This is an offprint from:

Simon Moore and Mike Oaksford (eds.)
Emotional Cognition.
From brain to behaviour
John Benjamins Publishing Company
Amsterdam/Philadelphia
2002
(Published as Vol. 44 of the series
ADVANCES IN CONSCIOUSNESS RESEARCH, ISSN 1381-589X)

ISBN 90 272 5168 1 (Eur.) / 1 58811 244 6 (US) (Hb)
ISBN 90 272 5164 9 (Eur.) / 1 58811 224 1 (US) (Pb)

CHAPTER 5

Affect and processing dynamics

Perceptual fluency enhances evaluations

Piotr Winkielman, Norbert Schwarz and Andrzej Nowak
University of Denver / University of Michigan / University of Warsaw

Research in psychology and neuroscience increasingly paints us as the "evaluating human," whose interactions with the world are facilitated by a variety of evaluative mechanisms. Traditionally, psychologists studying evaluations viewed them as resulting from the slow and careful consideration and integration of relevant stimulus attributes (e.g., Anderson 1981; Fishbein & Ajzen 1975). In contrast, recent psychological research suggests that evaluative judgments are often formed without such considerations, for example, by consulting one's apparent affective response to the stimulus (e.g., Schwarz 1990). Moreover, it is now widely accepted that people evaluate objects in their environment automatically and without conscious intention, extracting evaluative information from stimuli quickly and efficiently (e.g., Bargh 1996; Winkielman, Zajonc, & Schwarz 1997; Zajonc 2000). These observations are echoed by research in psychophysiology and neuroscience. For example, researchers have mapped out neuronal circuits allowing for rapid evaluative response (e.g., LeDoux 1996) and have highlighted the importance of quick affective feedback in decision making (e.g., Damasio 1994).

This chapter expands the portrayal of the evaluating human by reviewing our research on the relation between affect and the dynamics of information processing. We organize the presentation as follows. We first discuss differences between evaluative responses based on stimulus attributes and evaluative responses based on processing dynamics. Next, we review empirical findings that illustrate that ease of processing (high fluency) is consistently associated with more positive evaluations. Subsequently, we discuss why this might be the case and offer some speculations about possible computational mechanisms and neural instantiations. Finally, we address some boundary conditions governing the impact of processing dynamics on affect and evaluative judgment.

Feature-based and fluency-based sources of evaluative responses

Evaluative reactions can be based on multiple mechanisms that draw on different inputs. One source of relevant information are stimulus features. The analysis of such features, of course, can differ in complexity. On one end of the spectrum, there are simple affective responses to environmentally relevant stimuli, such as facial expressions or snakes, which require extraction of only few basic features (LeDoux 1996; Oehman, Flykt, & Lundqvist 2000; Zajonc 2000). On the other end, there are sophisticated emotions, such as hope or regret, which require intricate appraisals of the stimulus and its context (Frijda 1988; Ortony, Clore, & Collins 1988). Between these extremes are evaluative responses occurring during processes such as impression formation that involve integration of information from multiple features (e.g., Anderson 1981; Fishbein & Ajzen 1975).

Recently, researchers began collecting evidence suggesting another source of information underlying evaluative reactions, namely information provided by the dynamics of information processing itself. As we review below, this research shows that ease of processing, typically referred to as *high fluency*, tends to elicit a positive evaluative response that can be captured through self-reports as well psychophysiological measures. Before we review this evidence in more detail, it is useful to discuss a few conceptual differences between feature-based and fluency-based evaluative responses. An example may help here. Suppose you walk down a busy street and recognize one passing face as a neighbor who is smiling at you. One source of your pleasant affect might be the stimulus' descriptive features (i.e., your neighbor's smile). The other source of evaluative response, however, might be the fluency accompanying the processing of the stimulus (i.e., the ease of recognizing your neighbor's face). As we elaborate below, easy processing can trigger pleasant affect because it indicates that the stimulus is familiar or typical, and thus relatively likely to be positive. Further, easy processing can trigger pleasant affect because it indicates that your attempt at recognition is likely to be successful.

Although fluency-based affective reactions emerge in the course of processing stimulus features, they are *not* a function of these features in the same way that other affective reactions are. Most important, fluency-based evaluative reactions can be elicited by variables that are unrelated to the features of

the stimulus itself, but influence the ease with which the stimulus can be processed. Accordingly, variables that are known to influence the speed of stimulus recognition – like visual priming, stimulus repetition, and exposure duration – have been found to consistently influence evaluative responses. Of course, certain intrinsic features of a stimulus, like figure-ground contrast, symmetry, or semantic predictability may themselves facilitate fluent processing. However, in such cases, the affective reaction may not derive from analysis of the implications of stimulus features, but from the influence of such features on the processing dynamics. Finally, it is also worth noting that the assumption that fluency-based affective reactions do not derive from stimulus features is fully compatible with the assumption that affective reactions are *perceived* by people as a response to features of the stimulus. As research in social psychology points out (see Higgins 1998), people "by default" assume that feelings they experience while thinking about a target bear on that target – or why else would they be experienced at this point in time? However, we may expect that the influence of fluency-based affective reactions on evaluative judgment is eliminated when people become aware that their feelings may be due to a source other than the stimulus, as has been observed in other investigations of affective influences, like moods and emotions (e.g., Schwarz & Clore 1983; see Schwarz & Clore 1996, for a review).

Perceptual fluency enhances liking

Historically, the interest in the fluency-evaluation link was stimulated by research into the mere-exposure effect, i.e., the observation that repeated exposure enhances liking for an initially neutral stimulus (for reviews see Bornstein 1989; Zajonc 2000). Several authors proposed that the mere-exposure effect might reflect changes in perceptual fluency (e.g., Bornstein & D'Agostino 1994; Jacoby, Kelley, & Dywan 1989; Seamon, Brody, & Kauff 1983). This proposal is consistent with the observation that repeated exposure speeds up stimulus recognition and enhances judgments of stimulus clarity and presentation duration, which are indicative of processing facilitation (e.g., Haber & Hershenson 1965; Jacoby & Dallas 1981; Witherspoon & Allan 1985; Whittlesea, Jacoby, & Girard 1990). If so, we may expect that any variable that facilitates processing results in increased liking, even under conditions of a single exposure. Our initial studies were designed to test this possibility.

In one of these studies (Reber, Winkielman, & Schwarz 1998, Study 1), participants were exposed to pictures of everyday objects (e.g., a desk, bird, or plane). The fluency with which these target pictures could be processed was manipulated through a subliminal priming procedure that exposed participants to visual contours. Some target pictures were preceded by matched contours (e.g., contour of a desk followed by a picture of the desk), whereas others were preceded by mismatched contours (e.g., contour of a desk followed by a picture of a bird). We expected that matched contours would facilitate target processing, consistent with the finding that subliminal visual primes enhance recognition of related targets (e.g., Bar & Biederman 1998). Some participants were asked to indicate how much they liked the target pictures; other participants were asked to press a button as soon as they could recognize the object in the picture, thus providing an independent measure of processing ease. The data were consistent with our predictions: Pictures preceded by matched contours were recognized faster, indicating higher fluency, and were liked more than pictures preceded by mismatched contours. Importantly, participants were unaware of the priming manipulation, thus eliminating the possibility of strategic responding to pictures preceded by various primes.

Additional studies replicated and extended these findings. First, we wanted to show that perceptual fluency enhances liking even when it is manipulated by means other than priming. This is important since priming procedures require previous exposure to at least some form of the target stimulus, thus raising interpretational issues surrounding the effect of repetition on liking (Zajonc 1998). Second, we wanted to show that liking can be increased by manipulations that do not rely on inhibitory influences. This is important since priming with matched versus mismatched stimuli can either increase or decrease fluency. Reflecting these considerations, we conducted several studies using other manipulations of perceptual fluency. In one study (Reber et al. 1998, Study 2), we manipulated fluency through different degrees of figure-ground contrast, a variable that has been shown to influence identification speed (Checkosky & Whitlock 1973). Again, participants liked the same stimulus more when it was presented with higher contrast, and hence could be processed more fluently. In another study (Reber et al. 1998, Study 3), we manipulated fluency through subtle increases in presentation duration, taking advantage of the observation that longer presentation durations facilitate the extraction of information (Mackworth 1963). As expected, participants evaluated the same stimulus more positively when it was presented for a longer duration, but were unaware that duration was manipulated. In combination, the above studies, based on visual priming, figure-ground contrast and presentation duration, consistently show that high perceptual fluency leads to more positive evaluations of the perceived stimuli.

Perceptual fluency selectively elicits positive evaluation

Different process assumptions are compatible with the observation that high processing fluency elicits more positive evaluations. On the one hand, we proposed that fluency is itself hedonically marked and experienced as positive (e.g., Reber et al. 1998; Winkielman et al., in press). On the other hand, several researchers suggested that fluency is affectively neutral and proposed accounts of the evaluative effects of fluency that draw on the logic of Schachter and Singer's (1962) two-factor theory of emotion.

One variant is the *non-specific activation model* by Mandler, Nakamura, and Van Zandt's (1987). According to this model, manipulations that increase processing fluency merely ensure a greater activation of the stimulus representation, and this "activation may then be related to any judgment about the stimuli that is stimulus relevant" (Mandler et al. 1987, p. 647). Similarly, the *fluency–attribution model* (e.g., Bornstein & D'Agostino 1994; Jacoby, Kelley, & Dywan 1989; Seamon, Brody, & Kauff 1983) assumes that fluency is affectively neutral and that participants try to arrive at "the most parsimonious and reasonable explanation" of "the experience of perceptual fluency, given situational constraints and the available contextual cues" (Bornstein & D'Agostino 1994, p. 106). In the process, participants will attribute the experience "to liking or, for that matter, to any variety of stimulus properties that the subject is asked to rate" (Bornstein & D'Agostino 1994, p. 107). Finally, the *familiarity–attribution model* proposes that high fluency elicits a vague feeling of familiarity (Bonanno & Stillings 1986; Klinger & Greenwald 1994; Smith 1998), which is also assumed to be affectively neutral and able to influence a variety of judgments, depending on contextual factors. Specifically, "in the context of performing liking judgments, misattributions to liking and disliking are likely because the goal of the subject is to form a preference" (Klinger & Greenwald 1994, p. 77). Such misattributions are considered likely because "subjects are highly susceptible to subtle suggestions as to the particular stimulus qualities that might be taken as the source of their subjective experience" (Smith 1998, p. 416).

Empirically, these two-step models are well supported by studies that assessed non-evaluative judgments. For example, Mandler et al. (1987) observed pronounced focus-of-judgment effects: when asked to assess the brightness of a stimulus, participants rated high fluency stimuli as brighter than low fluency stimuli; yet when asked to rate their darkness, they rated the same stimuli as darker. Similarly, Jacoby and his colleagues (for a review see Kelley & Jacoby 1998) observed that fluency influences a broad range of different judgments, from recognition to truth and fame. Importantly, however, these models did not fare well in the evaluative domain, paralleling the general fate of Schachter and Singer's (1962) two-factor theory of emotion (see Reisenzein 1983). For example, in Mandler et al.'s (1987) studies, as well as a follow-up by Seamon, McKenna and Binder (1998), higher perceptual fluency increased judgments of liking, but not judgments of disliking. This pattern contradicts two-step accounts, but is consistent with the assumption that fluency itself is positively marked. Our own studies reiterate this observation.

In one study (Reber et al. 1998, Study 2), we asked some participants to judge the "prettiness" of the targets, but asked other participants to judge the "ugliness" of the targets. In another study (Reber et al. 1998, Study 3), we asked some participants to make "liking" judgments, but asked others to make "disliking" judgments. In both studies, increased perceptual fluency resulted in higher judgments of "prettiness" and "liking" and lower judgments of "ugliness" and "disliking," as reflected in significant interactions of fluency and judgment focus. In combination, these findings indicate that increased fluency does not facilitate more extreme evaluations in general, but selectively enhances positive evaluations.

Note, however, that these studies are subject to the objection that judgments of disliking or ugliness may be less "natural" than judgments of liking and prettiness. In fact, Mandler et al. (1987) suggested that in their studies repeated exposure did not lead to high disliking because "disliking is a complex judgment, often based on the absence of a liking response. Linguistically, liking is the unmarked and disliking the marked end of the imputed continuum" (p. 647). Hence, participants may prefer to initially evaluate prettiness or likeability of stimuli and only later reverse their response to report it along an ugliness or disliking scale, which would thwart the attempt to induce a focus on ugliness or dislikeability. Although possible in principle, this explanation cannot account for results of Study 1 by Winkielman and Cacioppo (2001). In this study, participants were presented with pictures that varied in processing fluency, manipulated through a visual priming manipulation. Some participants were told to selectively monitor and report only the presence of positive affective reactions, whereas other participants were told to selectively monitor and report only the presence of negative affective reactions. We framed the question this way because it is very hard to argue that it is more "natural" for participants to monitor or report positive responses than negative responses, especially since participants have been able to provide such valence-specific reports in other research (see Cacioppo & Berntson 1994; Cacioppo & Gardner 1997 for reviews). As expected, the results showed a selective effect of the fluency manipulation on affective responses. Specifically, participants who focused on positive affective responses reported more positive evaluations of the stimuli under high rather than low fluency conditions. In contrast to the predictions of two-step models, however, participants who focused on negative affective responses did *not* report more negative evaluations under high rather than low fluency conditions.

In sum, studies that tested the predictions of two-step models in the evaluative domain, using initially neutral stimuli, failed to support the hypothesis that increased fluency may result in more positive as well as more negative evaluations, depending on the focus of the judgment task. Instead, the available findings are consistent with the assumption that fluency is positively marked and selectively enhances positive evaluations of the processed stimuli. The next set of studies takes this conclusion even farther.

Perceptual fluency triggers genuine positive affective responses

Another theoretically important question concerns the nature of the evaluative responses elicited by high fluency. If high fluency is itself hedonically marked, processing facilitation should lead to a genuine increase in positive affect. This increase, in turn, should appear on psychophysiological measures that tap into the positive affect system (Winkielman, Berntson, & Cacioppo, 2000). A demonstration of this is important for several reasons. The presence of genuine affective responses would strengthen our assumption that fluency makes a "hot" contact with the affective system, and is not purely based on "cold" inferences, as argued by proponents of the two-step models. Further, a demonstration of selective positivity of affective responses to fluency would strengthen our assumption that the fluency signal is hedonically marked. Finally, psychophysiological evidence is not subject to the complexities of self-reports, discussed above in the context of Mandler et al.'s (1987) findings.

To provide such evidence, Winkielman and Cacioppo (2001) measured affective responses to fluent stimuli with facial electromyography (fEMG). This technique relies on the observation that positive affective responses manifest themselves in incipient smiles, as reflected by higher activity over the zygomaticus major region (cheek muscle). On the other hand, negative affective responses manifest themselves in incipient frowns, as reflected by higher activity over the corrugator supercilii region (brow muscle). Importantly, fEMG can capture affective responses to subtle, everyday stimuli that do not produce overtly visible facial expressions (Cacioppo, Bush, & Tassinary 1992; Dimberg, Thunberg, & Elmehed 2000).

In the Winkielman and Cacioppo (2001) studies, participants saw pictures of everyday objects varying in fluency, manipulated through visual priming (Study 1) and presentation duration (Study 2), while their fEMG activity was recorded. Several seconds after the presentation of each picture, participants also reported their affective responses (as described above). The results of both studies were very consistent. High fluency was associated with stronger activity over the zygomaticus region (indicative of positive affect), but was not associated with stronger activity of the corrugator region (indicative of negative affect). This effect was obtained across both fluency manipulations and occurred in the first 3 seconds after the presentation of the stimulus, several seconds before participants made their overt judgments.

In sum, Winkielman and Cacioppo's (2001) findings suggest that manipulations of processing fluency have genuine affective consequences, consistent with our assumption that fluency is hedonically marked and closely connected to the affect system. Further, these findings suggest that the affect generated by processing facilitation is positive, thus providing another argument against the assumption of the two-step models that fluency is equally likely to elicit positive as well as negative responses.

Perceptual fluency and the mere-exposure effect

As noted earlier, research into the fluency-evaluation link was initially stimulated by research into the mere-exposure effect (Zajonc 1968). The studies reviewed above are consistent with the idea the repetition may be just one manipulation that leads to an enhancement of fluency. However, our studies also make clear that the role of fluency in the mere-exposure effect is not captured by the two-step models discussed earlier. Instead, it seems that the positive hedonic marking of the fluency signal is the crucial ingredient. This suggestion is consistent with the accumulating evidence that mere exposure elicits positive affect. For example in a recent study by Monahan, Murphy, and Zajonc (2000), participants were subliminally exposed to 25 pictures of Chinese ideographs, and were later asked to report their tonic mood. For some participants, each of the 25 ideographs was different, while for other participants, 5 different ideographs were repeated 5 times each. The results showed that participants who were subliminally exposed to repeated ideographs reported being in a better mood than participants exposed to 25 different ideographs. Moreover, Harmon-Jones and Allen (2001) observed that repeatedly presented stimuli elicited stronger EMG activity over the zygomaticus region, indicative of positive affect, without changing the activity over the corrugator region. In combination, the Monahan et al. (2000) and Harmon-Jones and Allen (2001) studies demonstrate that stimulus repetition can elicit a positive affective response, as has been observed for other manipulations of processing fluency.

The fluency-affect connection

A satisfying theoretical account of the above findings needs to answer two fundamental questions. First, how is the organism able to respond to changes in its own processing dynamics? Second, why is fluency associated with positive affect? A satisfying account must also offer a plausible model of the underlying processes, which should be consistent with the available neurophysiological data. Unfortunately, no available model fully satisfies all of these criteria. However, we suggest that current knowledge offers at least an outline of possible answers.

Cognitive monitoring and affect

Empirical and neurophysiological data suggest the existence of metacognitive mechanisms that provide internal feedback about ongoing processing operations (Metcalfe & Shimamura 1994; Mazzoni & Nelson 1998). These mechanisms may monitor not only the content of the representations being processed, but also the dynamical parameters of cognition. For example, research on the "feeling of familiarity" suggests that people are sensitive to the absolute and relative speed of various mental operations involved in stimulus recognition and categorization (Kelley & Jacoby 1998; Whittlesea & Williams 2001). Similarly, research on the "feeling-of-knowing" phenomenon suggests that people access the strength of their memory traces (Koriat 2000). Further, research on novelty monitoring show that people trace a nonspecific signal of a match between the incoming information and stored representations (Metcalfe 1993). Throughout, the available findings indicate that such non-specific signals about the quality of internal processing can be accessed independently of an explicit representation of the underlying representational content (e.g., Curran 2000). This allows for subjective states that are characterized primarily by a metacognitive experience, such as a feeling of fluency, knowing, or familiarity (see Koriat 2000).

We assume that metacognitive feedback signals are likely to carry both cognitive and affective information, consistent with approaches that view affect as involved in cognitive regulation (e.g., Carver & Scheier 1990; Oatley & Johnson-Laird 1987; Reisenzein 1998; Simon 1967). There are several reasons why metacognitive signals that indicate a high fluency of processing may be connected with positive affective responses. First, high fluency may indicate that an external stimulus is familiar and may therefore trigger a positive response due to a presumably biological predisposition for caution in encounters with novel, and thus potentially harmful, stimuli (Zajonc 1998). The available data support a close correspondence between the familiarity signal and positive affect. For example, fluency manipulations, which produce positive affect, also tend to produce memory illusions, which presumably reflect misattributions of familiarity (Whittlesea 1993; Winkielman et al., in press). Conversely, illusions of familiarity can be produced through unobtrusive inductions of positive affect (Garcia-Marques & Mackie 2000; Phaf, Rotteveel, & Spijksma 1998). Second, the fluency signal may be connected to affect by indicating the state of the ongoing processing operations. Thus, high fluency may indicate progress toward successful recognition and trigger positive affect due to the reinforcing value of maintaining the current, successful cognitive strategy and the ability to free resources for other tasks (Carver & Scheier 1990; Ramachandran & Hirstein 1999; Vallacher & Nowak 1999).[1] Third, fluency may indicate that the current processing is consistent with expectations. We surmise that many of these relations have their mirror images in connections between metacognitive signals of low fluency and negative affect. Thus, signals of cognitive error or violations of expectations have been shown to trigger negative affective responses (Derryberry & Tucker 1994; Fernandez-Duque et al. 2000). Finally, the above ideas converge with observations that mental states characterized by low coherence, such as cognitive dissonance, tend to be experienced as hedonically negative, as reflected in self-reports as well as physiological indices (Devine, Tauer, Barron, & Elliot 1999; Harmon-Jones 2000; Losch & Cacioppo 1990).

The assumed connection between the metacognitive monitoring system and the affect system is further supported by neuroimaging and electrophysiological data. Recent studies point to the brain midfrontal regions, and particularly the anterior cingulate, as one of the primary structures involved in metacognitive regulation (Fernandez-Duque et al. 2000). Interestingly, as part of the limbic system, the anterior cingulate is involved in emotion processes and emotional control (Lane et al. 1998). There are also very close links between circuits responsible for memory and emotion. For example, the hippocampus and amygdala jointly contribute to memory and form a basis of the limbic system (Squire 1992). Although it is still unclear whether the midfrontal region and the limbic structures form an integrated cognitive-emotional system or independent cognitive and emotional subsystems, the accumulating evidence renders a close relationship between metacognition and affect highly plausible.

Possible computational mechanisms

Until recently, the role of dynamical parameters has received surprisingly little research attention (Nowak & Vallacher 1998; Port & Van Gelder 1995). One notable exception is the neural network approach, or connectionism, in which cognition is viewed in terms of the passage of activation among simple, neuron-like units organized in large, densely interconnected networks (Rumelhart & McClelland 1986). The individual units function as simple processors that can influence each other through connections, which vary in strength and sign (facilitatory or inhibitory). This massively interconnected and parallel architecture gives the neural network approach a certain neurophysiological realism and makes it suitable for a wide variety of applications. For more biological applications one can conceptualize the network units as actual neurons, whereas for more psychological applications one can treat the units as blocks of neurons or functional sub-systems (O'Reilly & Munakata 2000). Several different neural network architectures have been proposed that utilize dynamical parameters. Below we focus on a proposal by Lewenstein and Nowak (1989), which illustrates the role of dynamical parameters in learning and recognition using a simple attractor neural network (Hopfield 1982). Importantly, similar mechanisms can be implemented in more complex networks that successfully deal with typical problems plaguing simple attractor networks, such as the plasticity-stability dilemma, and conform to more realistic biological assumptions about the network architecture (Murre, Phaf, & Wolters 1992; Norman, O'Reilly, & Huber 2000; Smith 2000). Further, although the models discussed here have been primarily designed to understand memory processes, similar mechanisms can shed light on the role of dynamical parameters in a variety of mental activities, including cognition-emotion interactions (Beeman, Ortony, & Monti 1995).

In a typical Hopfield network, representations are encoded as attractors of the network, i.e. states into which the network dynamics converge. The processing of information with the network can be seen as a gradual, evolving process, during which each neuron adjusts to the signal coming from other neurons. For example, when presented with a to-be-recognized pattern, the network goes through a series of adjustments and after some time approaches a stable state, an attractor, corresponding to the "recognition" of a particular pattern. Lewenstein and Nowak (1989) proposed that a typical Hopfield model can be extended with a simple control mechanism, which allows the network to monitor the dynamics of its own processing. Such a control mechanism can draw on a variety of dynamical parameters, such as volatility, signal strength, coherence, settling time, and so on. These formally related parameters can then be used by the network to roughly estimate the characteristics of the stimuli being processed as well as monitor the quality of its own processing (Lewenstein & Nowak 1989).

The available simulations focused on how monitoring the dynamical parameters of cognition can allow the network to estimate proximity to its closest attractor during the recognition process. This, in turn, allows the network to estimate the likelihood that the presented pattern is "known." Specifically, two dynamical parameters were identified. The first parameter is the network's "volatility," or the proportion of neurons changing their state at a given point. When the incoming, "to-be-recognized" pattern matches or closely approximates a known pattern, corresponding to one of the attractors (memories), the network is characterized by a relatively small proportion of neurons changing their state. When the incoming pattern is novel and thus does not approximate one of the attractors, the network is characterized by a large number of neurons changing their state. The second means of implementing a control mechanism involves checking the coherence of the signals received by the neurons. In the vicinity of an attractor (old pattern), the signals arriving from other neurons at a given neuron are consistent in dictating its state. However, when the network is far from an attractor (new pattern), the signals arriving from other neurons at a given neuron dictate conflicting states. A closely related criterion is the signal-to-noise ratio, or differentiation. In the vicinity of the attractor (old pattern), signals from other neurons typically add up, resulting in a relatively large summary signal dictating the state of a given neuron. However, far from an attractor (new pattern), signals from other neurons cancel each other, resulting in a relatively weak summary signal dictating the state of a given neuron. As a consequence, the processing of "old" patterns is characterized by a higher signal-to-noise ratio than the processing of "new" patterns.[2]

Both implementations of the control mechanism (via volatility or coherence/differentiation) allow the network to estimate whether a pattern is "new" or "old" (i.e., proximity to its closest attractor) within the first few processing steps. Specifically, the actual completion of the recognition process in the above model usually takes about 3–6 steps of a Monte Carlo simulation. Yet, it is possible to determine the novelty of incoming stimuli by monitoring how frequently a mere 10% of the neurons change their state at the first Monte Carlo step, which amounts to only 0.1 Monte Carlo step (Lewenstein & Nowak 1989).[3] Thus, these computations allow for an estimation of novelty that far precedes completion of the recognition process.

The assumptions of the above model are consistent with neuropsychological evidence. For example, early work on the orienting response shows that novel stimuli elicit a non-specific, undifferentiated activity, which gradually decreases with repetition (Skarda & Freeman 1987; Sokolov 1963). More recent studies using single cell recording and neuroimaging suggest that stimulus repetition tends to decrease non-specific activation and leads to more selective firing (Desimone, Miller, Chelazzi, & Lueschow 1995; Rolls, Baylis, Hasselmo, & Nalwa 1989). One interpretation of these data is that stimulus familiarization leads to a gradual differentiation of the neurons that represent the incoming stimulus from neurons that do not represent the stimulus (Norman et al. 2000). Such differentiation processes may occur on the perceptual as well as conceptual level (e.g., McClelland & Chappell 1998).

A simulation

The usefulness of the above model for thinking about the relation between processing dynamics and affect is suggested by its success in simulating actual human data. For example, Drogosz and Nowak (1998) used a dynamic attractor neural network to simulate the behavior of participants in a subliminal mere-exposure study by Seamon, Marsh, and Brody (1984). In their study, Seamon and colleagues exposed participants to 50 repetitions of polygons, presented at exposure times ranging from 2 to 48 milliseconds. As in other mere exposure experiments, participants showed an increased preference for repeated polygons, even when these polygons were only shown for a mere 2 or 8 milliseconds. Moreover, their preference increased with increasing exposure times, but reached asymptote at 24 milliseconds. In contrast, recognition was at chance at low durations (2 and 8 milliseconds), and then gradually increased up to 90% recognition at 48 milliseconds.

Drogosz and Nowak (1998) showed that these asymmetric effects of exposure time on preference and recognition can be closely simulated by assuming that the affective response represents a non-specific signal about the early dynamics of the network, as indexed by the number of changes of neuron states at the 0.1 MC step, whereas the recognition response represents a stabilization of the network on a specific pattern, at about the 6 MC step. A psychological interpretation that can be attached to these simulation data is that at very short presentation durations, the participants only have access to the non-specific fluency signal, which elicits positive affect and influences their preference judgments. With progressively longer presentation duration, the fluency signal (affective response) increases only marginally, whereas the recognition response continues to grow until it reaches nearly perfect performance.

The above simulations explored the role of dynamical parameters in the context of stimulus repetition, and are best suited to understanding the mere-exposure effect (Drogosz & Nowak 1998). Many prior exposures to a pattern establish a relatively strong memory for this pattern, whereas few prior exposures establish a relatively weak memory for the pattern. Test patterns with relatively stronger memories (i.e., stronger attractors) are processed with higher processing fluency (less volatility, more coherent signals) than test patterns with weaker or no memories. These differential fluency signals are picked up early on, as indicated by the simulation, and precede the extraction of stimulus information. Because the fluency signal is hedonically marked, it allows for evaluative responses prior to stimulus recognition, as initially reported by Kunst-Wilson and Zajonc (1980).[4]

Computational models of this type can also help us conceptualize the results of studies that used all novel patterns and manipulated the fluency of processing through procedures like priming, figure-ground contrast, and presentation duration. To account for these effects, the model requires only minimal modifications. Specifically, the above simulations were carried out in attractor networks composed of neurons with binary states, where a state of the neuron corresponds either to the presence or the absence of a feature encoded by this neuron (Hopfield 1982). However, the same "fluency" criteria (volatility, coherence, differentiation) apply to networks with continuous neurons, where the state of a neuron encodes the degree to which a feature is present or activated (Hopfield 1984; O'Reilly & Munakata 2000). In such networks, priming may correspond either to the pre-activation of neurons that encode the pattern (activation-based priming) or to the slight changes in weights between the neurons (weight-based priming). The effects of the prime and the actual target sum up in determining the state of neurons. This results in more extreme values of activation (i.e., better differentiation) of the neurons for primed versus non-primed patterns. The influence of presentation duration may be conceptualized as reflecting a similar process, in which patterns presented for a long time are represented by more extreme values of activation than patterns presented for a short time. Finally, manipulations such as figure-ground contrast or clarity of the perceived pattern should have similar effects on the "fluency" signal. Because salient features of the stimulus are encoded by more extreme states of neurons, perceiving a pattern characterized by a high contrast or high clarity results in more differentiated states of the neurons, and thus stronger signals in the network.

In sum, according to the above computational model, liking for novel and even completely unfamiliar (e.g., abstract) patterns may be influenced by manipulations such as priming, presentation duration, figure–ground contrast, and clarity because all these manipulations reduce the network's volatility and increase its signal-to-noise ratio. Presumably, such changes result in a signal of fluency, which in turn triggers a positive affective response via the mechanisms discussed above.[5] It is worth emphasizing that the above manipulations have a similar effect on processing dynamics as previous repetition. This again highlights the parallel between the work on the mere-exposure effect and our empirical findings presented above.

Extensions and boundary conditions

The principles discussed in the current chapter may be extended in several ways. One interesting question is whether the above notions can explain other important findings on preferences. For example, numerous studies show that people prefer stimuli that are average or prototypical, including faces, birds, cars, watches, and colors (e.g., Halberstadt & Rhodes 2000; Langlois & Roggman 1990; Martindale & Moore 1988; Rhodes & Tremewan 1996). Other studies show preferences for symmetrical facial and non-facial stimuli (e.g., Berlyne 1974; Palmer 1991; Rhodes, Proffitt, Grady, & Sumich 1998). These observations are often explained by assuming a biological, built-in mechanism (Etcoff 1999; Pinker 1998). This is a plausible hypothesis – after all, it has been shown in several species that symmetry and averageness are indicative of mate value (e.g., Thornhill & Gangstead 1993). However, average (prototypical) and symmetrical stimuli also are associated with more fluent processing, as shown in several empirical studies (Checkosky & Whitlock 1973; Posner & Keele 1968; Palmer 1991) as well as computer simulations (Enquist & Arak 1994; Johnstone 1994; Rumelhart & McClelland 1986).[6] Thus, preference for averageness and symmetry may be just another example of the affective marking of processing fluency. Of course, the reverse possibility is also logically possible. That is, the reason why one can elicit preferences by facilitating processing with means other than symmetry or prototypicality (or familiarity) may potentially be that these manipulations feed into mechanisms designed to track biologically relevant dimensions. Future studies may examine if preferences for symmetry and prototypicality can be fully accounted for by differences in perceptual fluency.

Another topic to be addressed in future studies is the role of conceptual fluency. Note that the studies discussed in the current chapter manipulated perceptual fluency, that is, the ease of low-level operations concerned primarily with processing of stimulus form. Accordingly, they used manipulations like visual priming, duration, figure-ground contrast, repetition, etc. However, the logic of our argument extends as well to conceptual fluency, that is, high-level operations concerned primarily with processing of stimulus meaning, and its relation to other semantic knowledge structures (McGlone & Tofighbakhsh 2000; Roediger 1990; Schacter 1992; Whittlesea 1993). We recently began to explore the effects of conceptual fluency on liking and memory judgments using manipulations like semantic priming and associative learning and obtained findings that are fully compatible with the logic offered in the present chapter (see Winkielman et al., in press).

Boundary conditions

As discussed above, the fluency signal is available at very early stages of information processing, allowing for a quick affective response. Therefore, fluency effects on preferences are likely to be strongest under conditions that limit the extraction of additional information, which may compete with the fluency signal in the computation of a preference judgment. Such conditions include time pressure, limited cognitive capacity and a lack of motivation to process the stimulus in sufficient detail. In fact, preliminary data from our labs suggest that fluency effects on evaluations increase under cognitive load conditions (Winkielman et al., in press) and decrease as more stimulus information is extracted (Reber & Schwarz 2001). Similarly, the fluency signal may be the most informative input when little other information can be extracted from the stimulus. Consistent with these assumptions, exposure frequency, exposure duration and figure-ground contrast have been found to have the strongest influence on preference judgments when the stimuli are novel, neutral and presented for relatively short durations (e.g., Bornstein 1994; Reber & Schwarz 2001).

When fluency derives from incidental variables, like exposure duration, exposure frequency or priming manipulations, awareness of these variables is likely to undermine the perceived informational value of fluency and its accompanying affective response. This is consistent with studies showing that mere-exposure effects decrease with increasing awareness of the manipulation (Bornstein & D'Agostino 1992). Further, recent data from our lab show that fluency effects on preferences disappear when the source of fluency is made salient or when participants are informed that their affective reactions may come from an irrelevant, external source (Winkielman et al., in press). These findings parallel similar observations with regard to other sources of experiential information (for a review see Schwarz & Clore 1996).

It is also likely that the impact of experienced fluency is moderated by the person's processing expectations, which provide context-dependent, implicit norms for processing ease associated with each item. Whittlesea and Williams (2001) observed, for example, that participants who initially expected a stimulus to be processed with low fluency were more likely to attribute high processing fluency to prior exposure than participants who initially expected the stimulus to be processed with high fluency. Hence, the former were more likely than the latter to conclude that they had seen the stimulus before. The extent to which processing expectations may moderate the influence of fluency on preference judgment has so far received no attention.

Under some specific conditions, it is also possible that high fluency may lead to more *negative* evaluations. Although this has not yet been observed, it is conceivable under two conditions. First, in an environment where, say, familiarity or prototypicality are associated with danger, fluency may become an automatic cue to negativity. Second, and less speculative, such reversal of the default positive influence may occur when people are lead to consciously believe that the experience of processing fluency is an indicator of negative value. In this case, their initially automatic positive reaction to high fluency may be overridden by deliberate, theory-driven inference processes that result in a negative judgment. That individuals' "naive" theories about the meaning of subjective experiences can determine which inferences they draw from cognitive feelings, such as recall difficulty or familiarity, is well documented (see Skurnik, Schwarz, & Winkielman 2000; Winkielman & Schwarz 2001), but has not yet been tested for the influence of fluency on evaluative judgments. Further, this possibility assumes that the fluency signal is strong and distinct enough to be consciously available and accessible to strategic inferences. Future studies may address this issue.

Finally, to avoid overgeneralization, it is worth emphasizing that some evaluative judgments, like complex aesthetic judgments or judgments of morality, are likely to involve extensive consideration of stimulus meaning, and may be based on sophisticated inferences from multiple sources of information.

In summary, this discussion of boundary conditions indicates that fluency-based affective reactions are likely to have most impact under the conditions that are also known to give rise to pronounced mood effects in evaluative judgment: When little other information is available; when the person's processing capacity or motivation are low, thus limiting more deliberate information search and integration; and when the informational value of the affect has not been called into question (for discussions see Schwarz 1990; Schwarz & Clore 1996). However, these parallels should not distract from the unique character of fluency-based affect. Most important, fluency-based affect is not based on an analysis of stimulus meaning, in contrast to specific emotions, which involve complex, meaning-based appraisals. Instead, fluency-based affect results from the dynamics of information processing itself. As such, the work described in the chapter adds another important piece to the mechanisms that make us the "evaluating human."

Author's note

We thank John Cacioppo, Tedra Fazendeiro, Yuko Munakata, Randy O'Reilly, Rolf Reber, and the University of Denver Cognitive Research Group for helpful discussions of these issues. Preparation of this chapter was partially supported by a fellowship from the Center for Advanced Study in the Behavioral Sciences to Norbert Schwarz and by the Internationalisation Grant from the University of Denver to Piotr Winkielman.

Notes

1. The possibility that positive affect is triggered by signals of "recognition progress" does not require an assumption that a person has to actually achieve the goal of recognition to experience positive affect. Instead, a signal indicating that the ongoing processing moves towards recognition should be sufficient. This suggestion distinguishes our view from proposals that link positive affective responses to achievement of cognitive sub-goals (Carver & Scheier 1990). Our interpretation fits the available data better than the "affect-as-achievement" interpretation. After all, in our studies, participants have no problem achieving the goal stimulus recognition, yet they experience different affective reactions depending on the fluency of the recognition.

2. In neural networks, the strength of a signal arriving at a neuron is a product of the state of the neuron that is sending the signal and the weight of the connection. For novel patterns, the connections among neurons are uncorrelated with the states of the neurons. Thus, the distribution of the summary signals received by neurons during recognition of a novel pattern resembles a normal distribution with a mean of zero and a standard deviation proportional to 1/N, where N corresponds to the number of synapses transmitting the signal to a neuron.

3. Checking the coherence of incoming signals makes it possible to estimate not only the global novelty of the whole pattern, but also the novelty of fragments in the perceived pattern, such as elements of an object or objects in a scene (Zochowski, Lewenstein, & Nowak 1994).

4. The above simulations were conducted using very similar patterns, as is typical in the mere-exposure studies. Accordingly, the absolute processing fluency of a given pattern was a reliable indicator of its "oldness." For the fluency signal to be informative in a more realistic situation, in which stimuli differ widely in overall signal strength, the network needs to scale the absolute value of the fluency signal for the particular pattern against the expected value (Whittlesea & Williams 2001).

5. Our discussion of possible computational mechanisms is neutral on whether positive affect is triggered because high fluency indicates that a stimulus is likely to have been encountered before, because the stimulus is likely to be recognized, or because the processing is consistent with expectations. Our discussion also leaves open whether positive affect is directly triggered by the signal of fluency, without mediation of conscious awareness, or requires subjective mediation (i.e., a feeling that a stimulus is easy to process).

6. The effects of stimulus similarity (prototypicality) and symmetry are consistent with the above computational model (Lewenstein & Nowak 1989). Similarity between two patterns may be operationalized as the correlation between states of neurons representing the first and the second pattern. Accordingly, a novel pattern similar to one of the known patterns will trigger a stronger fluency signal than a dissimilar pattern. The same logic also suggests that novel patterns that follow the typical relations among neurons representing known patterns will trigger stronger fluency signals than novel patterns that violate typical relations among neurons. One example of such a case are symmetrical patterns. Objects in the real world typically are characterized by vertical symmetry (Palmer 1991). As a result, the connections between pairs of neurons representing the left and the right side of an object are typically positive. Accordingly, novel, but symmetrical patterns should produce a strong "fluency" signal because signals between the neurons that encode symmetrical features are coherent and thus add up.

References

Anderson, N. H. (1981). *Foundations of information integration theory.* New York: Academic Press.

Bar, M., & Biederman, I. (1998). Subliminal visual priming. *Psychological Science, 9*, 464–469.

Bargh, J. A. (1996). Automaticity in social psychology. In E. T. Higgins, & A. W. Kruglanski (Ed.), *Social Psychology: Handbook of Basic Principles* (pp. 169–183). New York: Guilford Press.

Beeman, M., Ortony, A., & Monti, L. A. (1995). Emotion-cognition interactions. In M. A. Arbib (Ed.), *The handbook of brain theory and neural networks* (pp. 360–363). Cambridge, MA: MIT Press.

Berlyne, D. E. (1974). *Studies in the new experimental aesthetics: Steps toward an objective psychology of aesthetic appreciation*. Washington, 1974: Hemisphere Co.

Bonanno, G. A., & Stillings, N. A. (1986). Preference, familiarity, and recognition after repeated brief exposures to random geometric shapes. *American Journal of Psychology, 99*, 403–415.

Bornstein, R. F. (1989). Exposure and affect: Overview and meta-analysis of research, 1968–1987. *Psychological Bulletin, 106*, 265–289.

Bornstein, R. F., & D'Agostino, P. R. (1994). The attribution and discounting of perceptual fluency: Preliminary tests of a perceptual fluency/attributional model of the mere exposure effect. *Social Cognition, 12*, 103–128.

Bornstein, R. F., & D'Agostino, P. R. (1992). Stimulus recognition and the mere exposure effect. *Journal of Personality and Social Psychology, 63*, 545–552.

Cacioppo, J. T., Bush, L. K., & Tassinary, L. G. (1992). Microexpressive facial actions as a function of affective stimuli: Replication and extension. *Personality and Social Psychology Bulletin, 18*, 515–526.

Carver, C. S., & Scheier, M. F. (1990). Origins and functions of positive and negative affect: A control-process view. *Psychological Review, 97*, 19–35.

Checkosky, S. F., & Whitlock, D. (1973). The effects of pattern goodness on recognition time in a memory search task. *Journal of Experimental Psychology, 100*, 341–348.

Curran, T. (2000). Brain potentials of recollection and familiarity. *Memory and Cognition, 28*, 923–938.

Damasio, A. R. (1994). *Descartes' error: Emotion, reason and the human brain*. New York: Grosset/Putnam.

Derryberry, D., & Tucker, D. M. (1994). Motivating the focus of attention. In P. M. N. & S. Kitayama (Eds.), (pp. 167–196). San Diego: Academic Press.

Desimone, R., Miller, E. K., Chelazzi, L., & Lueschow, A. (1995). Multiple memory systems in the visual cortex. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 475–490). Cambridge, MA: MIT Press.

Devine, P., Tauer, J. M., Barron, K. E., & Elliot, A. J. (1999). Moving beyond attitude change in the study of dissonance-related processes. In E. Harmon-Jones & J. Mills (Eds.), *Cognitive Dissonance: Progress on a pivotal theory in social psychology* (pp. 297–323). Washington, DC: APA.

Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science, 11*, 86–89.

Drogosz, M., & Nowak, A. (1998). Simulation theory of the mere exposure effect: The EXAC neural network model. *Unpublished manuscript.*

Enquist, M., & Arak, A. (1994). Symmetry, beauty and evolution. *Nature, 372*, 169–172.

Etcoff, N. (1999). *Survival of the prettiest: The science of beauty*. New York: Doubleday.

Fernandez-Duque, D., Baird, J. A., & Posner, M. I. (2000). Executive attention and metacognitive regulation. *Consciousness and Cognition, 9*, 288–307.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research*. Reading, MA: Addison-Wesley.

Frijda, N. H. (1988). The laws of emotions. *American Psychologist, 43*, 349–358.

Garcia-Marques, T., & Mackie, D. M. (2000). The positive feeling of familiarity: Mood as an information processing regulation mechanism. In H. Bless & J. Forgas (Eds.), *The message within: The role of subjective experience in social cognition and behavior* (pp. 240–261). Philadelphia: Psychology Press.

Haber, R. N., & Hershenson M. (1965). The effects of repeated brief exposures on growth of a percept. *Journal of Experimental Psychology, 69*, 40–46.

Halberstadt J., & Rhodes G. (2000). The attractiveness of nonface averages: Implications for an evolutionary explanation of the attractiveness of average faces. *Psychological Science, 4*, 285–289.

Harmon-Jones, E. (2000). A cognitive dissonance theory perspective on the role of emotion in the maintenance and change of beliefs and attitudes. In N. H. Frijda, A. R. S. Manstead, & S. Bem (Eds.), *Emotion and Beliefs* (pp. 185–211). Cambridge, UK: Cambridge University Press.

Harmon-Jones, E., & Allen, J. J. B. (2001). The role of affect in the mere exposure effect: Evidence from psychophysiological and individual differences approaches. *Personality and Social Psychology Bulletin, 27*, 889–898.

Higgins, E. T. (1998). The aboutness principle: A pervasive influence on human inference. *Social Cognition, 16*, 173–198.

Hopfield, J. J. (1982). Neural networks and physical systems with emergent collective computational abilities. *Proceedings of the National Academy of Sciences, 79*, 2554–2558.

Hopfield, J. J. (1984). Neurons with graded response have collective computational properties like those of two-state neurons. *Proceedings of the National Academy of Sciences, 81*, 3088–3092.

Jacoby, L. L. (1983). Perceptual enhancement: Persistent effects of an experience. *Journal of Experimental Psychology Learning, Memory, and Cognition, 9*, 21–38.

Jacoby, L. L., & Dallas M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110*, 306–340.

Jacoby, L. L., Kelley C. M., & Dywan J. (1989). Memory attributions. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 391–422). Hillsdale, NJ: Erlbaum.

Johnstone, R. A. (1994). Female preference for symmetrical males as a by-product of selection for mate recognition. *Nature, 372*, 172–175.

Kelley, C. M., & Jacoby, L. L. (1998). Subjective reports and process dissociation: Fluency, knowing, and feeling. *Acta Psychologica, 98*, 127–140.

Klinger, M. R., & Greenwald A. G. (1994). Preferences need no inferences?: The cognitive basis of unconscious mere exposure effects. In P. M. Niedenthal & S. Kitayama (Eds.), *The heart's eye* (pp. 67–85). San Diego: Academic Press.

Koriat, A. (2000). The feeling of knowing: Some metatheoretical implications for consciousness and control. *Consciousness and Cognition, 9*, 149–171.

Kunst-Wilson, W. R., & Zajonc, R. B. (1980). Affective discrimination of stimuli that cannot be recognized. *Science, 207*, 557–558.

Lane, R. D., Reiman, E. M., Axelrod, B., Yun, L., Holmes, A., & Schwartz, G. E. (1998). Neural correlates of levels of emotional awareness: Evidence of an interaction between emotion and attention in the anterior cingulate cortex. *Journal of Cognitive Neuroscience, 10,* 525–535.

Langlois, J. H., & Roggman, L. A. (1990). Attractive faces are only average. *Psychological Science, 1,* 115–121.

LeDoux, J. E. (1996). *The Emotional Brain.* New York: Touchstone.

Lewenstein, M., & Nowak, A. (1989). Recognition with self-control in neural networks. *Physical Review, 40,* 4652–4664.

Losch, M. E., & Cacioppo, J. T. (1990). Cognitive dissonance may enhance sympathetic tonus, but attitudes are changed to reduce negative affect rather than arousal. *Journal of Experimental Social Psychology, 26,* 289–304.

Mackworth, J. F. (1963). The duration of the visual image. *Canadian Journal of Psychology, 17,* 62–81.

Mandler, G., Nakamura, Y., & Van Zandt, B. J. (1987). Nonspecific effects of exposure on stimuli that cannot be recognized. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 646–648.

Martindale, C., & Moore, K. (1988). Priming, prototypicality, and preference. *Journal of Experimental Psychology: Human Perception and Performance, 14,* 661–670.

Mazzoni, G., & Nelson, T. O. (Eds.). (1998). *Metacognition and cognitive neuropsychology: Monitoring and control processes.* Mahwah, NJ.: Lawrence Erlbaum.

McClelland, J. L., & Chappell, M. (1998). Familiarity breeds differentiation: A Bayesian approach to the effects of experience in recognition memory. *Psychological Review, 105,* 724–760.

McGlone, M. S., & Tofighbakhsh, J. (2000). Birds of a feather flock conjointly (?): Rhyme as reason in aphorisms. *Psychological Science, 11,* 424–428.

Metcalfe, J. (1993). Novelty monitoring, metacognition, and control in a composite holographic associative recall model: Implications for Korsakoff Amnesia. *Psychological Review, 100,* 3–22.

Metcalfe, J., & Shimamura, A. P. (Eds.). (1994). *Metacognition: Knowing about knowing.* Cambridge, MA: MIT Press.

Monahan, J. L., Murphy S. T., & Zajonc R. B. (2000). Subliminal mere exposure: Specific, general, and diffuse effects. *Psychological Science, 6,* 462–466.

Murre, J. M. J., Phaf, R. H., & Wolters, G. (1992). CALM: Categorizing and learning module. *Neutral Networks,* 55–82.

Norman, K. A., O'Reilly, R. C., & Huber, D. E. (2000). Modeling hippocampal and neocortical contributions to recognition memory. *Poster presented at the Cognitive Neuroscience Society Meeting, San Francisco, CA.*

Nowak, A., & Vallacher R. R. (1998). *Dynamical social psychology.* New York: Guilford Press.

O'Reilly, R. C., & Munakata, Y. (2000). *Computational explorations in cognitive neuroscience: Understanding the mind by simulating the brain.* Cambridge, MA: MIT Press.

Oatley, K., & Johnson-Laird, P. (1987). Towards a cognitive theory of emotions. *Cognition and Emotion, 1,* 29–50.

Oehman, A., Flykt, A., & Lundqvist, D. (2000). Unconscious Emotion: Evolutionary perspectives, psychophysiological data and neuropsychological mechanisms. In R. Lane & L. Nadel (Eds.), *Cognitive Neuroscience of Emotion* (pp. 296–327). New York: Oxford University Press.

Ortony, A., Clore, G. L., & Collins, A. (1988). *The cognitive structure of emotions.* New York: Cambridge University Press.

Palmer, S. E. (1991). Goodness, gestalt, groups, and Garner: Local symmetry subgroups as a theory of figural goodness. In J. R. Pomerantz & G. R. Lockhead (Eds.), *Perception of Structure.* Washington, DC: APA.

Phaf, R. H., Rotteveel, M., & Spijksma, F. P. (under review). False recognition and affective priming.

Pinker, S. (1997). *How the mind works.* New York: Norton.

Poldrack, R. A., & Logan, G. D. (1998). What is the mechanism for fluency in successive recognition? *Acta Psychologica, 98,* 167–181.

Port, R. T., & van Gelder, T. (1995). *Mind as motion: Exploration in the dynamics of cognition.* Cambridge, MA: MIT Press.

Posner, M. I., & Keele S. W. (1968). On the genesis of abstract ideas. *Journal of Experimental Psychology, 77,* 353–363.

Ramachandran, V. S., & Hirstein, W. (1999). The science of art: A neurological theory of aesthetic experience. *Journal of Consciousness Studies, 6,* 15–51.

Reber, R., & Schwarz, N. (2001). The hot fringes of consciousness: Perceptual fluency and affect. *Consciousness & Emotion, 2,* 223–231.

Reber, R., Winkielman, P., & Schwarz, N. (1998). Effects of perceptual fluency on affective judgments. *Psychological Science, 9,* 45–48.

Reisenzein, R. (1983). The Schachter theory of emotion: Two decades later. *Psychological Bulletin, 94,* 239–264.

Reisenzein, R. (1998). A theory of emotions as metarepresentational states of mind. In A. H. Fischer (Ed.), *SRE'98. Proceedings of the 10th Conference of the International Society for Research on Emotions* (pp. 186–191). Faculty of Psychology: Amsterdam.

Rhodes, G., Proffitt, F., Grady, J. M., & Sumich, A. (1998). Facial symmetry and the perception of beauty. *Psychonomic Bulletin & Review, 5,* 659–669.

Rhodes, G., & Tremewan, T. (1996). Averageness, exaggeration, and facial attractiveness. *Psychological Science, 7,* 105–110.

Roediger, H. L. (1990). Implicit memory: Retention without remembering. *American Psychologist, 45,* 1043–1056.

Rolls, E. T., Baylis, G. C., Hasselmo, M. E., & Nalwa, V. (1989). The effect of learning on the face selective responses of neurons in the cortex in the superior temporal sulcus of the monkey. *Experimental Brain Research, 76,* 153–164.

Rumelhart, D. E., & McClelland, J. L. (Eds.). (1986). *Parallel Distributed Processes: Exploration in Microstructure of Cognition.* Cambridge, MA: MIT Press.

Schachter, S. E., & Singer J. (1962). Cognitive, social and physiological determinants of emotional state. *Psychological Review, 69,* 379–399.

Schacter, D. L. (1992). Understanding implicit memory: A cognitive neuroscience approach. *American Psychologist, 47,* 559–569.

Schwarz, N. (1990). Feeling as information: Informational and motivational functions of affective states. In E. T. Higgins & R. M. Sorrentino (Eds.), *Handbook of motivation and cognition* (pp. 527–561). New York: Guilford Press.

Schwarz, N. (1998). Accessible content and accessibility experiences: The interplay of declarative and experiential information in judgment. *Personality and Social Psychology Review, 2*, 87–99.

Schwarz, N., & Clore, G. L. (1983). Mood, misattribution, and judgments of well-being: Informative and directive functions of affective states. *Journal of Personality and Social Psychology, 45*, 513–523.

Schwarz, N., & Clore, G. L. (1996). Feelings and phenomenal experiences. In E. T. Higgins & A. W. Kruglanski (Eds.), *Social Psychology: Handbook of Basic Principles*. New York: The Guilford Press.

Seamon, J. G., Brody, N., & Kauff, D. M. (1983). Affective discrimination of stimuli that are not recognized: Effects of shadowing, masking, and cerebral laterality. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*, 544–555.

Seamon, J. G., Marsh, R. L., & Brody, N. (1984). Critical importance of exposure duration for affective discrimination of stimuli that are not recognized. *Journal of Experimental Psychology Learning, Memory, and Cognition, 10*, 465–469.

Seamon, J. G., McKenna, P. A., & Binder, N. (1998). The mere exposure effect is differentially sensitive to different judgment tasks. *Consciousness and Cognition, 7*, 85–102.

Simon, H. A. (1967). Motivational and emotional controls of cognition. *Psychological Review, 74* , 29–39.

Skarda, C. A., & Freeman, W. J. (1987). How brains make chaos in order to make sense of the world. *Behavioral and Brain Sciences, 10*, 161–195.

Skurnik, I., Schwarz, N., & Winkielman, P. (2000). Drawing inferences from feelings: The role of naive beliefs. In H. Bless & J. P. Forgas (Eds.), *The message within: The role of subjective experience in social cognition and behavior* (pp. 162–175). Philadelphia: Psychology Press.

Smith, E. R. (1998). Mental representation and memory. In D. T. Gilbert, S. T. Fiske, & G. Lindzey (Eds.), *The Handbook of Social Psychology* (pp. 269–322). Boston, MA: The McGraw-Hill Companies, Inc.

Smith, E. R. (2000). Subjective experience of familiarity: Functional basis in connectionist memory. In H. Bless & J. P. Forgas (Eds.), *The message within: The role of subjective experience in social cognition and behavior* (pp. 109–124). Philadelphia: Psychology Press.

Snodgrass, J. G., & Vanderwart M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6*, 174–215.

Sokolov, E. N. (1963). *Perception and the orienting reflex*. NY: MacMillan.

Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review, 99*, 195–231.

Thornhill, R., & Gangestad, S. W. (1993). Human facial beauty: Averageness, symmetry, and parasite resistance. *Human Nature, 4*, 237–269.

Vallacher, R. R., & Nowak, A. (1999). The dynamics of self-regulation. In R. S. Jr. Wyer (Ed.), *Perspectives on behavioral self-regulation* (pp. 241–259). Mahwah: Lawrence Erlbaum Associates.

Whittlesea, B. W. A. (1993). Illusions of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 1235–1253.

Whittlesea, B. W. A., Jacoby L. L., & Girard K. (1990). Illusions of immediate memory: Evidence of an attributional basis for feelings of familiarity and perceptual quality. *Journal of Memory and Language, 29*, 716–732.

Whittlesea, B. W. A., & Williams, L. D. (2001). The Discrepancy-Attribution Hypothesis: I. The Heuristic Basis of Feelings of Familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*, 3–13.

Winkielman P., Berntson, G. G., & Cacioppo, J. T. (2001). The psychophysiological perspective on the social mind. In A. Tesser & N. Schwarz (Eds.), *Blackwell Handbook of Social Psychology: Intraindividual Processes* (pp. 89-108). Oxford: Blackwell.

Winkielman, P., & Cacioppo, J. T. (2001). Mind at ease puts a smile on the face: Psychophysiological evidence that processing facilitation increases positive affect. *Journal of Personality and Social Psychology, 81*, 989–1000.

Winkielman, P., & Schwarz, N. (2001). How pleasant was your childhood? Beliefs about memory shape inferences from experienced difficulty of recall. *Psychological Science, 2*, 176–179.

Winkielman, P., Schwarz, N., Fazendeiro, T., & Reber, R. (in press). The hedonic marking of processing fluency: Implications for evaluative judgment. In J. Musch & K. C. Klauer (Eds.), *The Psychology of Evaluation: Affective Processes in Cognition and Emotion*. Mahwah, NJ: Lawrence Erlbaum.

Winkielman, P., Zajonc, R. B., & Schwarz, N. (1997). Subliminal affective priming resists attributional interventions. *Cognition and Emotion, 11*, 433–465.

Witherspoon, D., & Allan, L. G. (1985). The effects of a prior presentation on temporal judgments in a perceptual identification task. *Memory and Cognition, 13*, 103–111.

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology: Monograph Supplement, 9*, 1–27.

Zajonc, R. B. (1998). Emotions. In D. T. Gilbert, S. T. Fiske, & G. Lindzey (Eds.), *The Handbook of Social Psychology* (pp. 591–632). Boston, MA: McGraw-Hill.

Zajonc, R. B. (2000). Feeling and thinking: Closing the debate over the independence of affect. In J. P. Forgas (Ed.), *Feeling and thinking: The role of affect in social cognition* (pp. 31–58). Cambridge: Cambridge University Press.

Zochowski, M., Lewenstein, M., & Nowak, A. (1994). Local noise in neural networks with self-control. *International Journal of Neural Systems, 5*, 287–298.