraduates from Washington State University participated for optional research credit in a psychology course. All had normal color vision as assessed by the Pseudo-Isochromatic Plates for Testing Color Perception (American Optical Company, 1940) and 20/20 acuity as assessed by a Snellen chart. One participant's data were not included due to a program error.

Apparatus and stimuli. The apparatus was identical to that in the previous experiments. Stimuli consisted of one or three letters that varied in shape (*H*, *K*) and color (red, green).⁵ The degree of visual angle for each letter was 0.23° (in width) and 0.46° (in height). Luminance was 2.98 cd/m² for green-colored letters and 1.04 cd/m² for red-colored letters. Letters appeared among eight possible locations within a circular display centered on a fixation cross. Letters were 2.10° of visual angle from the fixation cross. When multiple letters were presented, they appeared in adjacent clock locations with a spatial separation of 1.57° of visual angle.

Procedure. Observers were to attend to a single letter (probe) that could appear in any one of eight locations and ignore any noise letters that flanked the probe (flankers). The probe and flankers consisted of red or green *H*s and *K*s. The probe location was indicated by two white dashes (precue) that appeared to the left and right of the probe (0.6° center-to-center precue–probe distance). The similarity of features (color and shape) between the probe and flankers was varied within blocks. There were five levels of flanker: (a) no flanker (*none*), (b) flanker color (*C*) and shape (*S*) same as probe (*C+/S+*), (c) flanker color same as probe and shape different from probe (*C+/S-*), (d) flanker color different from probe and shape same as probe (*C-/S+*), and (e) flanker color and shape different from probe (*C-/S-*; see Figure 5).

Each observer determined the presence or absence of each possible color (red, green), shape (*H*, *K*), and color–shape conjunction (red *H*, red *K*,

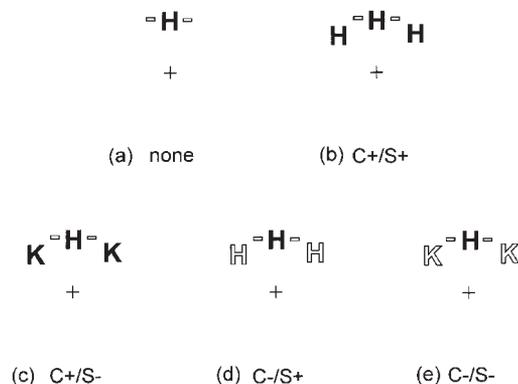


Figure 5. Example stimulus arrays for Experiment 4. Black letters represent letters that were red, and white letters represent letters that were green in the actual experiment. The probe is the middle letter, the dashes (which were white in the experiment) are the precue, and the flankers are the letters to the left and right of the probe. Each flanker-feature condition is as follows: (a) none = no flankers, (b) C+/S+ = flanker color and shape same as probe, (c) C+/S- = flanker shape different from probe, (d) C-/S+ = flanker color different from probe, and (e) C-/S- = flanker color and shape different from probe.

green *H*, green *K*) within the probe. A verbal message indicated the target feature(s) at the beginning of each trial. After this message was cleared, a small circle (0.20° of visual angle) appeared in the center of the screen and was replaced 1 s later by a fixation cross. The stimulus display was initiated by pressing the hand button. The precue appeared alone for 0, 50, 100, or 150 ms and was followed by the letters (probe and flankers). The probe, precue, and flankers appeared together for a duration of 50 ms. Observers had 2 s to respond, and response RT and accuracy feedback was presented after each trial. *Present* and *absent* response requirements and assignments were the same as those in the previous experiments.

Both the target-feature (i.e., specific color, shape, or color–shape conjunction) and precue stimulus onset asynchrony (SOA) were varied across blocks and presented in a counterbalanced order within and between observers. Also, each target-feature judgment occurred at each precue SOA equally often across sessions. The color-alone and shape-alone target judgments accounted for 40 trials per block, and each possible shape–color appeared equally often within the probe and flankers. Thus, response (present or absent) and target-feature frequency appearing in the probe was equal within each block. The color–shape target judgments contained 90 trials per block. Within a color–shape block, the target color and shape (e.g., red *H*) were both present in the probe (e.g., probe was red *H*) on 30 of the 90 trials (i.e., occurred six times with each of the five flanker conditions); the target color and/or shape features were absent in the probe (e.g., probe was red *K*, green *H*, or green *K*) on 60 of the 90 trials (i.e., occurred four times with each of the five flanker conditions). Thus, *absent* responses occurred on 2/3 of the trials, and *present* responses occurred on 1/3 of the trials, creating an *absent* response bias for the color–shape targets. This was necessary to approximate equal occurrence of all possible probe stimuli (red *H*, red *K*, green *H*, green *K*). The probe location and the flanker condition occurred equally in a random order within all blocks. Observers completed four sessions of 12 blocks of 40–90 trials. Each session lasted 60–90 min. At the beginning of the first session, observers completed 5 blocks of 8 practice trials with the precue SOA and target feature selected randomly.

⁵ Distractor interference effects found for these stimuli were similar to those found with stimuli that varied in shape (*X*, *O*)—for which feature overlap was minimal—and color (red, green).

Results and Discussion

The data are summarized in Figures 6, 7, and 8. A four-way, repeated measures ANOVA with the factors of response (present or absent), target feature (color, shape, color–shape), precue SOA (0 ms, 50 ms, 100 ms, 150 ms), and flanker (none, C+/S+, C+/S–, C–/S+, C–/S–) was conducted on correct RTs and accuracy. Significant effects for RT and accuracy are presented in Table 3. All planned comparisons reported below are based on 1 and 12 degrees of freedom ($p < .05$).

Conjunction benefits. There was a main effect of target feature for both RT and accuracy. Figure 6 shows the *present* and *absent* RTs and percentages of error (collapsed over precue SOA) for each target feature when no flankers were present. *Present* and *absent* RTs were shortest and most accurate for the color target, intermediate for the color–shape target, and longest and least accurate for the shape target. This indicates that color was easier to discriminate than shape. Furthermore, consistent with Experiments 1 and 3, conjunction benefits were found; *present* responses were faster and more accurate for the color–shape target than for the less discriminable single-feature target of shape. This was also true when flankers were present (see Figure 7).

Flanker incompatibility and task-relevant dimensions. Before the degree of flanker interference across the different target features could be compared, which flankers interfered with probe discrimination within each target-feature judgment had to be determined. As shown in Table 3, significant Target Feature \times Flanker, Response \times Target Feature, and Response \times Target

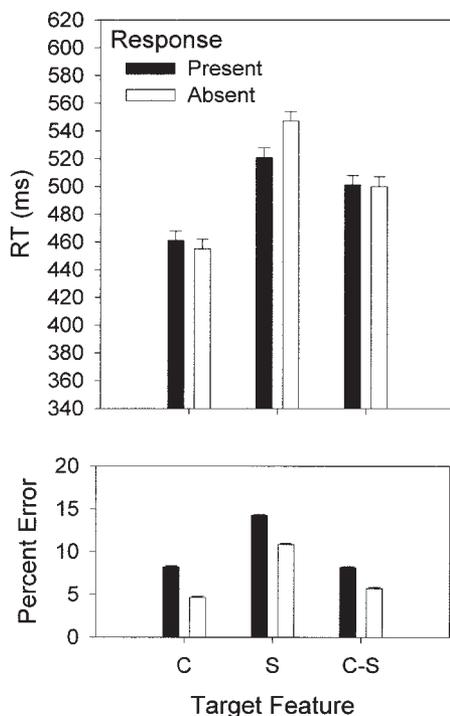


Figure 6. Mean correct reaction times (RTs) and percentages of error for *present* and *absent* responses (collapsed over precue stimulus onset asynchrony) for each target feature when no flankers were present in Experiment 4. Error bars represent mean standard errors. C = color target; S = shape target, C–S = color–shape target.

Feature \times Flanker interactions were found for RTs. There was also a significant Response \times Flanker interaction for accuracy. Figure 7 shows the *present* and *absent* RTs and percentages of error in each flanker condition separately for the different target features of color, shape, and color–shape. Both *present* and *absent* RTs and/or error rates increased when the flanker contained a feature that differed from the probe on a task-relevant dimension compared with when the flanker feature was identical to the probe. There were no differences in RTs and error rates between flankers that differed from the probe on a task-irrelevant dimension and flankers that were identical to the probe. Thus, consistent with past research (Fournier, Bowd, & Herbert, 2000), flankers inflated RTs or error rates only if they differed from the probe on a task-relevant dimension (i.e., a flanker feature was incompatible with a probe feature).

Comparison of the degree of incompatible flanker interference for each target feature. Figure 8 shows, for each target feature at the 0-ms precue SOA, the *present* RTs and percentages of error when the flanker features were identical to the probe compared with when at least one of the flanker features was different from the probe. Within each target feature (color, shape, color–shape), difference scores for *present* responses were calculated between flankers that were identical (C+/S+) to the probe and flankers that differed from the probe in terms of (a) shape only (C+/S–), (b) color only (C–/S+), or (c) color and shape (C–/S–). These difference scores were calculated at the 0-ms precue SOA because flanker interference should have been greatest at this SOA (e.g., Fournier, 1994). A repeated measures ANOVA with the factors of target feature (color, shape, color–shape) and flanker difference score [(C+/S–) – (C+/S+), (C–/S+) – (C+/S+), and (C–/S–) – (C+/S+)] was conducted on *present* response RT and accuracy (at the 0-ms precue SOA). The only significant effect was the Target Feature \times Flanker Difference Score interaction for RT, $F(4, 48) = 2.61, p < .05$.

First, the RT-difference scores between identical and shape-different flankers were equivalent for the shape target and color–shape target ($p = .80$) and were 15 ms greater than those for the color target, although this difference only approached significance ($p = .07$; compare slopes in Figure 8A). This indicates that when the flanker shape was incompatible with the probe, RT equally increased when observers judged the presence of a shape target and a color–shape target. Thus, when the discriminability between the features for the single-feature and the two-feature target were equated (i.e., when both required the less discriminable feature of shape to be discriminated), equivalent interference by an incompatible distractor (i.e., on the shape dimension) was observed.

Second, the RT-difference scores between identical (C+/S+) and color–shape-different (C–/S–) flankers were equivalent among the shape, color, and color–shape targets (all $ps > .50$; compare slopes in Figure 8C). This indicates that when the flanker color and shape differed from the probe, RT equally increased when observers judged the presence of a color target, a shape target, or a color–shape target. Thus, equating the discriminability of target features present in the probe with the incompatible features present in the distractors also leads to equivalent degrees of distractor interference.

Third, the RT-difference scores for identical (C+/S+) and color-different (C–/S+) flankers were greater for the color target than for the shape and color–shape targets ($p < .05$), which did not significantly differ ($p = .80$; compare slopes in Figure 8B). This

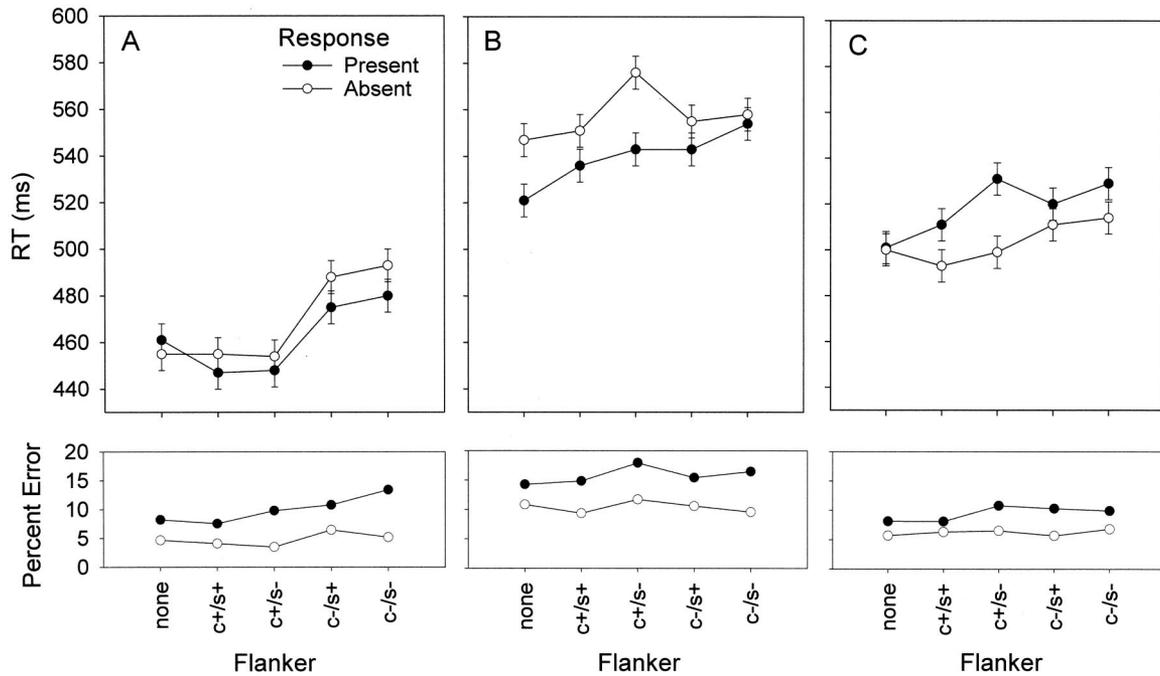


Figure 7. Mean correct reaction times (RTs) and percentages of error for *present* and *absent* responses for each target feature—color target (A), shape target (B), and color–shape target (C)—across each flanker-feature condition in Experiment 4. Error bars represent mean standard errors. none = no flankers; C+/S+ = flanker color and shape same as probe; C+/S- = flanker shape different from probe; C-/S+ = flanker color different from probe; C-/S- = flanker color and shape different from probe.

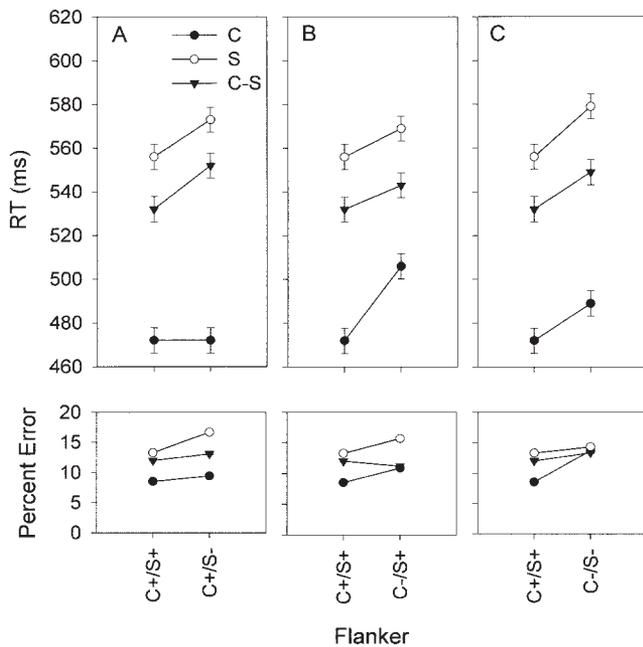


Figure 8. Experiment 4: Mean correct *present* reaction times (RTs) and percentages of error for each target feature—color (C) target, shape (S) target, and color–shape (C–S) target—at the 0-ms precue stimulus onset asynchrony when the flanker color and shape were identical to the probe (C+/S+) versus when at least one of the flanker features was different from the probe: shape different (C+/S-; Panel A), color different (C-/S+; Panel B), and both color and shape different (C-/S-; Panel C).

indicates that when the flanker color was incompatible with the probe, RT increased more when observers judged the presence of a color target than when they judged a color–shape target. Thus, when the discriminability between features for the single-feature and two-feature targets were not equated (i.e., only the two-feature target required the less discriminable feature of shape to be discriminated), incompatible distractor interference was less in the two-feature case. This suggests that the degree of incompatible distractor interference is influenced by the discrimination requirements of the task-relevant dimensions.

Taken together, these results show that the degree of incompatible distractor interference was equivalent between two-feature and single-feature targets when target features present in the probe were equated in terms of discriminability as well as response mapping and memory demands. Thus, the degree of incompatible distractor interference was not influenced by the number of target features to be discriminated. However, the degree of incompatible interference was influenced by the discrimination difficulty of a target feature.

Flanker incompatibility and precue SOA. If conjunction discriminations increase demands on attention, precuing the probe location before stimulus onset (e.g., SOA > 50 ms) should reduce interference by an incompatible-shape distractor more for the color–shape target than for the shape target. However, as is shown in Table 3, there was only a significant main effect of precue SOA for RT and a significant Precue SOA × Target Feature interaction for accuracy; precue SOA did not interact with any other factors, including flanker. Increasing precue SOA led to an overall decrease in RTs for both *present* and *absent* responses across all

Table 3
Analysis of Variance Results: Significant Effects for Correct Reaction Time and Accuracy in Experiment 4

Factor or interaction	<i>F</i> ratio	<i>MSE</i>
Reaction time		
Target feature (TF)	$F(2, 24) = 109.05^*$	8,203
Precue	$F(3, 36) = 39.37^*$	2,483
Flanker	$F(4, 48) = 33.15^*$	970
Response \times TF	$F(2, 24) = 23.34^*$	1,547
TF \times Flanker	$F(8, 96) = 10.94^*$	773
Response \times TF \times Flanker	$F(8, 96) = 6.14^*$	647
Accuracy		
Response	$F(1, 12) = 17.07^*$	0.04833
TF	$F(2, 24) = 57.09^*$	0.00921
TF \times Precue	$F(6, 72) = 3.78^*$	0.00404
Response \times Flanker	$F(4, 48) = 3.65^*$	0.00342

* $p < .05$.

target features (color, shape, and color–shape) and flanker conditions (none, C+/S+, C+/S–, C–/S+, C–/S–). Relative to the 0-ms precue SOA, the 50-, 100-, and 150-ms precue SOAs led to a decrease in RT by 24, 31, and 35 ms, respectively. In addition, error rate was highest for the shape target (13%), intermediate for the color–shape target (10%), and lowest for the color target (7%) at the 0-ms precue SOA. Increasing the precue SOA did not affect error rates for the color target and shape target. But increasing precue SOA from 0 to 50 ms did decrease the error rate (by approximately 3.5%) for the color–shape target, and performance for the color–shape target was just as accurate as that for the color target throughout the 50–150-ms precue SOA. This finding indicates that both *present* and *absent* response accuracies were hindered for the color–shape targets relative to the color target (but not the shape target) at the 0-ms precue SOA only. This suggests, consistent with results from visual search paradigms, that locating a target based on a color–shape conjunction may be more difficult than locating a target based on color alone (e.g., Treisman & Gelade, 1980). It is important to note that there is no evidence that precuing the probe location in advance of stimulus onset differentially affected distractor interference between the single-feature and two-feature targets. Thus, we found no evidence that more attentional capacity was allocated to two-feature targets.

Summary. Consistent with the AP model, attentional resource demands (based on incompatible-flanker interference and target-location precuing) did not differ between two-feature and single-feature targets when response mapping, memory demands, and discriminability of task-relevant dimensions were equated between these targets. Our findings indicate that attentional demands, based on the degree of incompatible flanker interference, were determined by the discriminability of the task-relevant dimensions, not by the number of task-relevant dimensions. Our findings also indicate that Lavie's (1995) failure to equate feature discriminability between her two-feature (color–shape) and single-feature (color) conditions likely led to the decrease in incompatible interference in her two-feature condition and to the erroneous conclusion that two-feature discriminations demanded more attention due to a feature integration process. Note also that Lavie's failure to equate memory demands and target–response mapping between

her single- and two-feature conditions may have additionally contributed to her conclusions. The fact that we controlled for these factors and found that target discriminability affected the degree of incompatibility interference indicates that feature discriminability not only affects how quickly one can judge the presence or absence of a feature, as assumed by the AP model, but also can influence attentional capacity demands.

General Discussion

We used a nonsearch task (with and without distractors) in four experiments and showed that conjunction benefits are due to asynchronous decision priming by individual task-relevant features without an increase in attentional capacity demands, consistent with the AP model. This study also demonstrated that differences in decision-based processing time between single- and two-feature targets are dependent on response mapping, memory demands, and discrimination of task-relevant dimensions within these targets. Below, we briefly review the AP model, as well as our findings, and discuss the relevance of our findings for some recent attention models.

The AP Account of Conjunction Benefits and Costs

The AP model assumes that each attended task-relevant dimension can partially activate a decision (e.g., *present* or *absent*) independently and in parallel. Moreover, dimensions that are easy to discriminate can partially activate decisions earlier than can those that are more difficult to discriminate as long as the feature on each attended dimension is consistently mapped to a response (e.g., *present* or *absent*) so that decision activation corresponding to each feature can be independently determined. The model further assumes that partial decision activation by each attended, task-relevant dimension is combined to meet a single decision criterion. Thus, when the task-relevant dimensions contain features that are all consistently mapped to the same response (e.g., *present*), decision activation by a less discriminable feature can benefit from early decision activation by a more discriminable feature and lead to conjunction benefits. Also, when task-relevant dimensions contain features that are consistently mapped to different responses (e.g., *present* and *absent*), feature-based decision competition (conjunction costs) can result, which will increase errors and delay correct responses (e.g., *absent*), especially when the more discriminable feature is mapped to the incorrect (e.g., *present*) response. Furthermore, this model does not assume that only an integrated feature representation can activate a decision, and hence it does not assume that extra attentional resources are needed to integrate features into objects.

Consistent with the AP model, conjunction benefits were observed only when target dimensions differed in discriminability and contained features with consistent feature–response mappings so that decision activation corresponding to each feature could be independently determined and could asynchronously contribute to a decision criterion (Experiments 1, 3, and 4). In contrast to the MC model, conjunction benefits were not observed in Experiment 1 when all target dimensions were similar in discriminability (Stimulus Set B), even though the number of alternatives that matched the target were fewer for the two-feature than for the single-feature targets. Equating discriminability between target dimensions led to equivalent *present* response performance for the

two-feature and single-feature targets, which indicates that memory demands and perceptual certainty were similar between these targets.

Conjunction costs found for correct, *absent* responses when features were consistently mapped to different responses (Experiment 1) further indicate that decision activation by individual, task-relevant dimensions can asynchronously contribute to response decisions. Consistent with the AP model, *absent* responses were delayed (and error rates increased) when one of the features was mapped to the incorrect, *present* response compared with when no features were mapped to the incorrect, *present* response, especially when the more discriminable feature was mapped to the incorrect, *present* response. This suggests that the more discriminable feature began to activate its associated *incorrect* response earlier and, hence, required more time for the *correct* activation by the less discriminable feature to override this buildup of incorrect activation.

Factors That Influence Disjunctive-Conjunction Target Discrimination

A critical assumption of the AP model is that the feature-based response priming responsible for conjunction benefits will not occur if the response associated with each feature on a task-relevant dimension is not consistently mapped to a response and, hence, cannot be independently determined. Also, conjunction benefits will not occur if memory demands are greater for two-feature than for single-feature targets. Consistent with these assumptions, conjunction benefits were not observed for disjunctive-conjunction targets. Experiments 2 and 3 showed that the variable feature–response mapping and increased memory demands for disjunctive-conjunction targets contributed to the slower *present* responses (and higher error rates) for these targets than for single-feature targets. Variable response mapping precluded asynchronous decision activation, and both variable response mapping and an increase in memory demand slowed the decision processes necessary to activate a response. Consistent with this interpretation, previous research has shown increased RTs and error rates for target stimuli that have variable feature–response mappings versus consistent feature–response mappings and also for target stimuli whose identification requires that more (vs. less) information be actively held in memory. Moreover, these same studies indicate that variable mapping as well as high memory demands impose more of a capacity demand on attention than do consistent mapping and lower memory demands, respectively (e.g., Schneider & Shiffrin, 1977; Strayer & Kramer, 1990, 1994).

Attentional Capacity Demands for Two-Feature and Single-Feature Targets

Consistent with the AP model, evidence that two-feature (conjunction) targets do not impose a greater demand on attention than do single-feature targets was found in Experiment 4, in which response mapping, memory demands, and discriminability of task-relevant dimensions were equated between these targets. Our findings indicate that attentional demand (determined by the degree of flanker interference) is influenced by the discriminability of the task-relevant dimensions at the attended target location and not by the number of task-relevant dimensions at the target location. Thus, judging whether two specific features are present as opposed

to one, although seemingly more complex, does not demand more attention. Furthermore, consistent with the AP model, discriminating the presence of a feature conjunction, as opposed to a single feature, does not impose an additional demand on attention to integrate these features as Lavie (1995) suggested. Our data reveal instead that task-relevant dimensions that are difficult to discriminate demand more attention than those that are easier to discriminate.

Conjunction Benefits Attributed to Decision-Based Processing

As mentioned earlier, conjunction benefits are not due to a decrease in memory demand or to an increase in attentional-resource allocation. Also, conjunction benefits cannot be attributed to increases in target-feature frequencies or *present* or *absent* response biases, because conjunction benefits were found when these factors were controlled in Experiment 3. Moreover, conjunction benefits do not occur at a low-level feature analysis or a feature integration stage of processing that precedes decision activation. This is because conjunction benefits were found only for conjunction targets (Experiment 3) and not for disjunctive-conjunction targets (Experiment 2) when the task-relevant dimensions as well as the stimuli for these two target types were physically identical. Only response mapping (consistent vs. varied) and memory demands differed between these targets, and memory demands were shown to be equivalent between conjunction and single-feature targets (Stimulus Set B, Experiment 1). Thus, consistent feature–response mapping must be necessary for conjunction benefits. This conclusion, in addition to the finding that conjunction benefits occurred only when target dimensions differed in discriminability and were consistently mapped to a response, indicates that conjunction benefits occurred at a decision level of processing, consistent with the AP model.

Findings That Challenge Some Assumptions of Feature Integration Theories

First, the finding that individual features can partially activate decisions is not consistent with most feature integration models, which assume that features are first integrated by attention such that response decisions are activated only by the integrated object representation (e.g., Cave, 1999; Treisman & Gelade, 1980; Treisman & Sato, 1990; Wolfe, 1994). If responses were only based on the integrated object representation, *present* response latencies should have been equivalent between the two-feature (conjunction) and less discriminable, single-feature targets (Experiments 1, 3, and 4). This is because *present* decision-activation time for the two-feature target would be limited by the time required to evaluate the less discriminable of the two features. Also, *absent* response latencies (Experiment 1) should have been equivalent among the two-feature target judgments regardless of whether one or both features on the task-relevant dimensions were mapped to the *absent* response. This is because *absent* decision-activation time should not be influenced by response mapping of individual features but by response mapping of the integrated object. Further evidence that decision activation is not necessarily determined by the integrated-object representation has been provided by Cohen and Shoup (1997). They showed that response competition occurred when a probe and flankers were associated

with different responses on the same, task-relevant dimension but not when the probe and flankers were associated with different responses on different dimensions.

Second, evidence that discriminating the presence of a two-feature conjunction as opposed to a single feature demands more attention, presumably due to a feature integration process, has been cited as evidence consistent with feature integration theories (Lavie, 1995; Treisman, 1991; Treisman & Gelade, 1980; Treisman & Paterson, 1984; Treisman & Schmidt, 1982). However, we showed in Experiment 4 that attentional capacity demands did not differ between two-feature and single-feature targets for which response mapping, memory demands, and discriminability of task-relevant dimensions were equated in a selection task. Although attentional capacity demands were shown not to vary on the basis of the number of task-relevant target dimensions, attentional capacity was shown to increase for target comparisons in which feature discriminability was not equated. This finding is important because in many visual search and nonsearch selection tasks, discriminability between two-feature and single-feature targets is not necessarily equated and, thus, can lead to incorrect conclusions that two-feature targets increase capacity demands due to a feature integration process (e.g., Cave & Wolfe, 1990; Lavie, 1995; Treisman, 1991; Treisman & Gelade, 1980; Treisman & Sato, 1990; Treisman & Schmidt, 1982). Also, a failure to equate feature–response mapping or memory demands between two-feature and single-feature targets can lead to inflated RTs (Schneider & Shiffrin, 1977) and similar erroneous conclusions. It is important to rule out these differences, as well as localization difficulties between two-feature and single-feature targets (Experiment 4), before making such strong claims. Although most researchers would agree with this assessment, the importance of equating these factors, particularly response factors, between target comparisons in object identification and visual search tasks is typically overlooked.

Compatibility of Findings With Recent Attention Models

The AP model is not unique in assuming that selected features within an object can independently activate decisions. Other recent attention models incorporate similar assumptions (e.g., Bundesen's, 2000, theory of visual attention; Cohen & Shoup's, 1997, response selection model and, 2000, cross-dimensional conjunction [CDC] model; Duncan's, 1996, integrated competition hypothesis; Duncan & Humphrey's, 1992, attentional engagement theory). The AP model, unlike these other models, assumes asynchronous decision activation based on feature discriminability when feature–response mappings are consistent, and it predicts conjunction benefits based on early, partial decision activation by the more discriminable, task-relevant dimension, which is combined with a less discriminable, task-relevant dimension to meet a decision criterion. This assumption is consistent with the idea of independent feature analyzers or independent report analyzers (e.g., Bundesen, 2000; Duncan, 1996). However, this assumption conflicts with the idea of interactive feature or report analyzers if it is assumed that decisions–responses must be based on the categorization of the entire object (i.e., object dimensions including those that are not task relevant) instead of task-relevant dimensions only. Furthermore, to be consistent with the AP model, the interactive feature or report analyzers must allow information to reach working memory, where decisions are made, before the

task-relevant features are fully represented in these analyzers. Thus, although interactive report or feature analyzers are not necessarily inconsistent with the AP model, they may not be necessary in cases in which task-relevant features are consistently mapped and can activate decisions in working memory directly.

The assumptions of the AP model can be incorporated into the recent CDC model developed by Cohen and Shoup (2000) to account for conjunction benefits and for the slower responses typically found for disjunctive conjunctions. Unlike other feature integration models, the CDC model explicitly accounts for response-competition effects among dimensions of different objects and assumes that response activation by features on different dimensions can independently contribute to a response decision. The model assumes that features from all objects that belong to a particular dimension (e.g., color, shape) are analyzed within a corresponding dimension module, and responses to single features (e.g., based on task instructions) are determined separately within each dimension module. The model also assumes that visual attention selects distal information and modulates which of the computed perception–action linkages across dimension modules will be executed and reach a decision-based executive system in working memory. Spatial attention mediates the output of the dimension-specific response selection units by enhancing the activation of feature detectors at the target location. That is, bottom-up activation from the distal stimulus is multiplied by activation from spatial attention, and the resultant activation must then exceed a high threshold at the dimension-specific response selection units to reach the central, decision-based executive system, where response-based activation from the different dimension modules is combined. These aspects of the model alone can account for decisions based on single-feature targets and conjunction targets that have consistent feature–response mappings, with the added assumption that task-relevant dimensions reach the higher order decision stage at different times on the basis of discriminability and are asynchronously combined to meet a common decision criterion. However, these aspects of the model alone cannot account for decisions based on disjunctive-conjunction targets.

To account for both decisions based on conjunction and disjunctive-conjunction targets, the CDC model incorporates a single conjunction map that receives input from the dimension modules and outputs to the central, decision-based executive system in working memory. The conjunction map can represent only one conjunction at any one time, and only one feature from each dimension module can gain access to the conjunction map at one time. Moreover, the conjunction map and, hence, response activation are generated somewhat differently when observers discriminate the presence or absence of a particular conjunction (e.g., red *H*) rather than a disjunctive conjunction (e.g., red *H* or green *O*). When an observer looks for a particular conjunction, the conjunction map can be preconfigured on the basis of top-down information regarding what specific conjunction he or she is looking for. That is, the connection between each task-relevant feature and its response is strengthened and has priority in entering the conjunction map. Detection of the presence of a target is based on activation of the conjunction representation within the conjunction map. Our data suggest that if these features match the conjunction target, and one feature is more discriminable than the other, this can lead to early activation of the conjunction map and, hence, early detection of the target in working memory, where responses

are assigned. Our findings of both conjunction benefits (response priming) and conjunction costs (response competition) indicate that individual features of a conjunction, if represented in a conjunction map, are not necessarily fully represented before a response can be activated. Furthermore, Fournier, Scheffers, et al. (2000) showed, using EMG and squeeze measurements, that this response competition occurs at a peripheral motor-execution level. Thus, highly learned response mapping of individual features can lead to response activation before the attended features are fully integrated. In fact, it is possible that decision activation occurring at a central decision stage feeds back to the conjunction map to aid feature integration (Cohen & Shoup, 1997). In contrast, for disjunctive-conjunction discriminations, the CDC model assumes that the conjunction map cannot be preconfigured. Instead, the system must rely on feature information from the dimension modules alone to determine what features are present. Evaluating a disjunctive conjunction requires more time because one must wait for each attended feature to enter the conjunction map and be fully evaluated before this information can be sent to working memory, where the conjunction representation is compared serially to each target alternative before a response is assigned.

Because all relevant features of an object must be fully evaluated before a decision about a disjunctive-conjunction target's presence or absence can be determined, a conjunction map in which features must be combined before a response can be generated appears to be a necessary assumption. However, it is less clear whether features in the single-conjunction case, in which feature-response mappings are consistent, must enter a conjunction map where features are first combined before a response can be activated. As mentioned earlier, responses for each task-relevant feature at the attended location for conjunction features that have consistent response mappings may directly activate their corresponding responses, in a manner similar to single features that are consistently mapped (Cohen & Shoup, 1997, 2000). There would be no reason to create a conjunction map based on top-down processing because a conjunction representation could be held in working memory, where features could be directly compared. Consistent with this assumption, several researchers have found evidence that feature dimensions may be represented independently in memory (Bundesen, 2000; Heathcote, Walker, & Hitch, 1994; Isenberg, Nissen, & Marchak, 1990; Stefurak & Boynton, 1986). However, it can be argued that incorporating a conjunction map can account for both conjunction and disjunctive-conjunction targets and, hence, is a more parsimonious assumption.

Regardless of whether conjunction features that are consistently mapped are or are not fed into a conjunction map before a response-based decision can be activated, we have shown that a decision can be activated before these features are fully integrated. Furthermore, our data are consistent with the CDC model's assumption that the capacity demand on spatial attention mechanisms can be the same for single-feature and conjunction targets as long as response, memory, and discriminability of the task-relevant features are equated between these targets. However, our data indicate that only task-relevant dimensions are selected and compared, not task-irrelevant dimensions also, as assumed by the CDC model. We showed that attentional demands for single- and two-feature targets can differ if the discriminability of the task-relevant dimensions between these targets differs even when the physical aspects of these stimuli are the same and response and memory demands of task-relevant features are equated between

these targets. Attentional demands increase when a less discriminable feature, as opposed to a more discriminable feature, must be selected and responded to independent of the number of features selected.

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