DOCUMENT SUMMARY This document is the full text of Anne Treisman and Garry Gelade's seminal 1980 paper, "A Feature-Integration Theory of Attention." The theory proposes that perceiving objects occurs in two stages: a **preattentive** stage where basic features like color, shape, and orientation are processed rapidly and in **parallel** across the visual field, and a focused attention stage where features are combined into objects through a slower, **serial** process. The paper presents a series of experiments on visual search and texture segregation to demonstrate that detecting single features is fast and independent of distractors, while detecting **conjunctions** of features requires serial, item-by-item attention.

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METADATA Category: RESEARCH Type: report Relevance: Core Update Frequency: Static Tags: [#attention, #feature-integration-theory, #cognitive-psychology, #visual-search, #serial-processing, #parallel-processing, #conjunctions, #illusory-conjunctions, #preattentive-processing] Related Docs: This foundational cognitive psychology paper complements Tversky & Kahneman's work on heuristics by detailing the attentional mechanisms that underpin judgment. It also relates to Rosenhan's study by explaining how attentional focus (or lack thereof) can lead to misperceptions (e.g., **illusory conjunctions**). Supersedes: N/A

FORMATTED CONTENT

A Feature-Integration Theory of Attention

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> A new hypothesis about the role of focused attention is proposed. The **feature-integration theory of attention** suggests that attention must be directed serially to each stimulus in a display whenever conjunctions of more than one separable feature are needed to characterize or distinguish the possible objects presented.

A number of predictions were tested in a variety of paradigms including visual search, texture segregation, identification and localization, and using both separable dimensions (shape and color) and local elements or parts of figures (lines, curves, etc. in letters) as the features to be integrated into complex wholes. The results were in general consistent with the hypothesis. They offer a new set of criteria for distinguishing separable from integral features and a new rationale for predicting which tasks will show attention limits and which will not.

We have recently proposed a new account of attention which assumes that features come first in perception.

> In our model, which we call the **feature-integration theory of attention**, features are registered early, automatically, and in parallel across the visual field, while objects are identified separately and only at a later stage, which requires **focused attention**.

We assume that the visual scene is initially coded along a number of **separable dimensions**, such as color, orientation, spatial frequency, brightness, direction of movement. In order to recombine these separate representations and to ensure the correct synthesis of features for each object in a complex display, stimulus locations are processed **serially** with focal attention.

Any features which are present in the same central "fixation" of attention are combined to form a single object.

> Thus focal attention provides the "glue" which integrates the initially separable features into unitary objects.

Once they have been correctly registered, the compound objects continue to be perceived and stored as such. However with memory decay or interference, the features may disintegrate and "float free" once more, or perhaps recombine to form "**illusory conjunctions**".

Our claim is that attention is necessary for the correct perception of **conjunctions**, although unattended features are also conjoined prior to conscious perception. However, in the absence of focused attention and of effective constraints on top-down processing, conjunctions of features could be formed on a random basis. These unattended couplings will give rise to "**illusory conjunctions**."

We developed a number of different paradigms testing different predictions from the theory.

1. **Visual search.** If, as we assume, simple features can be detected in parallel with no attention limits, the search for targets defined by such features (e.g., red, or vertical) should be little affected by variations in the number of distractors in the display. In contrast, we assume that focal attention is necessary for the detection of targets that are defined by a conjunction of properties (e.g., a vertical red line in a background of horizontal red and vertical green lines). Such targets should therefore be found only after a **serial scan** of varying numbers of distractors.
2. **Texture segregation.** It seems likely that **texture segregation** and figure-ground grouping are **preattentive**, parallel processes. If so, they should be determined only by spatial discontinuities between groups of stimuli differing in separable features and not by discontinuities defined by conjunctions of features.
3. **Illusory conjunctions.** If focused attention to particular objects is prevented, either because time is too short or because attention is directed to other objects, the features of the unattended objects are "free floating" with respect to one another. This allows the possibility of incorrect combinations of features when more than one unattended object is presented.
4. **Identity and location.** If focused attention is prevented, the features of unattended objects may be free floating spatially, as well as unrelated to one another. Thus we may detect the presence of critical features without knowing exactly where they are located. However, the theory predicts that this could not occur with conjunctions of features. If we have correctly detected or identified a particular conjunction, we must first have located it in order to focus attention on it and integrate its features. Thus location must precede identification for conjunctions, but the two could be independent for features.
5. **Interference from unattended stimuli.** Unattended stimuli should be registered only at the feature level. The amount of interference or facilitation with an attended task that such stimuli can generate should therefore depend only on the features they comprise and should not be affected by the particular conjunctions in which those features occur.

EXPERIMENT I

This experiment compares search for targets specified by a single feature and for targets specified by a conjunction of features. Subjects were asked to search concurrently for two targets, each defined by a different single feature: a color (blue) and a shape (S). Thus they were forced to attend to both dimensions in the feature condition as well as in the conjunction condition, although they had to check how the features were combined only when the target was a conjunction (a green T). The distractors were identical in the two conditions (green X's and brown T's). The experiment also explored the possibility that extended practice on a particular shape-color conjunction could lead to a change from **serial** to **parallel** detection.

Results The results showed that search time increased linearly with display size in the conjunction condition, suggesting that search is serial and self-terminating with a scanning rate of about 60 msec per item. With the feature targets, the results were very different. For the positive displays, search times were hardly affected by the number of distractors. This suggests that with single feature targets, a qualitatively different process may mediate the responses to positive and to negative displays. If the target is present, it is detected automatically; if it is not, subjects tend to scan the display. The effects of practice on conjunction search showed that positive and negative slopes remained linear throughout. There was little indication of any change in the pattern of results and no sign of a switch from serial to parallel search over the 13 blocks of practice.

Figure 1: Search for Colored Shapes (Description)

The graph plots reaction time against display size for conjunction and disjunction (feature) searches. For **conjunction search**, reaction times increase in a steep, straight line as display size increases, with negative trials (target absent) having a slope roughly twice as steep as positive trials (target present). For **disjunction search** (searching for a color OR a shape), reaction times for positive trials remain flat and fast regardless of display size.

Table 1: Linear Regressions of Reaction Times on Display Size in Experiment I

		Slope	Intercept	Percentage variance with display size which is due to linearity
Conjunction	Positives	28.7	398	99.7
	Negatives	67.1	397	99.6
Feature mean	Positives	3.1	448	67.9
	Negatives	25.1	514	96.6
Feature color	Positive	3.8	455	61.0
Feature shape	Positive	2.5	441	78.5

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EXPERIMENT II

This experiment explores the relation between the discriminability of the features which define a conjunction and the speed of detecting that conjunction. The prediction was that by making the two shapes and the two colors in a conjunction search harder to distinguish, the rate of scanning would change while retaining the characteristic serial search pattern.

Results The slopes in the difficult discrimination are nearly three times larger than those in the easy discrimination, but the linearity and the 2/1 slope ratio is preserved across these large differences. This wide variation in slopes is consistent with the theory and puts constraints on alternative explanations. The need for focused attention to each item in turn must be induced by something other than overall load.

Table 2: Linear Regressions of Search Times against Display Size in Experiment II

		Slope	Intercept	Percentage variance with display size which is due to linearity
Difficult discrimination	Positives	55.1	453	99.8
	Negatives	92.4	472	99.9
Easy discrimination	Positives	20.5	437	99.8
	Negatives	39.5	489	99.9

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EXPERIMENT III

This experiment explores an alternative explanation: that the difficulty of conjunction search is due to the target being "central" to the distractors in terms of similarity (e.g., a green T shares a feature with every green X and brown T distractor). We replicated this similarity structure using unidimensional stimuli (ellipses of varying sizes).

Results The pattern of results is quite different from that obtained with the color-shape conjunctions. All the functions relating latency to display size are negatively accelerated, not linear. The important point for the present theory is that when the intermediate target is present, its detection does not depend on a serial check of the distractors, whereas detection of the color-shape conjunction did. This rules out an explanation of the conjunction effect in terms of the "centrality" of the target to the set of distractors.

EXPERIMENT IV

This experiment explores the possibility that local elements or parts of shapes (like letters) function as separable features which must be integrated by focused attention. We contrasted search for a target 'R' in a background of 'P's and 'Q's (where features could be wrongly recombined) with search for 'R' in a background of 'P's and 'B's (a more similar but non-conjunction control).

Results The results on positive trials were consistent with predictions. Search was linear for the conjunction set (R in PQ) and non-linearly increasing for the similarity set (R in PB). The ratio of positive to negative slopes for the conjunctions was 0.45, suggesting a serial self-terminating search. The results suggest that our hypothesis holds not only with arbitrary pairings of colors and shapes but also with highly familiar, potentially "unitized" stimuli like letters.

Table 3: Linear Regressions of Search Times against Display Size in Experiment IV

		Positives		Negatives	
		Slope	**Intercept**	**Slope**	**Intercept**
Conjunction	T/Iz	12.2	363	34.7	349
	R/PQ	27.2	362	52.1	388
Similarity	T/YI	5.3	363	18.1	417
	R/PB	9.7	403	40.5	446
Heterogeneity control	T/PQ	4.9	340	20.5	386

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EXPERIMENTS V, VI, and VII: TEXTURE SEGREGATION

These experiments investigate the **preattentive** segregation of groups and textures. The theory predicts easy segregation when areas differ in one or more simple, separable features, and not when they differ only in conjunctions of features.

Results In Experiment V, using colored shapes, the difference between feature packs and the conjunction pack was qualitative and immediately obvious. The division was highly salient with feature packs, and the sorting time was much faster than for the conjunction pack, suggesting a complete failure of preattentive texture segregation with the conjunction displays. Experiment VI confirmed these findings with disjunctive features. Experiment VII extended the findings to letters, showing again that segregation was easier when the boundary divided areas differing in a single feature (e.g., presence of a diagonal line) rather than a conjunction of features.

EXPERIMENTS VIII and IX: IDENTITY and LOCATION

These experiments test the hypothesis that precise spatial location may not be available at the parallel feature level. For conjunctions, we predict that if a subject correctly identifies a conjunction, they must also have located it. For features, it should be possible to identify a feature without knowing exactly where it is.

Results For conjunction trials on which a distant location error occurred, target identification was random, as predicted. For feature targets, it was well above chance, again as predicted. The results suggest that the identity of features can be registered not only without attention but also without any spatial information about their location. Correct localization appears to be a necessary and sufficient condition for correct identification of a conjunction target.

Table 4: Median Probabilities of Reporting the Target Identity Correctly Given Different Categories of Location Responses

		Location response			
		Correct	**Adjacent**	**Distant**	**Overall**
Experiment VIII	Conjunction	0.930	0.723	0.500	0.793
	Feature	0.897	0.821	0.678	0.786
Experiment IX	Conjunction	0.840	0.582	0.453	0.587
	Feature	0.979	0.925	0.748	0.916

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GENERAL CONCLUSIONS

The experiments have tested most of the predictions we made and their results offer converging evidence for the **feature-integration theory of attention**. To summarize the conclusions: it seems that we can detect and identify separable features in parallel across a display; that this early, parallel, process of feature registration mediates texture segregation; and that if attention is diverted or overloaded, **illusory conjunctions** may occur. Conjunctions, on the other hand, require focal attention to be directed serially to each relevant location; they do not mediate texture segregation, and they cannot be identified without also being spatially localized.

> Perhaps this richness at the level of objects or scenes is largely an informed hallucination. We can certainly register a rich array of features in parallel... But if we apply more stringent tests to see how accurate and detailed we are in putting features together without prior knowledge or redundancy in the scene, the results are much less impressive.

To conclude: the **feature-integration theory** suggests that we become aware of unitary objects, in two different ways—through focal attention, or through top-down processing. In normal conditions, the two routes operate together, but in extreme conditions we may be able to show either of the two operating almost independently of the other.