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Familiar arrays of objects are perceived better than novel arrays, indicating a perceptual bias toward expected inputs. Yet a novel object in an otherwise familiar array attracts attention, indicating a perceptual bias toward unexpected inputs. These phenomena describe a highly adaptive system but pose a paradox: How can the mind be biased simultaneously toward both what it most expects and what it least expects? Our research on novel popout illuminates the empirical boundaries of this "stability/plasticity" dilemma, and our computational model, called mismatch theory, provides a resolution. In this report we summarize the last two years of research on novel popout and the evolution of mismatch theory. Among other findings, we cite evidence that novel popout represents an automatic and conceptually-driven form of attention capture and that it is not attributable exclusively to simple feature analysis. We argue that the data undermine certain widespread concepts of attention but are in accord with mismatch theory. The general idea behind mismatch theory is that because the processing of expected inputs can be knowledge-based or conceptually-driven, data-driven processing can be inhibited for expected inputs and thereby dedicated (CONT.)

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19. to any unexpected inputs. Mismatch theory accommodates our findings and resolves the stability/plasticity dilemma without appealing to the concept of attention as a special gate-keeping device between preattentive and postattentive processing. Instead, no distinction is drawn between preattention and postattention, and attention is viewed as an emergent phenomenon of ordinary perceptual processes.

Studies of Novel Popout: Final Report

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Novel Popout, Perceptual Inhibition, and the Stability/Plasticity Dilemma

Complex organisms, such as people, display an impressive ability to become perceptually and behaviorally attuned to their familiar habitats and yet remain vigilant to deviant or unexpected intrusions. The mind appears to be biased simultaneously toward both what it most expects and what it least expects to encounter, a phenomenon that Grossberg (1987) refers to as the stability/plasticity dilemma. The bias toward expected inputs promotes mental stability by ensuring a degree of empirical validation of the knowledge/belief system from which the expectancies arise, and the bias toward unexpected inputs promotes mental plasticity by ensuring a degree of sensitivity to disconfirmations of this same knowledge/belief system. A wealth of evidence affirms both sides of the dilemma. Mental stability is indicated by schematic perception (e.g., Biederman, Glass, & Stacy, 1981; Tulving & Gold, 1963), perceptual memory (e.g., Jacoby & Dalls, 1981), and various related phenomena such as perceptual restoration (e.g., Warren, 1970) and the word-superiority effect (e.g., Reicher, 1969). Mental plasticity is indicated by the attention capturing power and physiological arousal potential of novel and unexpected inputs in otherwise familiar scenes or event sequences (e.g., Berlyne, 1960; Cambell, Hayne, & Richardson, 1992; Friedman, 1979; Loftus & Mackworth, 1978; Naatanen, 1992, Sokolov, 1963).

The remainder of this report comprises three main sections. The first section reviews the evidence for both sides of the dilemma that has been generated from a single experimental paradigm in our own laboratory. The second section summarizes a possible account of our findings and resolution to the dilemma in the form of a new theory of perceptual processing called mismatch theory. The third section examines various implications of the evidence and theory associated with the stability/plasticity dilemma. Some of our more recent findings are summarized in this final section.

Novel Popout

We have investigated the automatic capture of attention by novel objects in otherwise familiar fields (e.g., Hawley, Johnston, & Farnham, 1994; Johnston, Hawley, Plewe, Elliott, & DeWitt, 1990; Johnston, Hawley, & Farnham, 1993). In a typical study, observers receive 200-ms or briefer glimpses of backward-masked, four-object arrays. Each array is followed by a probe to localize one of the objects. The four objects in some of the arrays, called all-familiar, are repeated together many times across a session. The objects in other arrays, called all-novel, are presented one time only. Accuracy of localization is consistently higher for objects in all-familiar arrays than for those in all-novel arrays. This baseline effect illustrates the mental bias toward familiar inputs and the stability half of the stability/plasticity dilemma.

In a third kind of array, called one-novel, one of the objects from an all-familiar array is replaced by a novel object. The usual superiority of accuracy of localization for familiar over novel objects is diminished, and often reversed, in one-novel arrays. Accuracy of localization tends to rise above the all-novel baseline for the novel singletons, defining novel popout, and to fall below the all-familiar baseline for the familiar field objects, defining familiar sink-in. Under certain conditions, accuracy of localization is actually higher for the novel singletons than the familiar field objects, defining novel popout/familiar sink-in. These popout and sink-in effects illustrate the mental bias toward novel inputs and the plasticity half of the stability/plasticity dilemma.

The full pattern of effects was first observed in Experiment 4 of Johnston et al. (1990). A recent replication of this experiment produced the data summarized in Figure 1. The full pattern of effects again emerged in terms of accuracy of localization (top panel) and tended to be reflected in terms of latency of localization (bottom panel). This pattern has been found to hold up under a wide range of conditions. It remains intact for durations of array exposure ranging from 33 to 200 ms (Johnston et al., 1993, Experiment 6), for both speed and accuracy emphases on responding, for array loads up to 6 items, for numbers of prior repetitions of all-familiar arrays ranging from 15 to 144 (Johnston et al., 1993, Experiment 3; Farnham, 1994), and for different degrees of spatial predictability of the familiar objects (Hawley et al., 1994, Experiment 3; also see Figure 4 below). Among other things, these findings indicate that novel popout is not attributable to strategic processing, such as the deliberate search for novel items.

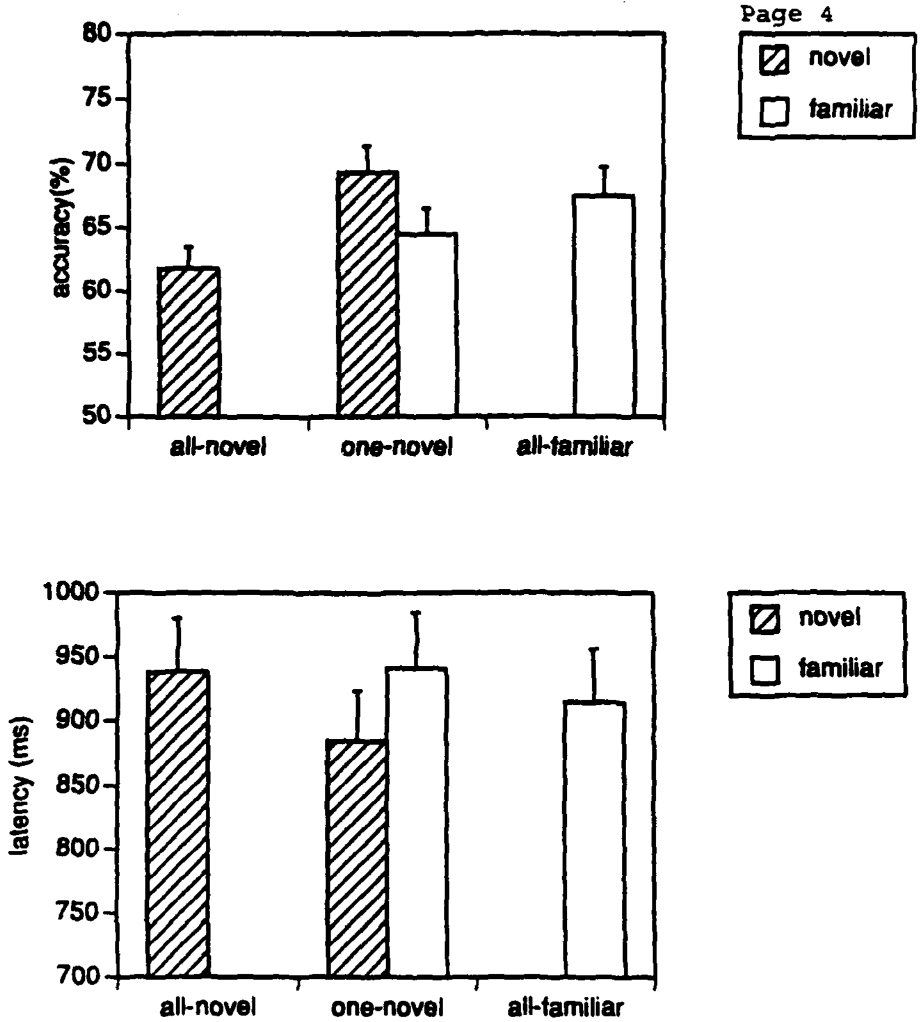

Figure 1. Mean accuracy (top panel) and latency (bottom panel) of localizations of novel and familiar words in the three array compositions (array exposure = 200 ms).

We have observed two other effects very comparable to novel popout. One of these, called odd popout, is that a familiar object extracted from one all-familiar array was found to pop out when it was transplanted into a different all-familiar array (Johnston et al., 1993, Experiment 5). Another effect, called nonprimed popout, is that a word, like CHEAT, was found to pop out from an all-novel array when the field words were both associatively related, like PEST, INSECT, and ITCHY, and primed by a preceding word, like FLEA (DeWitt, 1994, Experiment 2). On the other hand, a single primed word was not observed to pop out from a field of nonprimed words (DeWitt, 1994), and a single familiar object was not observed to pop out from a field of novel objects (Johnston et al., 1990, Experiment 3). Collectively, these findings suggest that an object will tend to capture attention to the extent that it is incongruent with an associatively unitized and either episodically or semantically primed field of objects.

Mismatch Theory

Mismatch theory was developed to account for the effects associated with novel popout and, therefore, for the stability/plasticity dilemma. More detailed descriptions of the theory are provided elsewhere (Hawley, Johnston, & Farnham, 1993; Johnston & Hawley, 1994). The general idea behind the theory is that once a familiar scene is recognized, the continued data-driven processing of it would be unnecessary and could retard the detection of any unexpected intrusions. Mismatch theory proposes that the perception of an array of objects is accomplished by the dynamics that unfold across two tiers of nodes: a lower, iconic tier and an upper, conceptual tier. The iconic tier encodes the physical details of external inputs, and the conceptual tier encodes their meanings. The iconic nodes are interconnected by inhibitory links, and the conceptual nodes are interconnected by excitatory links. The two tiers are interconnected by both bottom-up excitatory links and top-down inhibitory links. The onset of an array of objects launches a spreading of both inhibition and excitation throughout the system. The array-driven excitation of iconic nodes initiates both a lateral inhibition of neighboring iconic nodes and a bottom-up excitation of conceptual nodes. In turn, the excitation of conceptual nodes spreads laterally to associated conceptual nodes and ricochets a proportional volume of inhibition back down to the iconic tier. The effect of this top-down inhibition is to dampen the continued data-driven excitation of the already active conceptual nodes.

The top-down inhibition of iconic nodes is the main innovative feature of mismatch theory. This inhibition is especially pronounced in all-familiar arrays. Because of the massive spreading of excitation across the conceptual nodes representing these arrays, a relatively large volume of inhibition is reflected downward to the corresponding iconic nodes. However, because conceptually-driven processing suffices for the accurate perception of these arrays, it more than compensates for the suppressed data-driven processing and is responsible for the baseline advantage of all-familiar arrays. However, an important by-product of the suppressed data-driven processing of familiar objects is a reduction in the lateral inhibition that they would otherwise deliver to the iconic nodes representing any novel object in their midst. In turn, this disinhibition of the iconic nodes representing novel singletons accentuates both the bottom-up processing of these objects, yielding novel popout, and the lateral inhibition that they radiate to the iconic nodes representing the familiar field objects, contributing to familiar sink-in. Thus, the inhibited data-driven processing of expected objects carries minimal costs with respect to the perception of unperturbed familiar scenes but carries an important benefit with respect to the perception of novel intrusions.

In order to assess more definitively whether mismatch theory provides a resolution to the stability/plasticity dilemma, Johnston and Hawley (1994) rendered it computationally explicit and ran it through some of our novel popout experiments (also see Hawley et al., 1993). Mismatch theory generated the full pattern of effects associated with novel popout as well as its robustness across a wide range of durations of array exposure. Figure 2 depicts the typical behavior of a simplified version of the model soon after the onset of a one-novel array. The baseline levels of node activation are indicated by the horizontal arrows in the margins. It can be seen that the iconic and conceptual nodes representing the novel singleton rise above the all-novel baseline, yielding novel popout, and that the conceptual nodes representing the familiar field items fall below the all-familiar baseline, yielding familiar sink-in.[1]

[1] Familiar sink-in is due not only to the lateral inhibition originating from novel singletons but also to the reduced spreading of excitation that results from the absence of one of the familiar items.

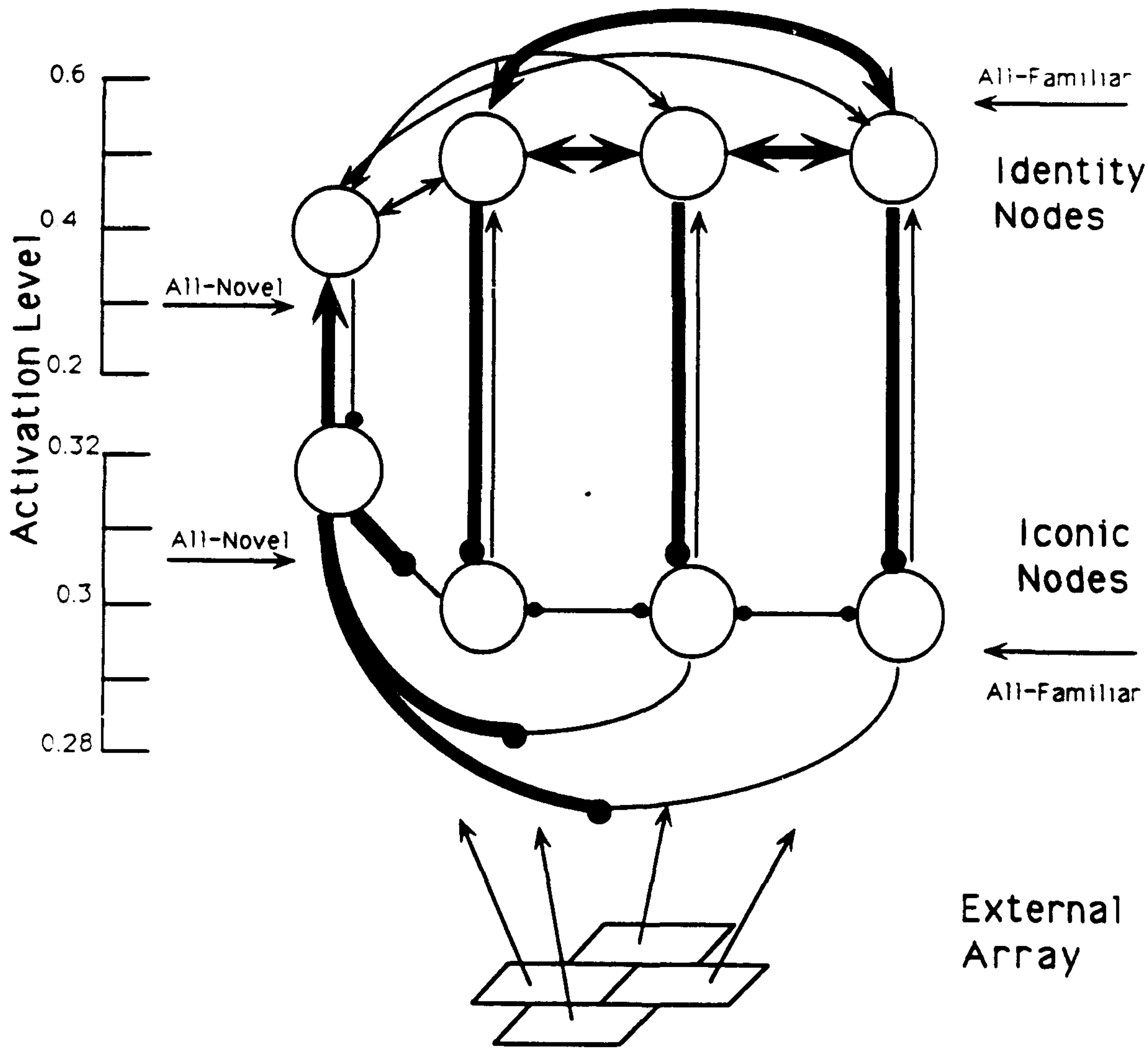

Figure 2. Computational behavior of mismatch theory shortly after the onset of a one-novel array. Data-driven processing of an array proceeds through lower, iconic nodes to upper, identity nodes. Lines ending in arrows indicate excitatory connections, and those ending in knobs indicate inhibitory connections. The thickness of a line indicates its level of activity. The levels of node activity for the all-novel and all-familiar arrays are indicated by the horizontal arrows to the left and right of the network of nodes. The left-most node on each tier represents the novel singleton. See text for an explanation of the dynamics that cause these nodes to rise above the all-novel baselines and those representing the familiar field items to fall near or below the all-familiar baselines.

In brief, the opposing mental biases are assumed to operate at different levels of perceptual analysis, the bias toward expected inputs at a conceptual level and that toward unexpected inputs at a physical level. In addition, the two biases are symbiotically interdependent. The top-down inhibitory links render the conceptually-driven bias toward expected inputs a precondition for the data-driven bias toward unexpected inputs. Because our familiar habitats are usually as we expect them to be, conceptually-driven processing or schematic perception provides a valid and useful representation of these habitats at the same time that it prepares data-driven processing for the detection of any deviations from expectation. Thus, mismatch theory appears to provide an elegant and adaptive solution to the stability/plasticity dilemma.

Theoretical Implications

In this section we address some of the implications of the stability/plasticity dilemma, mismatch theory, and associated empirical findings for some current theoretical issues and the prevailing conceptual framework within which these issues are cast. We begin by outlining what we regard the prevailing framework to be.

Prevailing framework. A distinction is commonly drawn between preattentive and postattentive processing of inputs. Various physical features of inputs are analyzed in parallel during preattentive processing, and the meaningful bundles of features defining specific attended inputs are analyzed serially during postattentive processing. All inputs automatically undergo preattentive processing, but only attended inputs undergo postattentive processing. A special gate-keeping mechanism selects inputs for postattentive processing. This mechanism, variously called executive, attention director, central processor and controlled processor, is in charge of the limited pool of capacity or resources upon which postattentive processing is dependent. The executive "pays attention" to inputs by allocating a portion of its resources to them.

Within this framework, attention can be either directed to or captured by particular inputs. In the case of directed attention, the executive systematically searches external scenes and arrays for specific targets; that is, it attends to preattentively analyzed inputs one-by-one until it encounters a target. In the case of attention capture, the preattentively analyzed features of certain inputs automatically draw the executive's attention (i.e., resources). We examine below four research issues that have been defined within this conceptual framework: preattentive feature analysis, early vs. late selection, attention capture, and primed popout.

Preattentive feature analysis. Viewed in terms of this framework, novel popout is a form of attention capture. Observers cannot see all of the items in a brief array and are not encouraged to look for particular targets; they just happen to be particularly likely to see novel singletons in familiar fields. The deviant features by which the singletons are defined must be preattentively analyzed in order for them to capture attention. If they were only postattentively analyzed, then by definition, they would already have received attention and could not be said to have captured it. However, if the deviant features are extracted preattentively, then questions arise as to what kind of features they might be and how their deviance is detected. The words and other objects that we use in our studies of novel popout are randomly assigned to serve the familiar and novel functions, and there are no apparent simple features or feature conjunctions that reliably discriminate between these words. Rather, in addition to their possible semantic properties, novel and familiar objects are likely to be distinguishable only in terms of complex bundles of physical features, and this would mean that these bundles would have to be assembled preattentively, compared to expectations, and earmarked for potential attentional priority.

The implication that preattentive analysis is sophisticated and complex challenges theories, such as feature-integration theory (e.g., Treisman & Gelade, 1980), that delimit preattentive analysis to simple features. However, because the featural difference between our novel and familiar objects were not controlled, one might argue that novel popout is attributable to those novel objects that happen to bear distinctive simple features. In a recent series of studies, we tested this possibility by systematically manipulating the featural composition of novel and familiar objects. The first study tested whether simple feature analysis is sufficient to produce novel popout. A color-localization task was performed on arrays composed of objects that differed only in terms of the simple feature of color. All-familiar arrays always contained the same four colors, all-novel arrays contained variable combinations of other colors, and one-novel arrays contained three familiar colors and one novel color. As the left-most panel of Figure 3 shows, the full pattern of novel popout effects was observed. These findings attest that the analysis of simple features, at least task-relevant ones, is sufficient to produce novel popout.

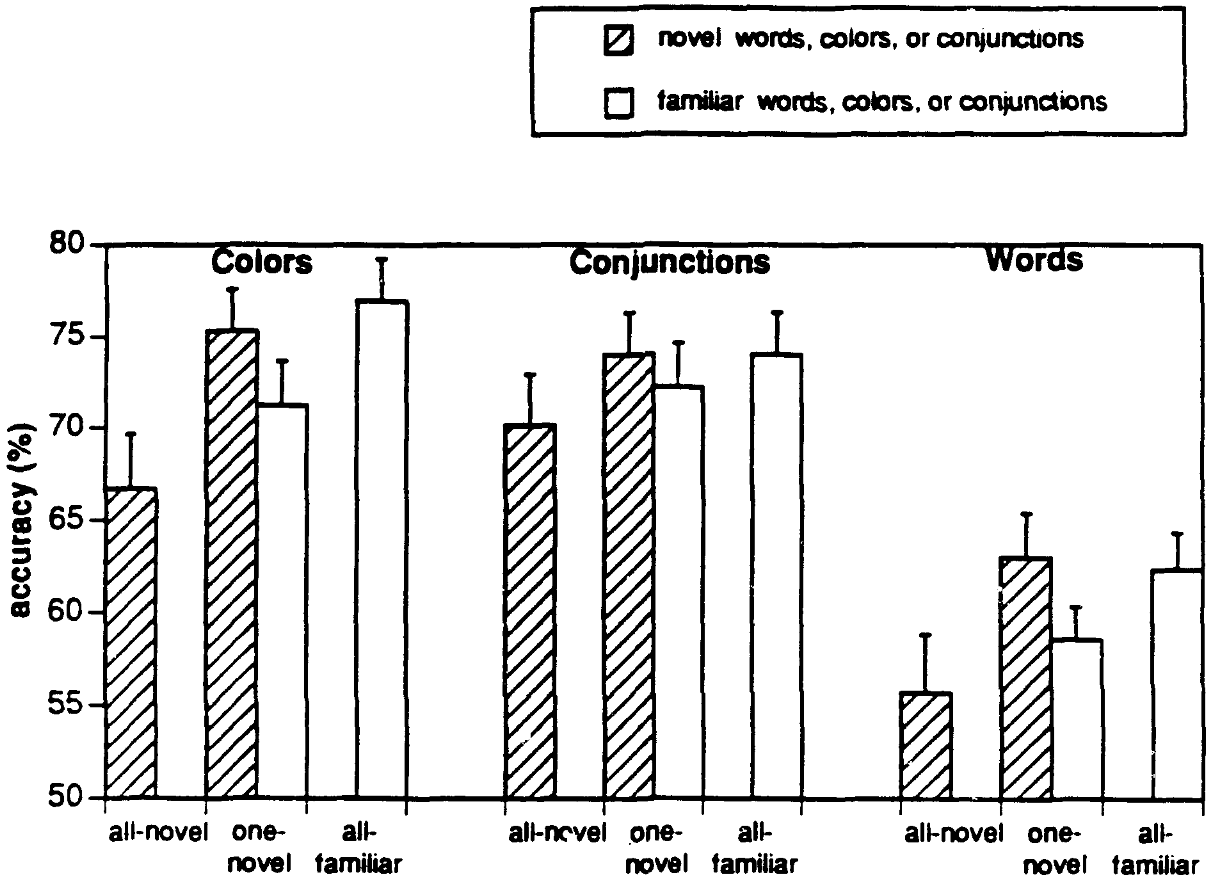

Figure 3. Mean accuracy of localizations of novel and familiar colors (left panel), feature conjunctions (middle panel), and words (right panel) in the three array compositions (array exposure = 200 ms).

The second study tested whether simple-feature deviancy is necessary to produce novel popout. A conjunction-localization task was performed on arrays composed of objects defined by unique conjunctions of five colors, five shapes, and five lengths. Five such conjunctions served as familiar objects and other conjunctions served as novel objects. The all-familiar arrays were composed of a random four of the five familiar objects. The one-novel arrays were composed of three of the five familiar objects and a reconjunction of the features defining the other two familiar objects. Specifically, the color of one these objects was conjoined with the shape and length of the other. Thus, all of the simple features composing a novel singleton were familiar, as was the conjunction of shape and length. Only the reconjoined color made the singleton novel. However, color was made irrelevant to the localization task by presenting the probes in a neutral color (viz., white). Nonetheless, as the middle panel of Figure 3 shows, novel popout and familiar sink-in were again observed, thereby discrediting the argument that these effects are attributable exclusively to the preattentive analysis of simple features. Not only do novel conjunctions pop out, but they do so even when what is novel about them is irrelevant to the task.

The right-most panel of Figure 3 summarizes the data generated by a comparison study in which our standard word-localization task was performed on the different array types. The novel and familiar words composing these arrays were presumably distinguishable primarily in terms of complex configurations of feature conjunctions and meaning. Although the overall level of localization accuracy was lower in the word-localization study, the full pattern of novel-popout effects was again observed. Indeed, a cross-experiment analysis revealed that the pattern of effects was statistically equivalent in the three panels of Figure 3. Thus, in terms of the prevailing conceptual framework, our composite findings indicate that preattentive processing proceeds through several levels of physical and semantic analysis, any one of which is sufficient to yield novel popout.

<u>Early vs late selection</u>. A classic issue that has evolved within the prevailing framework concerns the level of preattentive processing that all inputs undergo before any of them receives attention. Early-selection theory argues that preattentive processing encompasses only relatively low level physical analysis and that postattentive processing is necessary at least for semantic analysis and

perhaps for higher level physical analysis. By contrast, late-selection theory contends that preattentive processing extends at least to the level of semantic analysis. This issue and the massive empirical literature it has generated is reviewed elsewhere (e.g., Holender, 1986; Johnston & Dark, 1986; Kahneman & Treisman, 1984; Naatanen, 1992). Suffice to note here that our novel-popout findings, including those summarized in Figure 3, appear to line up on the side of late selection. Not only must preattentive processing extend well beyond the extraction of simple physical features, but it must somehow compute the relationship between an input and the observer's expectancies and earmark any deviations from expectancies so that they can capture attention. All of this implicates a very complex and sophisticated preattentive system and a very late locus of attention.

A potential early-selection account of novel popout is that preattentive analysis automatically supplies a physical representation of the object at each location, but postattentive analysis is necessary to identify it. Relatively little time and capacity are required to identify the familiar objects, allowing the executive to sequentially process more familiar objects than novel objects during the brief exposure of an array. This accounts for the baseline advantage of all-familiar arrays over all-novel arrays. Because the executive can identify familiar objects more quickly than novel objects, it is more likely to reach the novel singleton in a one-novel array than it is to reach any given novel item in an all-novel array. This accounts for novel popout. By the same token, once a novel singleton is encountered, its postattentive processing consumes time and capacity that would otherwise be allocated to the remaining familiar items in the array. This accounts for familiar sink-in.

Several of our findings question this account. For one thing, not one of the several hundred observers that we have interviewed has indicated that he/she noticed any novel singletons in otherwise familiar arrays. For another thing, the phenomenon of odd popout shows that even familiar and, presumably, fluently identified items, pop out when they are transplanted into a different familiar field. Finally, we recently tested the prediction, based on the serial-search account, that novel popout should increase with the perceptual fluency of the field items. Observers viewed a long sequence of all-novel, one-novel, and both spatially-predictable and spatially-unpredictable all-familiar arrays. The spatial arrangement of the familiar objects remained constant in the spatially-predictable arrays but varied in the spatially-unpredictable arrays. Duration of array exposure was manipulated between groups at two levels (50 and 200 ms). The data are summarized in Figure 4. As in prior studies, overall accuracy of localization increased with duration of array exposure but the magnitude of novel popout was not affected. In accordance with the assumption that the executive can scan through spatially predictable familiar arrays more efficiently than spatially unpredictable ones, localization accuracy was substantially higher in the former arrays. It follows from the same assumption that a novel singleton is more likely to be encountered and identified if it is inserted into a spatially-predictable field of familiar objects. However, although both novel popout and familiar sink-in attained statistically reliable levels, they showed no inclination to be more pronounced for spatially-predictable familiar fields (also see Hawley et al., 1994).

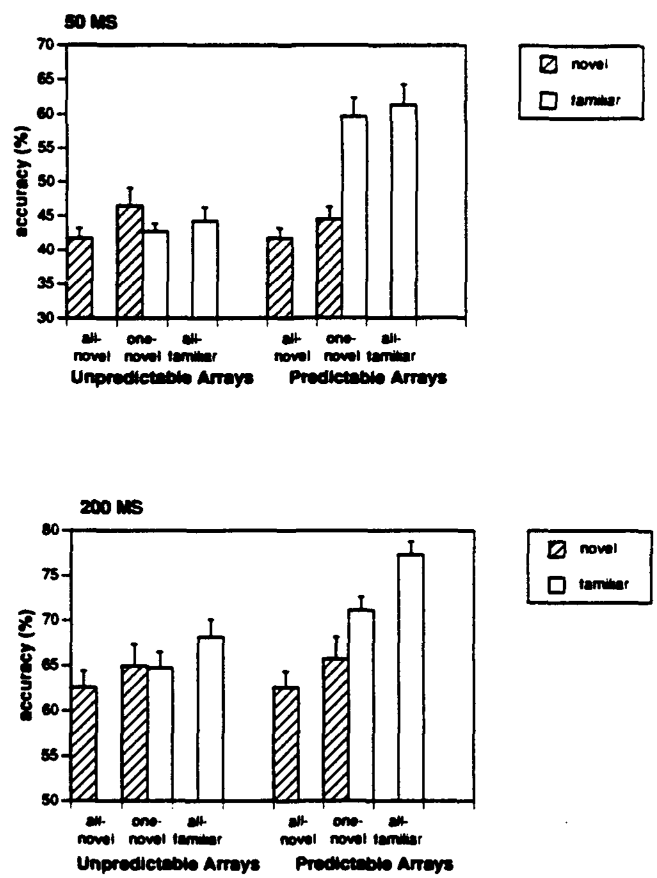

Figure 4. Mean accuracy of localizations of novel and familiar words in the three array compositions for durations of array exposure of 67 ms (upper panel) and 200 ms (lower panel) and for both predictable and unpredictable spatial configurations of the familiar words.

Thus, novel popout appears to reinforce the voluminous empirical indications of late selection. However, in so doing, it confronts the equally voluminous empirical indications of early selection. Indeed, the fact that four decades of research, theory, and argument have reached a stalemate on the issue may be a clue that the conceptual framework from which it arises is fundamentally flawed.

Attention capture. Most of the research on attention capture has focused on the attention-capturing power of singletons defined in terms of relatively simple physical features. Much of this research is summarized by Yantis (1993) and Folk, Remington, and J. Johnston (1993). These investigators appear to agree that attention can be captured only by certain preattentively analyzed, simple-feature singletons in an array of objects. However, there is some debate about what features are capable of attracting attention and under what conditions. On one side of the debate, Yantis (1993) argues that only singletons defined by their sudden onsets can capture attention but that they can do so regardless of the relevance of sudden onsets to the observers' task (e.g., the targets for which the observers are explicitly searching). On the other side of the debate, Folk et al. (1993) argue that any preattentively defined singleton can capture attention, but only to the extent that the featural dimension along which the singleton is defined is relevant to (i.e., has been primed by) the observers' task. Thus, Folk et al. would allow for color singletons (e.g., a green object in a field of red objects) to capture attention, but only if color is relevant to the observers' task.

We suggest that novel popout constitutes mixed news for both sides of the debate and undermines the conceptual framework in terms of which the debate is cast. The singletons in our studies are defined in terms of the task-irrelevant property of novelty. Thus, novel popout indicates that the capture of attention is not restricted to sudden onsets (against Yantis), to singletons defined along task-relevant dimensions (against Folk et al.), or even to singletons defined in terms of conspicuous physical features (against both sides of the debate). The field items in one-novel arrays do not share some common physical property that is lacking in the novel items, and the novel items, by definition, do not possess any physical features toward which attention could be preset. Rather, the novel and field items are distinguished in terms of their relationship to the knowledge and expectancies of the observers, rendering novel popout a conceptually-driven form of capture of attention.

Feature priming. The prevailing conceptual framework allows for a conceptually-driven form of attention capture, but one that might be called primed popout rather than novel popout. In primed popout, attention is drawn to inputs that are most, rather than least, congruent with the observers' expectancies. Primed popout is the predicted consequence of the top-down priming of preattentive feature nodes by currently active conceptual nodes, and top-down priming is the defining feature of the popular interactive-activation models of perceptual processing (e.g., McClelland & Rumelhart, 1981). These models stand in sharp contrast to mismatch theory. Instead of top-down inhibition of the physical analysis of expected inputs, interactive-activation models assume top-down facilitation. William James (1890/1950) might have had top-down priming in mind when he noted:

> When watching for the distant clock to strike, our mind is so filled with its image that at every moment we think we hear the longed-for or dreaded sound. So of an awaited footstep. Every stir in the wood is for the hunter his game; for the fugitive his pursuers (p. 442).

Likewise, Folk et al. (1993) may be suggesting a form of primed popout in their assumption that only singletons bearing task-relevant features can capture attention.

As attractive as a primed-popout interpretation of attention capture might be, it encounters a serious problem in the phenomenon of novel popout. Any top-down priming of expected features should yield the sink in, rather than popout, of novel inputs. Nonetheless, novel popout indicates that the perceptual system is biased somehow toward novel objects. The problem is not solved by the suggestion that observers can be specifically primed for novel inputs. Because the features of novel inputs are, by definition, unpredictable, observers cannot be specifically primed for them. Similarly, the idea of some sort of controlled search for novel inputs has been discredited empirically by the findings, noted above, that novel popout does not depend on the either the opportunity for (i.e., duration of array exposure), or the nature of (i.e., speed/accuracy emphasis), controlled processing.

Where does this leave effect theory and the intuitively appealing notion of primed popout? Does the strike of the distant clock we are watching pop out or sink in? The evidence for primed popout is mixed. In addition to the findings of Folk et al. (1992), evidence in favor of primed popout has been reported by Dark and Vochatzer (1992). On a given trial in the latter research, observers saw a prime word (e.g., NIECE) followed immediately by a briefly-exposed, two-word array. Some of these arrays contained a primed word (e.g., NEPHEW). Accuracy of identification was higher for primed words than for nonprimed words, indicating primed popout. However, we have recently gathered evidence against primed popout. Observers performed our standard localization task on a long series of four-word arrays. On occasion, the word that appeared as a probe for a localization response to one array was a prime for one of the words in the next array. Accuracy of localization was reliably <u>lower</u> for primed singletons (56%) than for nonprimed field words (60%), indicating primed sink-in rather than popout (also see DeWitt, 1994). This primed sink-in effect constitutes new evidence for the inhibited data-driven processing of expected inputs and, along with novel popout, contradicts interactive-activation theories.

<u>Critique of the prevailing framework</u>. As Johnston and Hawley (1994) noted, interpretations of novel popout in terms of the prevailing framework can be criticized on theoretical grounds alone:

> We submit that such...interpretations of novel popout are circular and vacuous. They are circular because they essentially assert that novel objects pop out (i.e., receive more attention) because they receive more attention (i.e., pop out). They are vacuous because they do not explicate the nature of the executive and its resources...These "explanations" encounter the same problem of infinite regress that characterizes all appeals to intelligent processing homunculi. The mystery of the big mind is not solved by equipping it with a little mind. (p. 68)

We suggest that the prevailing conceptual framework has lost its usefulness and needs to be replaced by an approach that makes no appeal to attention as a special device or resource. Mismatch theory is an example of this approach; it conceptualizes attention not as a mechanism or a resource but rather as an emergent by-product of ordinary perceptual processing. Attention is defined by, but is not a cause of, selective perceptual processing.

The conceptualization of attention as an emergent phenomenon rather than a causal mechanism may resolve various empirical ambiguities and theoretical stalemates that have arisen from the prevailing framework. For example, mismatch theory offers a resolution to the conflicting evidence of primed popout and primed sink-in. Because conceptual processing is facilitated for expected inputs, primed popout is likely to be observed when the tasks and measures are biased toward conceptual processing, as in Dark and Vochatzer's (1992) identification task. By contrast, because data-driven processing is inhibited for expected inputs, primed sink-in is likely to be observed when the tasks and measures are biased relatively more toward data-driven processing, as in our localization task.

In addition, mismatch theory sheds new light on the stalemate between early- and late-selection theories of attention. Attention is not conceived of as a discrete transition from preattentive to postattentive processing. Indeed, no distinction is even drawn between these two levels of processing. In terms of mismatch theory, the amount of "attention" accorded an input may be best conceived of in terms of the levels of physical and conceptual processing it undergoes (i.e., node excitation it engenders). If physical processing is considered early and conceptual processing late, then novel singletons are selected early but familiar field items are selected late, an impossible outcome from the perspective of the prevailing framework. Moreover, the levels of physical and conceptual analyses are dynamically interdependent and highly variable from moment to moment. High levels of conceptual analysis yield low levels of physical analysis which, in turn, attenuate conceptual analysis, and so on until the system stabilizes (which is unlikely in a normal, fluctuating world). In brief, from the perspective of mismatch theory, the question of the locus of attention is meaningless; it is everywhere and it is nowhere. As William James (1890/1950) suggested:

> Attention may have to go, like many a faculty once deemed essential, like many a verbal phantom, like many an idol of the tribe...No need of it to drag ideas before consciousness or fix them, when we see how perfectly they drag and fix each other there. (p.452)

Summary

Evolution appears to have engineered two very adaptive, but superficially contradictory, mental biases: the bias toward expected inputs and familiar environments, and the bias toward unexpected inputs and novel intrusions. These biases define the stability/plasticity dilemma and are exemplified in the typical pattern of novel-popout effects. Mismatch theory attributes the former bias to conceptually-driven processing and the latter to data-driven processing. A top-down inhibitory link between the two levels of processing renders the two biases dynamically interdependent. The facilitated conceptual processing of expected inputs dampens the physical processing of these same inputs which, in turn, disinhibits the physical processing of any unexpected singletons in their midst. Thus, the bias toward unexpected inputs is a natural by-product of the bias toward expected inputs.

Our research on novel popout both supports the assumed inhibition of the data-driven processing of expected inputs and poses a challenge to the prevailing conceptual framework, especially, to the concept of attention as a special device in charge of a limited pool of vital processing resources. By contrast, mismatch theory resolves the stability/plasticity dilemma and accounts for the empirical findings without appealing to special attention mechanisms or resources. The two horns of the dilemma and the phenomenon of attention are conceptualized as emergent phenomena of ordinary perceptual processing rather than sophisticated feats performed by an intelligent homunculus.

In addition to its theoretical implications, the assumed inhibition of the bottom-up processing of expected inputs has implications for the phenomenology of everyday perception. Because organisms typically inhabit familiar environments, their perceptual experiences of these environments should be more conceptually- than data-driven. We may not see the wear marks on our living-room furniture or the signs of age on our reflections in the mirror. To underscore this idea, we close with another quote from James (1890/1950):

> Whilst part of what we perceive comes through our senses...another part (and it may be the larger part) always comes...out of our own head" (p. 747, italics James').

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