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The proactive brain: Using rudimentary information to make predictive judgments

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- *In a recent cognitive neuroscience framework we proposed to consider the human brain as proactive, in that it continuously generates predictions about what to expect in the environment. These continuous predictions are extremely rapid, and depend on similarities between novel inputs and the closest familiar representations stored in memory. For example, if you see a chair that you have never seen before, you can still determine what it is, its function, approximate weight, approximate price, and other such characteristics. To derive these analogies rapidly we rely on surprisingly little information. This paper provides a theoretical expansion of our work by describing studies and ideas that collectively synthesize to illustrate this unifying principle of the human brain. We specify the nature of the information used to form impressions, preferences, judgments and predictions, propose neural circuits that mediate these vital mental skills, and derive novel hypotheses that can be tested in the future. This proposal implies that mental life and behavior are guided by "scripts," which are developed with experience and stored in memory. This framework has broad ramifications, ranging from clinical psychology and mental illness, to the study of consumer behavior.*

Introduction

People form opinions rapidly and continuously. This paper synthesizes cognitive neuroscience findings and theoretical ideas, which together provide a framework for understanding and studying visual opinions in particular. The ability to form a rapid opinion about a newly encountered stimulus, such as an object, a person, or a situation, requires a mechanism for extracting rudimentary information from the input, and effectively connecting it with memory. In the present framework this operation is termed *analogy*: linking a new input with the most similar representation in memory. Such analogies are therefore based on extracting enough information from the input to allow linking with memory based on similarity. The similarities on which these analogies rely can be defined by physical/perceptual properties (e.g., features, such as the contour or orientation, that are

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Note: All figures will be produced in colour in the online published version.

shared between the novel input and the analogous object in memory), functional properties, semantic information, contextual relations and so on. Once an analogy has been made successfully, our mental processes gain access to a vast amount of knowledge that is associated with the analogy. Somewhat similar scripts were originally described by Schank (Schank and Abelson, 1977) in the context of language understanding. For example, when you find yourself hungry in a strange city and recognize a restaurant sign, your subsequent actions and perceptions follow a familiar pattern (which we call *procedure*) that is virtually dictated to you; you drive your car toward the sign, you know where and how to park your car, how to enter the restaurant, that you need to be seated and by whom, that you will be given a menu, and you will know what to do with it. In more formal terms, the analogy triggers the activation of *associations*; the knowledge linked to the representation. The activated associations, in turn, provide *predictions* of what to expect next (**Figure 1**) (Bar, 2007). This mechanism is powerful and can provide a foundation for guiding our perceptions, actions, and interactions with the environment. In computer programming a similar concept is called a ''routine'' or a ''procedure''; performing the same operations applied with different parameters in different incidents. These scripts are conceptually related to ''action plans'' often mentioned in the context of executive function in the frontal lobes (e.g., Luu *et al.*, 2000). Procedures are distinguished from such action plans in that they are not limited to action, and their underlying mechanisms are not confined to the frontal cortex. Given all the experience we have accumulated, such scripts exist in our memory for almost any scenario we might encounter in everyday life, and it is rare that we encounter a completely novel scenario that does not resemble anything with which we are familiar.

We will describe here findings from various domains, including visual recognition, the formation of lasting first impressions of others, and the formation of opinions and preferences about objects around us. These converge to support the framework described above, and provide a platform with which to understand how humans form opinions about their everyday environment based on visual information.

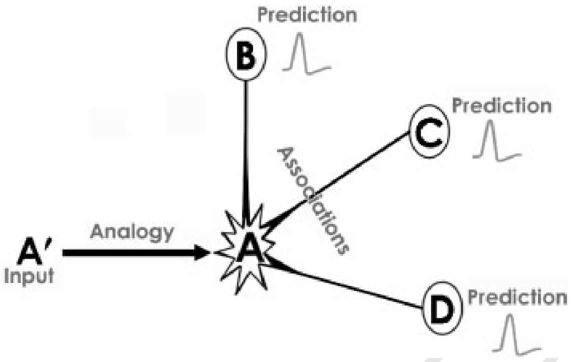

Figure 1. A schematic depiction of the overarching framework with which to consider the mechanism mediating predictions in judgment formation. A novel input (A') is matched with the most similar representation in memory (A) via an analogy. This existing representation is linked via associations to many other related representations containing information about the properties of (A), items that tend to share its context, and so on. Activating these associated representations (B, C, D) triggers predictions about what to expect in the relevant environment (adapted from Bar, 2007).

Rapid predictions that facilitate visual recognition

Our visual system recognizes objects with impressive speed. The traditional view of object recognition in the cortex is that information flows along a hierarchy of visual areas in a bottom-up fashion. However, recent models have proposed that top-down predictions are critical for facilitating the speed and efficiency of the bottom-up recognition processes (Grossberg, 1980; Mumford, 1992; Ullman, 1995; Siegel *et al.*, 2000; Engel *et al.*, 2001; Bar, 2003; Friston, 2005). To be useful in aiding bottom-up processes, top-down processes must quickly propagate downwards from the top of the visual hierarchy and be available to bottom-up processes quickly, before recognition is completed. This top-down processing requires a mechanism for rapidly extracting basic information from visual input, and for rapid transfer of information between

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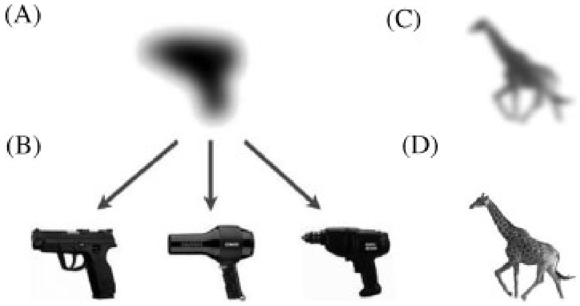

Figure 2. The powerful information conveyed by coarse, global properties. The identities of the blurred items in (A) and (C) can be guessed within close proximity, in spite of the lack of detail. Such blurred representations consist of primarily low spatial frequencies, which we know are available in the brain early and rapidly.

brain regions. Object recognition can therefore be seen as a matching problem, whereby the system must find a match (i.e., analogy) between the input object and the most similar object in memory. This matching can be accelerated significantly if we can generate a predictive ''initial guess'' about the object's identity based only on its global properties. It is easy to appreciate how powerful this principle can be by considering the examples in **Figure 2**. A blurred representation of an object, made of its low spatial frequencies (LSF), is sufficient to eliminate the vast majority of possible matches, leaving the recognition process with only a handful of candidates to choose from. In previous work, we described a model of top-down facilitation in object recognition that is based on this LSF principle (Bar, 2003), and tested several of its aspects in a series of functional magnetic resonance imaging (fMRI), and magnetoencephalography (MEG) studies that allowed us to systematically examine the spatial and temporal cortical dynamics of top-down modulation (Bar *et al.*, 2006a).

According to this top-down facilitation model, a coarse, partially processed version of visual afferents is rapidly projected from early visual regions to the orbitofrontal cortex (OFC), a key multimodal association region (Barbas, 2000; Kringelbach and Rolls, 2004). The top-down facilitation model posits that the rapidly processed information is projected through the magnocellular pathway, based on the rapid conduction velocities of this pathway (Shapley, 1990; Merigan and Maunsell, 1993; Bullier and Nowak, 1995). The magnocellular pathway is particularly well attuned to LSF visual information; therefore the model predicts that the partially processed visual information projected to OFC primarily contains LSFs. We have subsequently demonstrated the central role of the magnocellular pathway in top-down facilitation of recognition (Kveraga *et al.*, 2007) and that this top-down stream is initiated by LSFs in the input image (Bar *et al.*, 2006a). OFC selects potential matches based on the global, LSF-based properties of the visual input. Predictions about the candidate objects from which the particular LSF image might have arisen are then projected to the object recognition regions in the inferior temporal (IT) cortex. Bar (2003) hypothesized that top-down predictions bias the output of the bottom-up visual analysis and facilitate the search by providing global constraints on the possible interpretations of the bottom-up outputs. This would reduce the number of candidate objects that need to be considered to

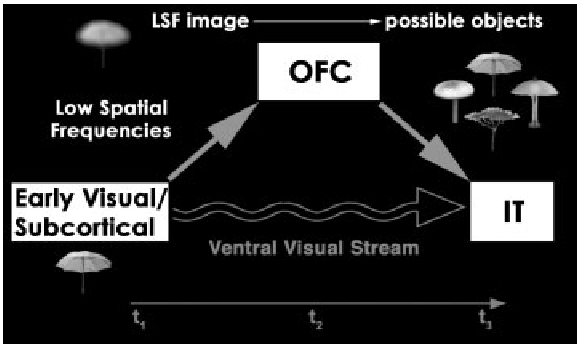

Figure 3. A schematic description of the top-down facilitation model of object recognition. According to this model, a coarse, low spatial frequency representation of the input image is rapidly extracted and projected to OFC from early visual or subcortical regions. OFC uses this low spatial frequency gist information to generate a set of predictions regarding the possible identity of the object. In parallel, detailed, systematic processing proceeds along the ventral visual stream culminating in IT. The initial guesses produced by OFC facilitate recognition by sensitizing IT to the most likely candidate objects, thereby reducing the search space that the visual system needs to consider to identify the object (Adapted from Kveraga *et al.*, 2007).

identify the stimulus, enhancing the speed and accuracy of recognition (**Figure 3**).

In an fMRI study, we found differential activity in the OFC for successfully recognized, compared with unrecognized, stimuli (Bar *et al.*, 2006a). In a critical follow-up MEG study, we showed that differential recognition-related activity developed in OFC 50 ms before it did in areas in IT cortex associated with recognition (**Figure 4A**). Subsequently, we manipulated the spatial frequency content of our stimuli and found differential activation in OFC for LSF compared with high spatial frequency (HSF) images (**Figure 4B**). We also showed that the LSF stimuli elicited differential activity in OFC before activating the object recognition regions in IT. Furthermore, we used phase-locking analyses of these MEG data to evaluate functional communication between the areas of interest. This analysis revealed strong signal synchrony for LSF, but not HSF, stimuli between occipital visual cortex and OFC early in the recognition process. This was followed by another period of synchronous activity ~50 ms later, this time between OFC and fusiform gyrus. Thus, our findings support a central role for OFC in orchestrating top-down facilitation of visual recognition, and reveal a cortical chain of neural events where timing, spatial location, and the primary type of information conveyed (i.e., LSF) are highly consistent with our model.

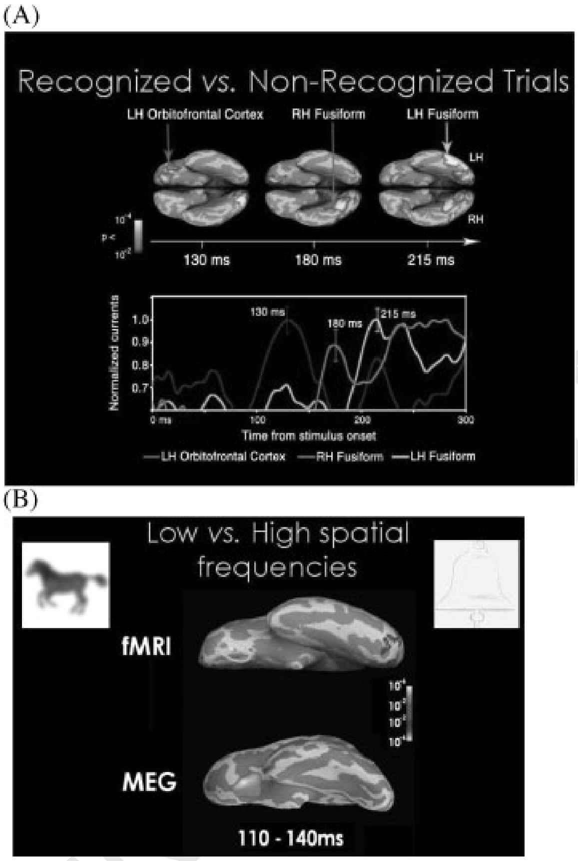

Figure 4. (A) MEG maps and timecourses demonstrating that successful object recognition involves early OFC activation, preceding the corresponding activation in IT by about 50 ms. This high temporal resolution finding supports the notion that OFC projects top-down predictions to recognition areas in the visual cortex. (B) fMRI and MEG evidence supporting our proposal that early top-down projection from OFC to visual cortex is triggered by coarse, LSF, information in the image. Comparing the recognition of LSF and HSF images, which were carefully equated for recognition difficulty using reaction times, differed significantly in the OFC.

Judging others for predictions: Our prejudiced mind

Humans make first impressions of others rapidly, and these impressions are persistent. The main function of such apparently superficial judgments is to help generate predictions about what to expect from potential interactions with others, especially with new people. According to the framework described here, just like with objects and other stimuli, judgments of others can be made by finding an analogy: who is this person reminding me of? Once we link a new person to a familiar person in memory, we project the attributes of the familiar, similar person onto the new one. This somewhat prejudiced mechanism helps us start interactions with others with some initial assumptions, which could be correct or incorrect assumptions. Provided more experience with the new person, these initial impressions are updated accordingly.

The initial analogy is rapid, and depends, naturally, on the physical properties of the face, for example, of which we are forming an impression. We conducted studies to see just how quickly these impressions could be formed consistently, and to determine what

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information people use for such rapid first impressions (Bar *et al.*, 2006b). Specifically, our goal was to study impression formation independent of emotional cues. Therefore, participants made threat judgments about faces with a neutral expression so that their judgments pertained to the personality, rather than to a certain temporary emotional state (e.g., anger). This line of research has clear ramifications both for understanding social interactions and for determining the visual properties used to shape them.

We review these findings here through four experiments: the first measured the speed in which first impressions about threat can be formed, the second examined the role of awareness in these judgments, and the third and fourth helped to determine that LSF mediate the formation of such rapid first impressions. For each of these studies, we used images depicting males in an emotionally neutral expression.

In the first experiment, we presented these faces on a computer screen for 26, 39, or 1700 ms, followed by a mask, which was designed to be effective for grayscale pictures of faces (**Figure 5**). Participants rated the level at which they perceived each face to belong to a threatening person, using their ‘‘gut’’ reaction. We used presentations of 1700 ms to assess ‘‘accurate’’ impressions from each participant, as they represent the ratings when participants were given time to consider each face carefully. There was a strong correlation between threatening ratings of the faces obtained for the 39 and the 1700 ms groups. However, threatening ratings of the faces obtained for the 26 and the 1700 ms groups were not correlated. These results demonstrated that people’s assessments of threat are consistent even with a very brief exposure (39 ms).

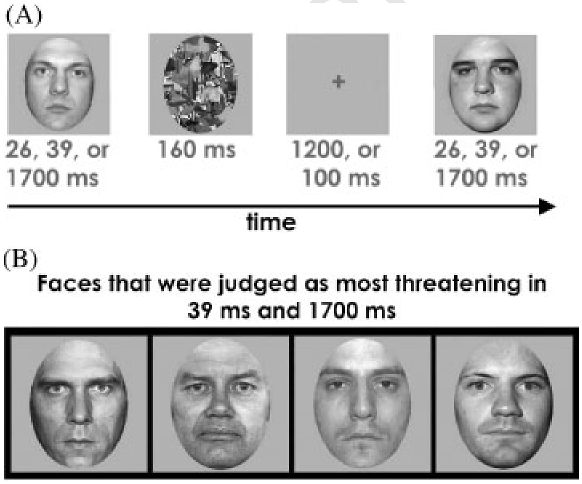

Figure 5. Rapid first impressions of threat. (A) Experimental design, (B) faces that were judged as most threatening consistently by subjects who saw them for 39 ms and subjects who saw them for 1700 ms.

Our hypothesis was that such rapid first impressions have evolved to promote survival. Accordingly, we suspected that we would not observe such extremely rapid consistent impressions if the judgment was less directly related to survival, and we chose intelligence judgments to test this hypothesis. Indeed, unlike threat judgments, participants could not form reliable first impressions of intelligence for rapid 39 ms presentations. This supports the notion that survival-related judgments benefit from faster analysis routes in the brain.

In the second experiment, we determined that when faces were presented for 39 ms, participants were aware of at least some aspects of those faces, particularly those aspects critical for the formation of a threatening impression (e.g., the angle of the eyebrows and/or the lips). Participants in the 26 ms experiment, on the other hand, might have not been aware of sufficient face information, leading to their inconsistency in forming impressions about threat. Therefore, stimulus information required for forming consistent threat impressions is extracted very early and requires at least some awareness of the face information. We proposed that such first impressions are based primarily on the LSFs in the image (Bar *et al.*, 2006b), given that years of visual psychophysical and neurophysiological research have shown that LSFs are extracted and available in the cortex rapidly (Shapley, 1990; Merigan and Maunsell, 1993; Bullier, 2001; see Bar, 2003 for review). Furthermore, LSFs recruit a neural circuitry

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implicated in threat perception (Adolphs *et al.*, 1999).

We tested this hypothesis in a third experiment, where subjects were first presented with a picture of a neutral face and then were given four alternatives to choose from. The four alternative choices were filtered to include either the LSFs (up to eight cycles per image) or HSFs (higher than 24 cycles per image). All target faces were presented at 39 ms. Participants in the LSF experiment performed significantly above chance, while participants in the HSF experiment performed at a level statistically indistinguishable from chance. Importantly, when presented at 1700 ms, recognition level in this task was identical for both the HSF and LSF filtered faces, indicating that the difference in levels of awareness to the information in the two spatial frequency conditions was not caused by an inherent difference in recognition difficulty. In sum, we have found that 39 ms presentations are sufficient for subjects to be aware of at least some features of a face, containing the rapidly extracted LSFs in the image.

In the final experiment of this series, we demonstrated that this early detection of LSFs mediates the rapid formation of threat impressions. In other words, the spatial frequencies contributing the majority of the information for threat judgments, at least in brief presentations, are the LSFs. Together, these results have provided new insights into the type of visual information used to create first impressions, and how rapid they can be, providing support to the framework proposed here.

Object preference for predictions: Humans like curves

Our preference for objects has been shown to be influenced by many factors, including symmetry, familiarity, contrast, complexity, and perceptual fluency (Reber *et al.*, 2004). Based on previous research that demonstrates how quickly these first impressions can be formed (Ambady *et al.*, 2000; Bar *et al.*, 2006b; Willis and Todorov, 2006), we proposed that these judgments rely on some visual primitives that can be extracted from the image quickly. Specifically, we have recently proposed and demonstrated that preferences are significantly influenced by the nature of an object's contour, whether its edges are sharp-angled or curved (Bar and Neta, 2006; Bar and Neta, 2007).

We tested this hypothesis using stimuli that included pairs of emotionally neutral, real objects with either primarily pointed features and sharp angles or the similar objects with curved features (e.g., a guitar with a sharp-angled contour compared with a guitar with a curved contour). As such, the items in each pair had the same semantic meaning and general appearance, and the only consistent difference between them was the curvature of their contour (**Figure 6A**). Importantly, the objects used were everyday objects with no inherent positive or negative valence (e.g., a watch or a sofa). To control for any possible role of semantic meaning, familiarity, and associations that might influence preference ratings across participants, we created also pairs of meaningless patterns that were likewise matched across all visual features except for contour (**Figure 6B**). Finally, we included

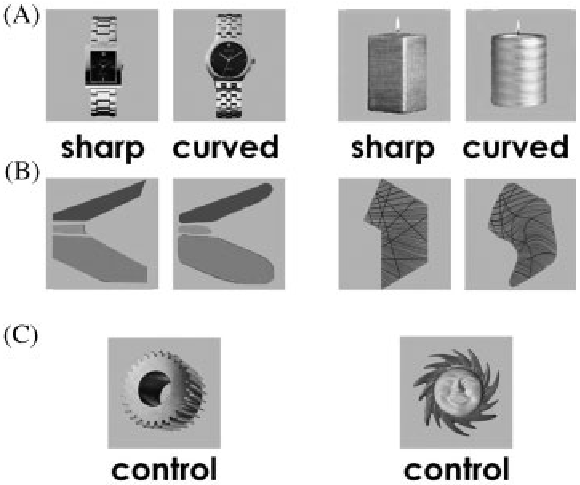

Figure 6. Examples of the stimuli. (A) Pairs of real objects with sharp-angled and curved contours, (B) pairs of novel patterns with sharp-angled and curved contours, (C) real objects with both sharp-angled and curved contours used as a control.

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a control condition with real objects with a roughly equal mixture of curved and sharp-angled features (**Figure 6C**). These objects were included to assess the direction of preference formation (i.e., whether sharp contours lead to decreased liking, curved contours lead to increased liking, or both). Like the other real objects, the objects in the control condition were not associated with an inherent valence.

Participants viewed one member of each pair (either the sharp-angled or the curved item, counterbalanced across subjects) and all the control objects, for 85 ms. For each image, they made a like or dislike forced-choice decision based on their immediate ''gut'' reaction. For each condition, we calculated percentage liking as the proportion of ''like'' responses, and found that participants liked the curved objects significantly more than the control objects, and liked the sharp-angled objects significantly less than the control objects. Thus, the curved objects were liked significantly more than the sharp-angled objects. A similar outcome was obtained with preference for the meaningless patterns. Finally, to determine whether this bias in favor of the curved objects can be explained by perceptual fluency, we examined reaction time (RT) differences in rating liking for these pictures and found no significant differences. As such, it is not the case that the preferred items were those that could be processed more readily. This result also suggests that there was no consistent difference in a gestalt-like good continuation between the objects in the curved and the sharp-angled conditions. Taken together, the results indicate that the nature of the contour provided the critical influence on liking judgments.

This finding was replicated and extended by others recently (Silvia and Barona, in press), where the preference bias for curved compared with sharp-angled objects was examined while specifically controlling for effects of symmetry, by presenting displays that consist of circles or hexagons that vary in size. These stimuli were round and angular, respectively, according to their geometric definitions, to manipulate angularity directly. Moreover, both the circles and hexagons were symmetrical along their vertical, horizontal, and diagonal axes. Consistent with our research, participants found the angular hexagons less pleasing than the round circles. Furthermore, they tested the effect of expertize in the arts on the preference for curved over angular objects (Silvia and Barona, in press), and found that people with low expertize prefer curved over angular shapes when they are simple (circles and hexagons), but experts show such curved versus sharp preference bias for the more complex polygons.

Naturally, a dangerous object (e.g., a knife) can impose a negative sense of threat on the viewer. However, our results demonstrate that a negative bias toward a visual object can be induced not only by the semantic meaning of that object (e.g., ''used for cutting,'' ''used as a weapon''), but also by low-level perceptual properties. In other words, even a picture of something as harmless as a watch will be liked less if it has sharp-angled features than if it has curved features. We propose that disliking of sharp-angled neutral objects might stem from a similar feeling of threat, and that this feeling is triggered by the sharpness of the angles *per se*. Indeed, previous research studying human facial expression and bodily movements suggest that sharp elements (e.g., a V-shaped corner) convey threat, whereas round elements convey ''warmth'' (Aronoff *et al.*, 1992). Similarly, we propose that preferences can be driven by a threatening impression conveyed by contour, and, specifically, that preferences are influenced by the sharp angles, rather than by the mere straightness of the contour.

To test this proposal, we conducted the same experiment using fMRI. Specifically, we examined activation of the amygdala in response to these everyday sharp objects (e.g., a sofa with sharp corners) compared with their curved-contour counterparts. We chose to focus on response of the amygdala because it has been implicated in fear processing and has been shown to exhibit activation level that is proportional to general arousal (Whalen *et al*., 2004). In the process, we also replicated our original finding that sharp-angled objects were liked significantly less than their curved counterparts for the real objects and for novel patterns, that there was no significant difference in average RT between the sharp and curved items, and no effect of gender.

Critically, we found significantly greater activation for objects with sharp contours than for objects with curved contours, for both real objects and novel patterns, in both the right and left amygdala (**Figure** 7). Overall, these results provide strong support for the proposal that sharp-angled objects are liked less because of an increased perception of threat that they convey, consciously or not, even for visual stimuli whose semantic meaning is emotionally neutral. As can be seen in the example in **Figure 8**, advertisers have already been using this principle of visual-based preference.

We concentrate on the threat-related aspects of amygdala function, though the amygdala has also been implicated in response to positive valence (Gottfried *et al*., 2003; Paton *et al*., 2006), vigilance (Whalen, 1998), and a general sensitivity to stimulus' relevance (Vuilleumier, 2005; Zald *et al*., 2002). Moreover, the amygdala has been shown to respond to biologically relevant information (Whalen *et al*., 2004). Because we used mundane, neutral (and, in the case of the patterns, meaningless) stimuli, however, they were not likely to recruit a significant level of amygdala activation due to any of these alternative interpretations (e.g., positive affect, vigilance, relevance, and unpredictability). Indeed, while amygdala response has an important role in emotion processing, it serves related, more primitive and ubiquitous functions.

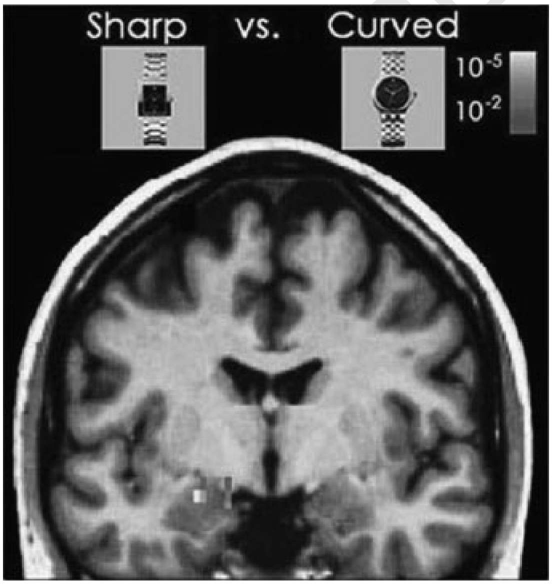

Figure 7. Bilateral amygdala activation was increased for sharp-angled stimuli compared with the same stimuli when they have curved contours instead.

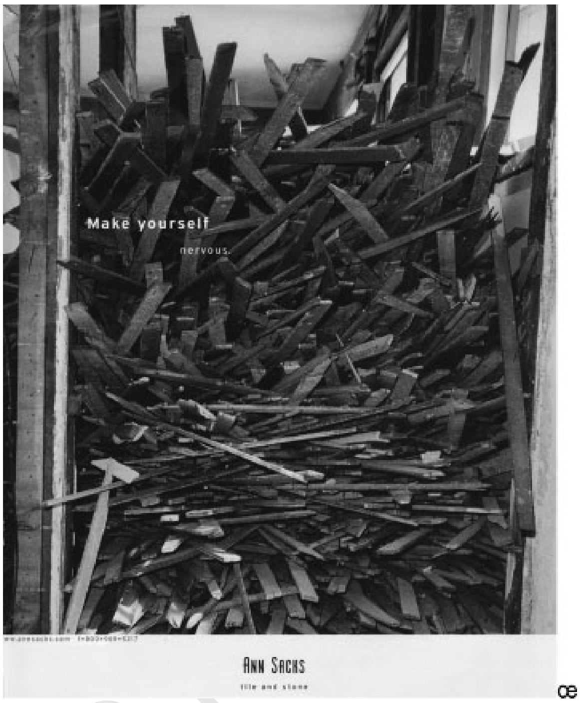

Figure 8. The use of our proposed principle that sharp corners might convey fear in the world of advertising, as illustrated in this 'make yourself nervous' ad.

Interestingly, the amygdala has recently also been shown to respond to unpredictability (Herry *et al*., 2007). This specific finding provides an excellent link to the overarching framework proposed here, that we rely on predictions on a regular basis, when we encounter something really unexpected, our brain interprets this as potential threat and thus elicits a fear response, as suggested by the corresponding activation of the amygdala. This could be at least part of the explanation of why people find it hard to judge other people's affect without a more specific context (Barrett

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et al., 2007). We rely on predictions to derive stability in our environment; when uncertainty increases or predictions are violated we might perceive the environment as more intimidating than when events are more predictable.

In a subsequent experiment, we examined whether the bias in preference toward curved objects is also mediated by the LSFs in the image, supporting the central role of coarse, rapid information in various types of visual opinions. Indeed, if sharp-angled objects were liked less than curved objects because of some detection of a potential threat, humans would benefit from extracting the relevant information rapidly. Specifically, our goal was to examine whether a preference bias for curved over sharp-angled objects would be significantly stronger when viewing the LSF version of the images than when viewing the corresponding HSF version. We found that participants who viewed the LSFs of an object liked the curved objects significantly more than the control (i.e., mixed contour) objects, and liked the sharp-angled objects significantly less than the control objects. Thus, sharp-angled LSF objects were liked significantly less than the curved objects. Conversely, those who viewed the HSFs of an object showed no significant difference in preference for the curved objects and the control objects. Importantly, the preference bias for curved objects over sharp-angled objects was greater when viewing the LSFs than when viewing the HSFs. Thus, the bias in preference against the sharp-angled objects is more readily influenced by the information conveyed by the LSFs of an image. Furthermore, the sharp versus curved bias in preference in the LSF condition in this experiment was almost identical to the corresponding difference when the object images were intact in the original experiment. Therefore, the rapidly extracted LSFs of an image seem to play a dominant role in shaping our contour-based visual preferences.

To summarize, our findings indicate that humans like sharp-angled objects significantly less than they like objects with a curved contour, and that this bias can stem from an increased sense of threat and danger conveyed by these sharp visual elements. We propose that the danger conveyed by the sharp-angled stimuli was relatively implicit. Indeed, the amygdala has been shown to respond to implicit, non-conscious cues of threat (Whalen *et al.*, 1998). It is possible that our brains have evolved to detect sharp features rapidly, using low-level features such as spatial frequency, which can help signal a potential danger.

Importantly, there are also other types of basic physical features, aside from contour, that can influence high-level judgments (Yue, Vessel and Biederman, 2007). For example, people wearing black-colored sports uniforms were shown to perceive themselves, and to be perceived by observers, as being more aggressive than those wearing uniforms of another color (Frank and Gilovich, 1988). This idea has been utilized in the world of product design. For example, manufactured products often make a statement through visual features such as texture, shape, and color, using these basic features to appeal to human emotions (Demirbilek and Sener, 2003). Furthermore, research on car interior design suggests that curved designs are preferred to straight elements, and that curvature elicits increased positive emotions (Carbon and Leder, 2005).

In summary, we are aware of perceptual features of an object but not necessarily aware of their influence on our preferences. Indeed, many types of first impressions are determined unconsciously (Bargh and Pietromonaco, 1982; Fazio *et al.*, 1986; Greenwald and Banaji, 1995). Sharp contours associated with a dangerous object, such as a knife, can impose a sense of threat on the viewer. But we are showing that this preference bias can stem not only from the semantic meaning of the object, but also by its low-level perceptual properties such as LSF, even if the object is a mundane everyday object with a neutral emotional meaning.

One issue that remains relatively unanswered is whether these preference biases are innate or learned through experience. Our results suggest that the preferences for curved visual objects might be learned, because the low level primitive features might be associated with sharp objects that can be dangerous (knife). Indeed, an evolutionary standpoint suggests that people might learn to prefer objects that promote safety, and fear objects that impede it (Feist and Brady, 2004). In other words, as humans, we learn to stay away from objects that might hurt us (sharp) and to learn to associate the sharpness with the potential danger. Future studies in developmental research might target this issue by examining this preference bias in younger children.

General discussion

We have proposed (Bar, 2007), and demonstrated together with others, a candidate unifying principle for the operation of the brain: that the human brain is proactive in that rather than passively ''waiting'' to be activated by sensations, it is continuously generating predictions that approximate the relevant future based on memories of past experiences and associative activation. These predictions facilitate cognition and action by pre-sensitizing relevant representations in memory. This cognitive neuroscience framework, and the findings we have accumulated, help to explain a variety of phenomena, from recognition (Bar *et al.*, 2006a) to first impressions (Bar *et al.*, 2006b), and from the brain's ''default mode'' (Bar *et al.*, 2007) to a host of mental disorders (Bar, 2007).

The framework presented here is explicit about the underlying function and neural mechanism of the proactive brain. Using human neuroimaging, we recently studied the cortical mechanisms mediating predictive associations (Bar and Aminoff, 2003; Bar, 2004). The associations that tie items that share the same context (e.g., a traffic light, a parking meter and a car), in a structure we have termed context frames, consistently activate three interconnected cortical foci: parahippocampal cortex and the hippocampus in the medial temporal lobe (MTL), retrosplenial complex in the medial parietal cortex (MPC), and the medial prefrontal cortex (MPFC). This contextual/associative predictions network shows a striking overlap with the cortical network termed the ''default network'' as we have shown recently (Bar *et al.*, 2007). The default network (Raichle *et al.*, 2001) is believed to subserve the mental processes that occur in the brain when subjects are not engaged in a specific goal-oriented task. This overlap between the default network and the network subserving associative processing of contextually related information is taken as the cortical manifestation that associative predictions is a crucial element of natural thought (Bar *et al.*, 2007).

In conclusion, the results and theoretical framework we described here have broad implications for most aspects of visual preference and impression formation. With regard to the implications of this framework in consumer behavior, we have revealed basic visual features that affect attitudes toward the environment. Our brains rapidly extract coarse information that, for important judgments, is sufficient for making a link with memory, which then allows us to predict what to expect with accuracy that can guide our behavior. This effective mechanism plays an important role in survival, whereby, for example, it would not be useful to identify each pattern on the skin of a snake before realizing the need to run for your life. Instead, you are motivated to flee first and consider the details later, if at all. In our modern lives, however, snakes and lions are less common, and this mechanism remains to serve the formation of rapid visual opinions.

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