Processing Visual Context Violations:

The Roles of Attention and Awareness

Liad Mudrik
Tel Aviv University, Israel

The ease and speed by which biological organisms grasp and interpret visual scenes is one of the greatest puzzles in the study of visual perception; given the complexity and diversity of rich details and the numerous possible combinations by which these details can interact, constructing a meaningful and coherent interpretation of the scene forms a formidable computational challenge. How can such a challenge be met within a few milliseconds (as few as 26ms, see Rieger, Braun, Bulthoff, & Gegenfurtner, 2005; Rousselet, Joubert, & Fabre-Thorpe, 2005), with seemingly no effort whatsoever?

A possible key to solving this question lies in contextual regularities. Prior knowledge and expectations regarding objects' tendency to co-appear in particular scenes narrow the range of probable interpretations and thereby render scene analysis easier. Indeed, when such expectations are violated by incongruent objects (e.g., a polar bear in the middle of a concert hall), scene processing is impeded (e.g., Biederman, Glass, & Stacy, 1973; Biederman, Rabinowitz, Glass, & Stacy, 1974; Friedman, 1979; Palmer, 1975; Rayner & Pollatsek, 1992), both in terms of speed (Bar & Ullman, 1996; Boyce & Pollatsek, 1992; Chun & Jiang, 1998; Davenport & Potter, 2004) and accuracy (e.g., Antes, Penland, & Metzger, 1981; Bar & Ullman, 1996; Biederman, 1972; Boyce, Pollatsek, & Rayner, 1989).

However, this potential solution evokes yet another theoretical difficulty, not easily reconciled within the existing framework of cognitive psychology: on the one hand, high-level integrative and semantic mechanisms should be involved in detecting contextual regularities. Such detection requires at least partial identification of the scene's constituents, an assessment of their probability to co-appear, and most likely the activation of some pre-existing schemes of previous knowledge about them. Arguably, such high-level computations are performed by upstream areas in the visual hierarchy, at relatively late stages of scene processing that already require attention and awareness (Baars, 2005; Koch, 2004; Tononi & Edelman, 1998a). Yet on the other hand, these very same contextual regularities are claimed to *guide* perception, and play a constitutive role in scene processing and interpretation (Bar, 2004; Biederman, 1981; Kosslyn, 1994). For contextual regularities to facilitate perception, they must be detected early enough to guide subsequent processing. *How then can such regularities both involve high-level semantic processing and play a fundamental role in guiding perception, possibly even at its early low-level stages?*

The main thrust of my dissertation was to resolve this theoretical difficulty. In doing so, I employed an interdisciplinary approach, drawing from traditional cognitive psychology theories, current neuroscientific models, electrophysiological methods and philosophical arguments regarding this long-lasting debate over scene perception and its encapsulation from cognition. I was able to find first electrophysiological evidence for early contextual influences on scene processing (Mudrik, Lamy, & Deouell, 2010), and replicate the effect (Mudrik, Lamy & Deouell, in preparation), providing clear support for one of three contradicting theoretical models of contextual processing. I then showed that contextual violations (i.e., a defiance of contextual regularities. For example, a man drinking from a potato rather than from a bottle) can be detected in the absence of awareness (Mudrik, Lamy, & Deouell, 2011), although they don't seem to attract attention via pre-attentive mechanisms (Mudrik, Deouell, & Lamy, 2011). Based on these findings, I put forward a theoretical account that challenges some of the traditional dichotomies in cognitive psychology, and allows for the involvement of high-level cognitive mechanisms in early stages of perception. Furthermore, the finding of context violations detection in the absence of conscious awareness widened the scope of my dissertation, and allowed for more comprehensive discussions – both at the psychological and the philosophical level – regarding the casual efficacy of consciousness. Personally speaking, this fit well with my additional academic interests, as I am currently pursuing a second PhD in philosophy of neuroscience, while also working as a postdoctoral fellow in Christof Koch's lab at Caltech (division of biology).

The interdisciplinary nature of this dissertation was thus in the combination of cognitive models, electrophysiological methods, psychophysics, neuroscientific findings and philosophical discussions. It involved applying electrophysiology to compare and examine cognitive models of contextual processing, suggesting new measures of attentional maintenance vs. capture in Binocular Rivalry, and suppressing the awareness of congruent and incongruent scenes using Continuous Flash Suppression. The latter study has drawn interdisciplinary interest, from psychology through neuroscience to philosophy (e.g., Koch, 2012; Lau & Rosenthal, 2011; Siegel, 2012; Sklar et al., 2012; Zadbood, Lee, & Blake, 2011).

Chapter 1: Theoretical background

Three opposing models for contextual influences on scene processing have been suggested (Figure 1). According to the *perceptual schema model* (Antes et al., 1981; Biederman, Mezzanotte, & Rabinowitz, 1982; Boyce et al., 1989), global, low-resolution contextual information leads to rapid activation of a scene schema (Loftus, Nelson, & Kallman, 1983; Schyns & Oliva, 1994). This, in turn, prompts feature-selective attention that facilitates the subsequent detection of perceptual features associated with objects specified within the schema itself (Antes et al., 1981; Friedman, 1979).

Object model selection or *matching models* (Bar, 2004; Bar & Aminoff, 2003; Bar & Ullman, 1996; Kosslyn, 1994) similarly suggest that contextual information activates a scene schema, which primes identification of schema-congruent object types by modulating the observer's criterion regarding the amount of perceptual information needed to match a particular object representation. Thus, while both models predict that context affects perception prior to objects' complete identification, matching models propose that context influences mainly the decision about object identity and not the actual perceptual analysis of the object.

On the other hand, the *functional isolation model* (De Graef, 1992; Hamm, Johnson, & Kirk, 2002; Hollingworth & Henderson, 1998, 1999) denies any early contextual influences on object recognition. Here, contextual information comes into effect only after object identification, and influences semantic knowledge activation and/or decision-making (Henderson & Hollingworth, 1999). In Chapter 1, I describe these accounts and the predictions they entail, and discuss their relations with the question of attention and consciousness: while the first two models imply that these processes might not be necessary for contextual processing, the latter suggests otherwise.

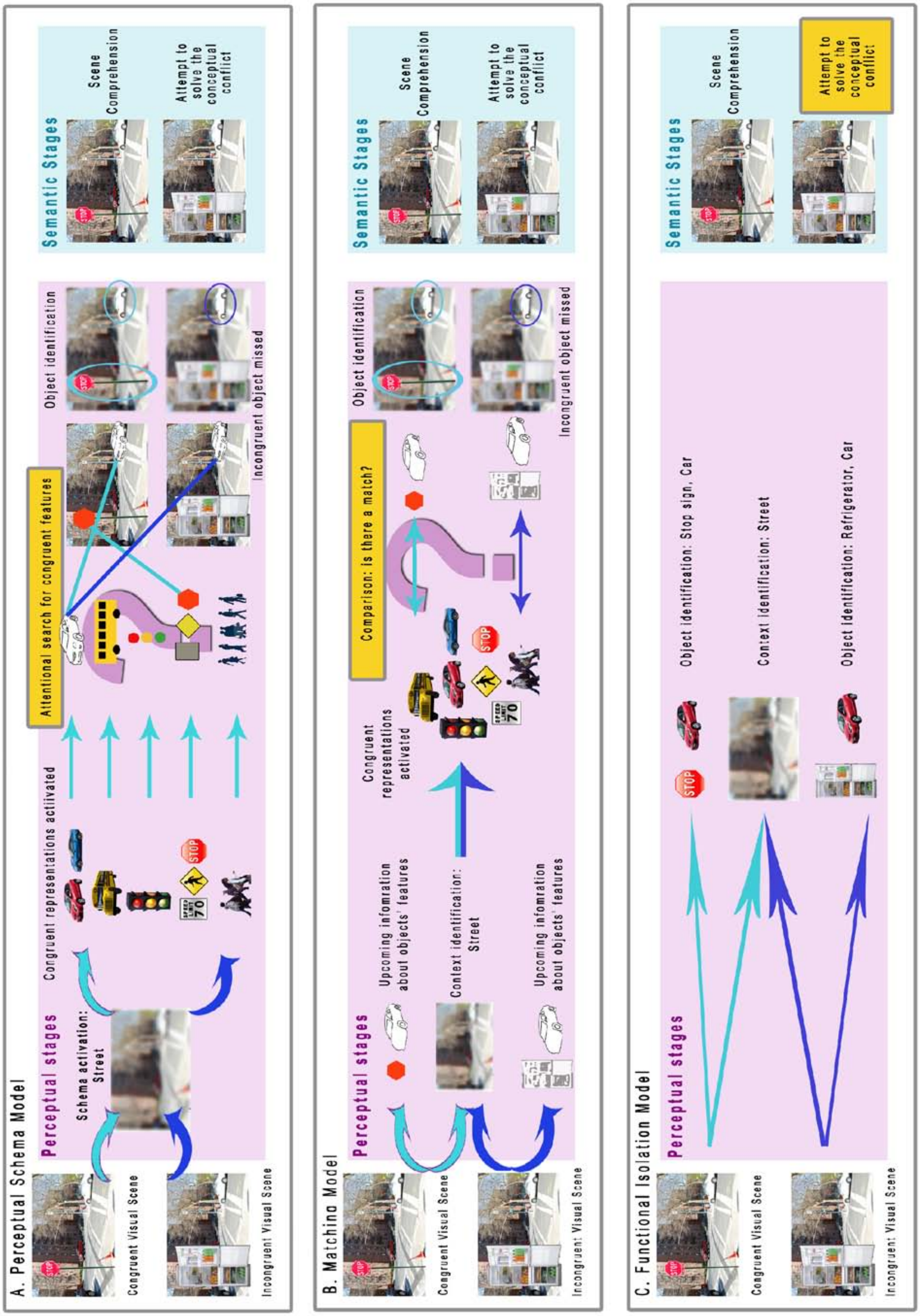
A. Perceptual Schema Model
Perceptual stages
Schema activation: Street
Congruent representations activated
Attentional search for congruent features
Object identification
Incongruent object missed
Semantic Stages
Scene Comprehension
Attempt to solve the conceptual conflict
Congruent Visual Scene
Incongruent Visual Scene
B. Matching Model
Perceptual stages
Upcoming infomration about objects' features
Context identification: Street
Upcoming infomration about objects' features
Congruent representations activated
Comparison: is there a match?
Object identification
Incongruent object missed
Semantic Stages
Scene Comprehension
Attempt to solve the conceptual conflict
Congruent Visual Scene
Incongruent Visual Scene
C. Functional Isolation Model
Perceptual stages
Object identification: Stop sign, Car
Context identification: Street
Object identification: Refrigerator, Car
Semantic Stages
Scene Comprehension
Attempt to solve the conceptual conflict
Congruent Visual Scene
Incongruent Visual Scene

Fig. 1: Illustrations of the three accounts of contextual influence on scene perception. (a) Perceptual schema model: context prompts selective attention to schema-congruent features (b) Matching models: context affects matching routines between upcoming information and activated representations by lowering observer's criterion in favor of context-congruent representations (c) Functional isolation model: context only affects semantic stages of scene processing, after objects and scene identification.

Chapter 2: Behavioral congruity effects and the establishment of a stimuli bank

In order to systematically study contextual processing, I created a stimuli bank that included 188 pairs of congruent (e.g., a woman talking over the phone) and incongruent (e.g., a woman "talking over" a shoe) images (Figure 2). Images' congruency was validated in a pretest of 24 subjects (where 27 pairs were excluded, so that the final stimuli bank included 161 pairs). As opposed to previous studies that controlled for some, but not all, low level features of the stimuli (e.g., Davenport & Potter, 2004; Ganis & Kutas, 2003; West & Holcomb, 2002), we put special care on equating or controlling for a myriad of low level features, from contrast and luminance to chromaticity and spectral frequency. I implemented two image analysis algorithms (Itti & Koch, 2000; Neumann & Gegenfurtner, 2006) using a bootstrapping procedure in order to look for systematic low-level differences between the groups. No such differences were found, hereby making this stimuli bank a unique collection of semantically different image pairs that do not differ in their low-level features. This stimuli bank is currently being used by our group and others for further studies of semantic processing of visual scenes.

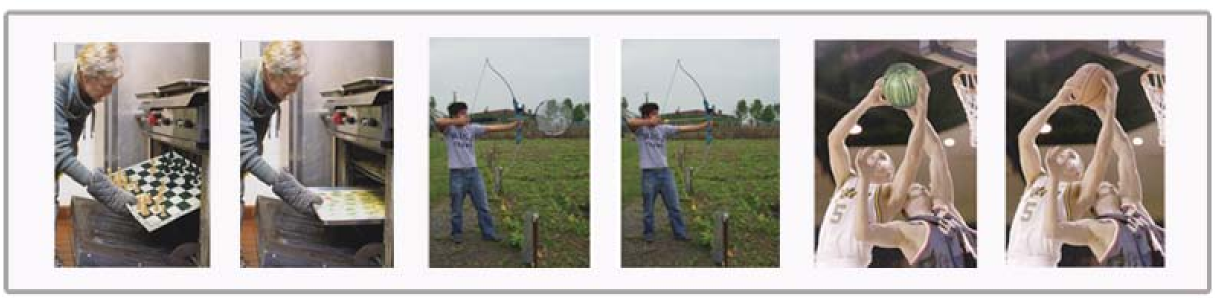

Fig. 2: Examples of the congruent (right) and incongruent (left) images. On the left, a woman putting either food or a chessboard in the oven. In the middle, a boy holding a bow and either an arrow or a tennis racket, and two athletes playing basketball with either a ball or a watermelon.

Chapter 3: Stages of contextual influences on scene processing – an EEG study

Thanks to the insuperable temporal resolution of EEG, one can track the exact moment in time in which waveforms elicited by congruent and incongruent images start to differ. Critically, this allows to empirically contrast the three theoretical models described above, as each of them bears different predictions regarding this moment (Ganis & Kutas, 2003): the perceptual schema model predicts that such differences would be found as early as 0-200 ms post stimulus presentation, when early perceptual processes of attentional selection unfold (e.g., N1 & P1; see, for example, Heinze et al., 1994; or the selection negativity component; Thorpe, Fize, & Marlot, 1996). The matching models, on the other hand, imply finding first differenced between 250 and 350 ms; namely, greater negativity at frontal cites should emerge for incongruent images, representing the difficulty to match the upcoming visual information with the preactivated scene-congruent representations (N300/N350; see Holcomb & McPherson, 1994; McPherson & Holcomb, 1999; Schendan & Kutas, 2002). Finally, the functional isolation models would only allow for late components to be found, more specifically the well-known N400 component (Kutas & Hillyard, 1980a, 1980b, 1980c), held to index neural processes involved in the activation of semantic knowledge (Nobre & Mccarthy, 1995; Van Petten, 1995).

Only one study used EEG to compare the processing of congruent and incongruent visual scenes, reporting late differences in the 300-500 ms window (N390; Ganis & Kutas, 2003). However, these results might have been mitigated by the fact that the context and location of the congruent/incongruent object were known to subjects before this object appeared. Thus, rather than indexing processing of object-context relations per se, the N390 in Ganis and Kutas' study might have reflected either a mismatch between a previously formed expectation and the object that actually appears, or a mismatch between the prepared response and the response that turns out to be correct, much like the mismatch that usually evokes the N400 component (Ganis, Kutas, & Sereno, 1996; Kutas & Hillyard, 1980a, 1980b, 1980c).

I therefore presented object and scene simultaneously, so that subjects cannot form prior expectations about the object's identity. I found an ongoing anterior negativity emerging around 270 ms post stimulus presentation and lasting for about 330 ms. This negativity was followed by a later and broadly distributed negativity between 650 and 850 ms, possibly related to late processes of semantic evaluation and response preparation (Figure 3). The early N300/N400 effect is the first electrophysiological evidence for contextual influences on object identification, rather than post perceptual processes. Its relatively early onset suggests that contextual information may affect *object* *model selection processes*: a context-congruent scene schema is activated, thereby facilitating identification of schema-congruent object types by modulating the observer's criterion regarding the amount of perceptual information needed to match a particular object representation.

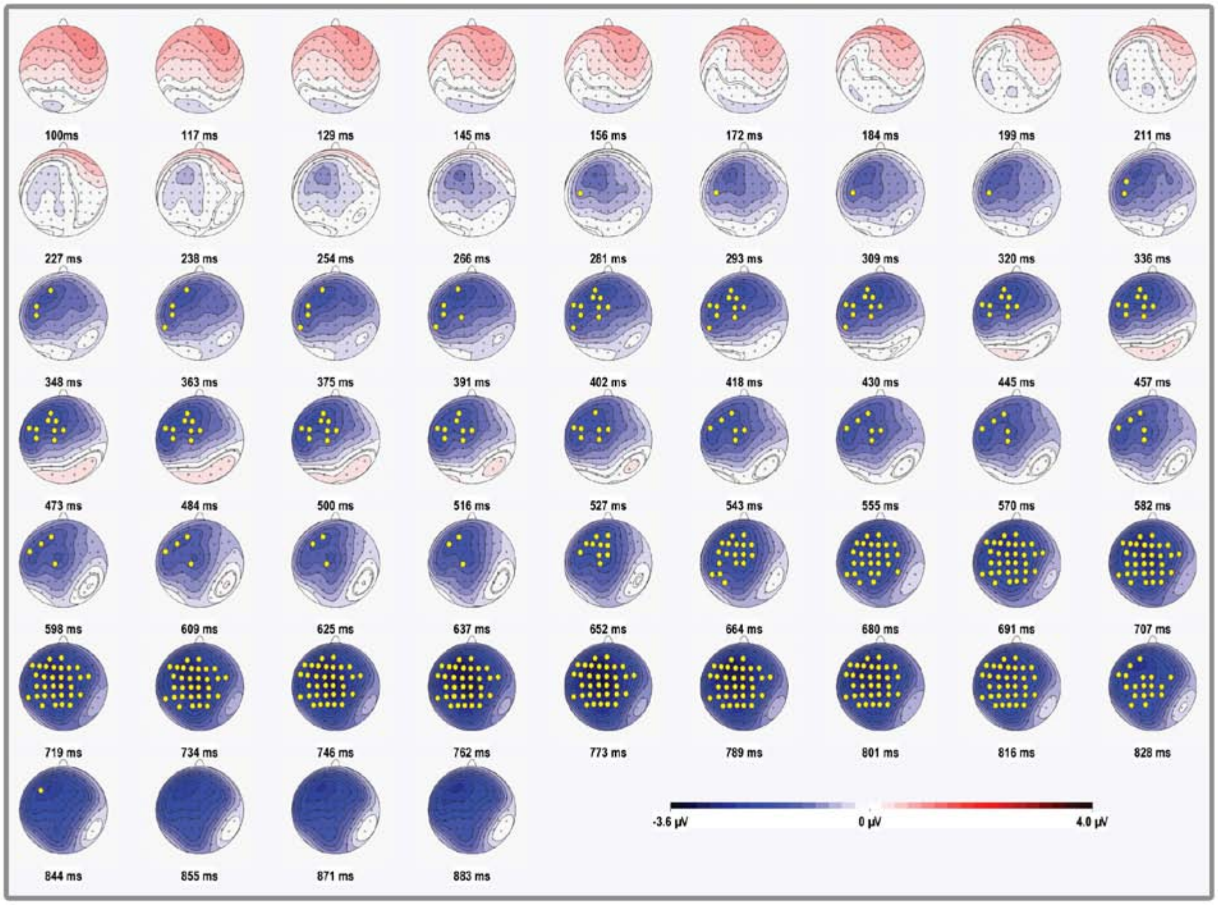

Fig. 3: Distribution maps of the incongruency effect (incongruent – congruent) over time. Electrodes in which a significant effect ($p<0.05$) was found at each time point are highlighted in yellow, with the constraint that the difference was significant for at least 20 consecutive data points.

Chapter 4: the role of attention in processing context-objects relations

The N300/N400 component I found implies that context might affect early stages of perception. This raises the possibility that context-object relations might be preattentively assessed during these early perceptual stages, even when the critical object is outside the focus of attention. Indeed, previous research has shown that both objects (e.g., Delorme, Rousselet, Mace, & Fabre-Thorpe, 2003; Evans & Treisman, 2005; Li, VanRullen, Koch, & Perona, 2002) and scenes (e.g., Brockmole & Henderson, 2006; Hidalgo-Sotelo, Oliva,

& Torralba, 2005; Oliva, 2005) presented outside the focus of attention can be correctly categorized. However, it remains unclear whether the semantic relationship that links an object to the scene or to the context in which it appears can also be processed in the absence of attention. Evidence from eye-fixation studies are inconclusive, as some report earlier fixations on incongruent objects (Friedman, 1979; Loftus & Mackworth, 1978; Underwood & Foulsham, 2006; Underwood, Foulsham, van Loon, Humphreys, & Bloyce, 2006), and others do not (De Graef, Christiaens, & Dydewalle, 1990; Henderson, Weeks, & Hollingworth, 1999).

To examine this question, I conducted another EEG study where subjects' attention was directed to/away from the congruent/incongruent object in the scene using salient exogenous cues (Posner, 1980). I further aimed at replicating the early differences I found in the previous experiment, as this was the first finding of early contextual influences at the stage of representation matching.

Ongoing frontocentral negativity was found for incongruent scenes even earlier, starting as early as 240 ms after stimulus presentation (Figure 4). This early negativity was found both when the critical object was attended and when it was unattended. On the face of it, this seems to indicate that context-object relations can be processed in the absence of attention to the critical object. However, a follow-up behavioral experiment I conducted showed that the attentional manipulation I've used was not effective enough in diverting subjects' attention. Thus, this experiment couldn't shed much light on the possible preattentive processing of congruent and incongruent object. This limitation notwithstanding, the current experiment was important in replicating the former evidence I found for early contextual influences on perceptual processes.

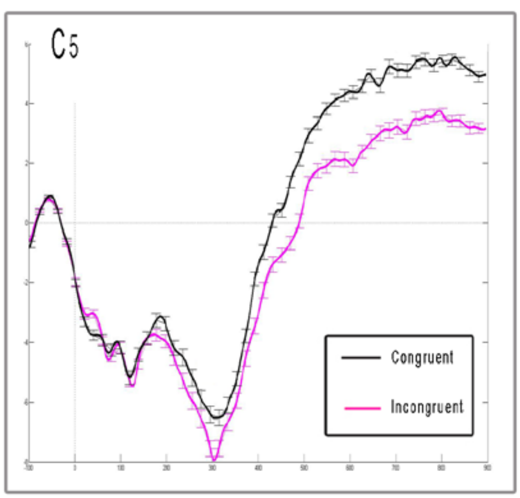

Fig. 4: Congruent and incongruent waveforms at electrode C5, with standard errors, across subjects (n=16). Significant effect begins at ~240ms.

This finding further emphasizes the theoretical difficulty this dissertation was set to solve: how can high-level, semantic contextual relations be processed early enough to influence perception? The findings in the next chapters of my dissertation help disentangle this difficulty.

Chapter 5: the role of awareness in processing context-objects relations

The strong evidence for early contextual processing suggests that not only attention, but also awareness, might not be needed for detecting contextual violations. Since awareness and attention are closely related (so much so that some have even considered them identical; see Merikle & Joordens, 1997; O'Regan & Noe, 2001; Posner, 1994), finding contextual processing in the absence of awareness might also hint on the possibility of such processing outside the focus of attention.

Critically, contextual processing inherently involves the integration of an object and its background. Thus, it should be extremely unlikely to find evidence for unconscious contextual processing, as all the theories that assign functional significance to awareness consider information integration as one of its fundamental features (e.g., Baars, 2005; Edelman, 1989; Koch, 2004; Tononi, 2005; Tononi & Edelman, 1998a). While conscious awareness is thought not to be required for low-level perceptual binding (e.g. of object parts), it is postulated as necessary for rapidly joining together perceptual and conceptual data from a great variety of sources to create a unified, coherent scene or idea (Tononi & Edelman, 1998a, 1998b).

Contrary to all these theories, I managed to demonstrate that object and background relations are indeed integrated in the absence of awareness. Using Continuous Flash Suppression (Tsuchiya & Koch, 2005; Tsuchiya, Koch, Gilroy, & Blake, 2006), I suppressed awareness of congruent and incongruent scenes (Figure 5a).

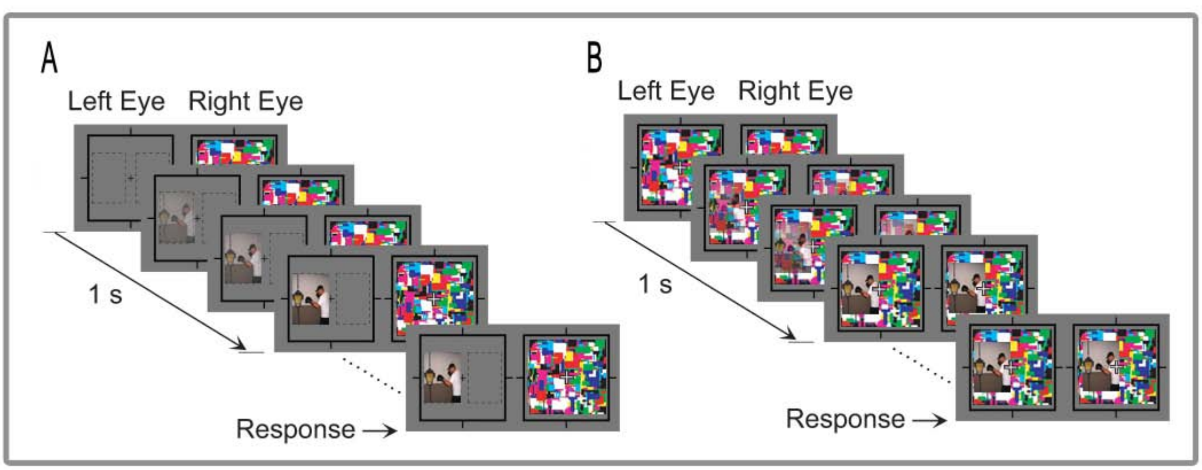

Fig. 5: (a) CFS procedure in the experimental session: The test image (either congruent or incongruent) was gradually introduced to one eye to compete with a Mondrian presented to the dominant eye. The contrast of the test image was linearly ramped up from 0% to 100% within a period of 1 s starting from the beginning of the trial, and then the contrast of the Mondrian decreased at a rate of 2% every 100 ms for the next 5100 ms. (b) Control condition in which the same test stimuli were blended into the dynamic noise pattern and their contrast was ramped up gradually. The images were presented binocularly and their contrast was ramped up at a rate of 2.5% every 100ms.

The scenes were presented to one eye and rivaled against distinct color images (Mondrians) that were flashed into the dominant eye at a frequency of 10 Hz. Incongruent scenes were faster than congruent scenes to escape perceptual suppression and emerge into awareness, indicating that the relations between the congruent/incongruent object and its context were processed without conscious awareness of the object or scene. To rule out the option that the effect stemmed from partial awareness rather than unconscious processing, I run a control condition (Figure 5b). There, the congruent and incongruent images were blended into the dynamic noise pattern of the Mondrian and presented binocularly. The contrast of the images was ramped up, to mimic the perceptual experience during CFS and evoke similar partial awareness. No effect was found in the control condition, suggesting that the difference in emergence times did not rest on partial awareness processes, but on unconscious ones (Figure 6).

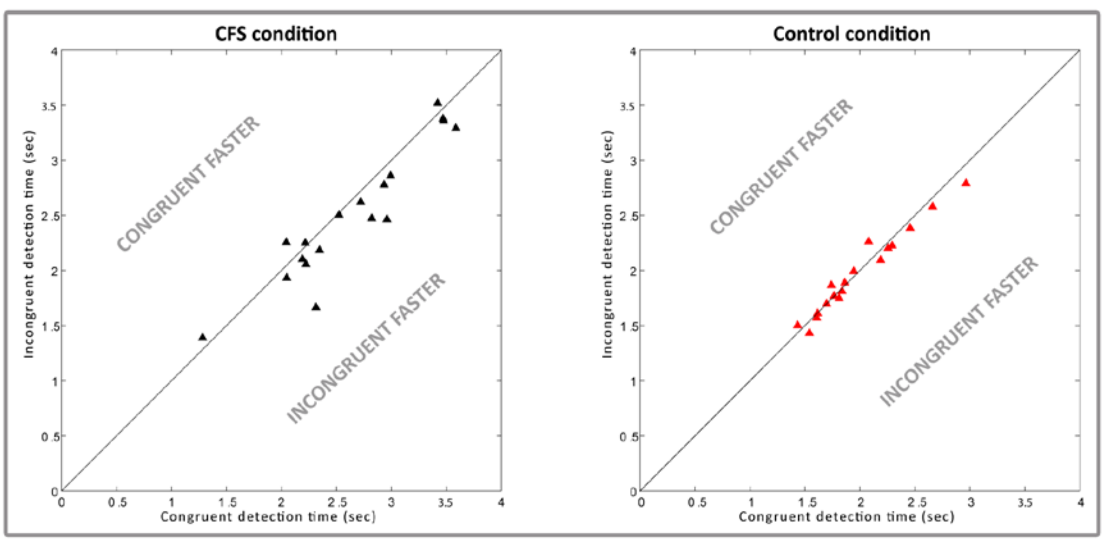

Fig. 6: Suppression durations (detection time) for congruent and incongruent scenes in the CFS condition (left) and control condition (right). Each triangle represents the average suppression duration for an individual subject, where the x coordinates represent the suppression duration of congruent scenes, and the y

coordinates that of incongruent scenes. The diagonal represents equal suppression durations, and data points below the diagonal indicate shorter suppression for incongruent scenes.

This finding is the first evidence of semantic, high-level information integration during unconscious perception. This implies that unconscious processes run deeper in scene analysis than previously thought, and that consciousness might be more about novelty than integration: integration can be unconsciously achieved, yet when it yields unexpected results, consciousness is called upon to comprehend the novel situation (so that incongruent images emerge faster). This new account of the functionality of consciousness, although challenging existing theories, finds support both in previous suggestions for the need for consciousness in the face of novel situations (Baars, 1988; Dehaene & Naccache, 2001; Gray, 1995). In the dissertation, I combine psychological and philosophical discussions of this issue, in order to better clarify the concepts at hand, the solution I suggest and its philosophical limitations.

Chapter 6: preferential status of context violations for attention and awareness

The results of the CFS experiment clearly demonstrated that scenes containing context violations are more potent in reaching subjects' awareness than scenes devoid of such violations. This strengthens the hypothesis that context violations can attract attention. But is it the whole scene that attracts attention or the actual incongruent object? Since in CFS whole scenes were competing against dynamic colored patterns, this question remained unanswered.

Thus, in chapter 6 I describe three experiments that directly compared the attentional status of incongruent and congruent objects. I developed a version of Binocular Rivalry (BR; for reviews, see Blake & Logothetis, 2002; Leopold & Logothetis, 1999; Sterzer, Jalkanen, & Rees, 2009) in which congruent and incongruent objects rivaled against each other within a given scene (Fig. 7). Contrary to previous studies that only reported overall predominance during BR (e.g., Alpers & Pauli, 2006; Coren & Russell, 1992; Yoon, Joormann, Hong, & Kang, 2009), I defined new measures that differentiated between attentional attraction and attentional maintenance (the difficulty to disengage attention from a stimulus, after it has been attended).

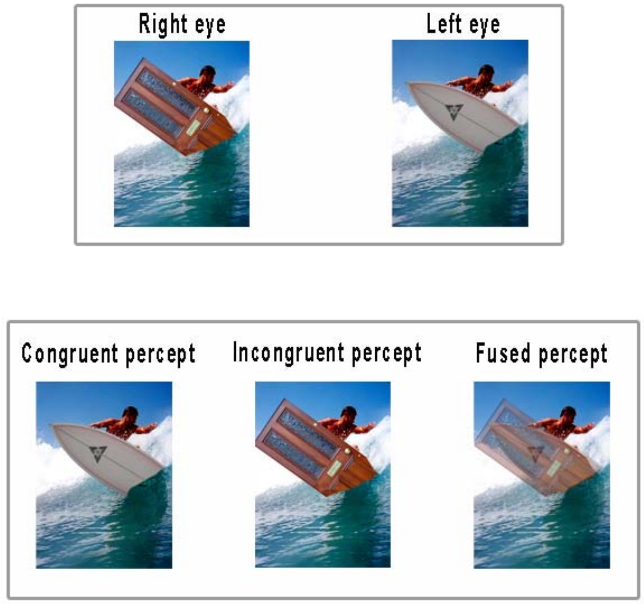

Fig. 7: Top: Dichoptic stimulus presentation of a congruent scene to one eye and of an incongruent scene to the other eye. Bottom: Examples of the possible visual percepts: a congruent scene, an incongruent scene or a mixture of both (i.e., the congruent and incongruent objects are perceived simultaneously, which is referred to as a fused percept).

Incongruent objects were perceived during a higher proportion of the viewing time compared with congruent objects. Using the measures I defined, I showed that this overall predominance of incongruent objects stems from *the difficulty to disengage attention from them*, rather than from their ability to attract attention. In a control experiment I showed that when the objects rivaled against each other in isolation, with no background with which they might be congruent or incongruent, no difference was found in BR dominance. This confirmed that the effects found in the first two BR experiments genuinely reflected the objects' semantic relations with the background, rather than some low level attributes of the objects themselves (note that low level features of the entire images were equated and controlled for; see Chapter 2). Based on these results, I suggested a model for scene perception that accounts for the roles of attention and awareness in contextual processing, so that once an incongruent object is incidentally detected during parallel scene and object processing, the entire scene becomes attentionally salient and requires conscious inspection in order to resolve the conceptual conflict evoked by the contextual violation embedded in the scene.

Chapter 7: General discussion & conclusions

Taken together, my findings show that high-level contextual information affects relatively early perceptual stages and can be processed in the absence of awareness;

semantic links between objects and their background are processed relatively early, starting from about 240 ms (Chapter 4) to 270 ms (Chapter 3) post stimulus presentation. In addition, while previous studies have limited their investigation of unconscious semantic processing of single items (for review, see Kouider & Dehaene, 2007), I found that object-background integration of complex real-life scenes can also take place without conscious perception (Chapter 5). Finally, I showed that while incongruent objects fail to attract attention, it is more difficult to disengage one's attention from them, once they have been incidentally attended (Chapter 6).

Drawing from these findings I proposed a theoretical framework for contextual processing that undermines traditional dichotomies between perception and cognition, and between low-level unconscious processing and high-level mechanisms that require conscious awareness. I claimed that high and low level information continuously interact during scene perception, influencing one another. While doing so, I examined the concepts of perception and cognition, and the different theoretical accounts put forward to describe their relations. I then turned to examine how the cognitive model I suggested fits with neuroscientific findings regarding the neural correlates of contextual processing. Relying on these findings, I suggested a possible neural mechanism of context-object relations processing in the absence of awareness, during early perceptual stages. Finally, I discussed some of the leading philosophical arguments regarding the nature of consciousness and its functionality, as the results seem to tap not only issues about cognitive processing and the neural mechanisms that might underlie them, but also regarding philosophy of mind.

To conclude, I hope the Glushko prize committee will be willing to consider this dissertation as an example for a truly interdisciplinary approach to solving a major theoretical question in cognitive psychology: the possible involvement of high-level cognitive processes in what is commonly considered as low-level perceptual stages. In an attempt to tie together electrophysiological, psychophysical and neuroscientific findings with some theoretical work that combines both classical psychology and philosophy, I have tried to put forward an answer to this question.

I consider cognitive neuroscience a uniquely interdisciplinary field, combining knowledge and methods drawn from psychology, biology, computation and philosophy – among other disciplines. This was one of the motivations that drove me to be a student of the interdisciplinary program for outstanding students, and to pursue two PhD degrees rather than one – both aim at understanding mind-brain relations, yet from different perspectives. Thus, I would be honored to be considered as a possible candidate for the

Glushko prize that puts that much emphasize on the importance of interdisciplinarity in the studying the mind.

References

Alpers, G. W., & Pauli, P. (2006). Emotional pictures predominate in binocular rivalry. *Cognition & Emotion, 20*(5), 596-607.

Antes, J. R., Penland, J. G., & Metzger, R. L. (1981). Processing Global Information in Briefly Presented Pictures. *Psychological Research-Psychologische Forschung, 43*(3), 277-292.

Baars, B. J. (1988). *A cognitive theory of consciousness*. Cambridge: Cambridge University Press.

Baars, B. J. (2005). Global workspace theory of consciousness: toward a cognitive neuroscience of human experience. *Progress in Brain Research, 150*, 45-53.

Bar, M. (2004). Visual objects in context. *Nature Reviews Neuroscience, 5*(8), 617-629.

Bar, M., & Aminoff, E. (2003). Cortical analysis of visual context. *Neuron, 38*(2), 347-358.

Bar, M., & Ullman, S. (1996). Spatial context in recognition. *Perception, 25*(3), 343-352.

Biederman, I. (1972). Perceiving real-world scenes. *Science, 177*(43), 77-80.

Biederman, I. (1981). On the semantics of a glance at a scene. In M. Kubovy & J. R. Pomerantz (Eds.), *Perceptual organization* (pp. 213–253). Hillsdale, New Jersey: Lawrence Erlbaum Associates Inc.

Biederman, I., Glass, A. L., & Stacy, E. W. (1973). Searching for Objects in Real-World Scences. *Journal of Experimental Psychology, 97*(1), 22-27.

Biederman, I., Mezzanotte, R. J., & Rabinowitz, J. C. (1982). Scene perception: detecting and judging objects undergoing relational violations. *Cognitive Psychology, 14*(2), 143-177.

Biederman, I., Rabinowitz, J. C., Glass, A. L., & Stacy, E. W. (1974). Information Extracted from a Glance at a Scene. *Journal of Experimental Psychology, 103*(3), 597-600.

Blake, R., & Logothetis, N. K. (2002). Visual competition. *Nature Reviews Neuroscience, 3*(1), 13-23.

Boyce, S. J., & Pollatsek, A. (1992). Identification of Objects in Scenes - the Role of Scene Background in Object Naming. *Journal of Experimental Psychology-Learning Memory and Cognition, 18*(3), 531-543.

Boyce, S. J., Pollatsek, A., & Rayner, K. (1989). Effect of Background Information on Object Identification. *Journal of Experimental Psychology-Human Perception and Performance, 15*(3), 556-566.

Brockmole, J. R., & Henderson, J. M. (2006). Recognition and attention guidance during contextual cueing in real-world scenes: Evidence from eye. *Quarterly Journal of Experimental Psychology, 59*(7), 1177-1187.

Chun, M. M., & Jiang, Y. H. (1998). Contextual cueing: Implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology, 36*(1), 28-71.

Coren, S., & Russell, J. A. (1992). The Relative Dominance of Different Facial Expressions of Emotion under Conditions of Perceptual Ambiguity. *Cognition & Emotion, 6*(5), 339-356.

Davenport, J. L., & Potter, M. C. (2004). Scene consistency in object and background perception. *Psychological Science*, *15*(8), 559-564.

De Graef, P. (1992). Scene-context effects and models of real-world perception. In K. Rayner (Ed.), *Eye Movements and Visual Cognition: Scene Perception and Reading* (pp. 243–259). New York: Springer.

De Graef, P., Christiaens, D., & Dydewalle, G. (1990). Perceptual Effects of Scene Context on Object Identification. *Psychological Research-Psychologische Forschung, 52*(4), 317-329.

Dehaene, S., & Naccache, L. (2001). Towards a cognitive neuroscience of consciousness: basic evidence and a workspace framework. *Cognition, 79*(1-2), 1-37.

Delorme, A., Rousselet, G. A., Mace, M. J. M., & Fabre-Thorpe, M. (2003). Interaction of top-down and bottom-up processing in the fast analysis of natural scenes. *Cognitive Brain Research, 19*, 103-113.

Edelman, G. M. (1989). *The remembered present : a biological theory of consciousness* New York Basic Books.

Evans, E., & Treisman, A. (2005). Perception of objects in natural scenes: Is it really attention free? *Journal of Experimental Psychology: Human Perception and Performance, 31*, 1476-1492.

Friedman, A. (1979). Framing Pictures - Role of Knowledge in Automatized Encoding and Memory for Gist. *Journal of Experimental Psychology-General, 108*(3), 316-355.

Ganis, G., & Kutas, M. (2003). An electrophysiological study of scene effects on object identification. *Cognitive Brain Research, 16*(2), 123-144.

Ganis, G., Kutas, M., & Sereno, M. I. (1996). The search for "common sense": An electrophysiological study of the comprehension of words and pictures in reading. *Journal of Cognitive Neuroscience, 8*(2), 89-106.

Gray, J. A. (1995). The Contents of Consciousness - a Neuropsychological Conjecture. *Behavioral and Brain Sciences, 18*(4), 659-676.

Hamm, J. P., Johnson, B. W., & Kirk, I. J. (2002). Comparison of the N300 and N400 ERPs to picture stimuli in congruent and incongruent contexts. *Clinical Neurophysiology, 113*(8), 1339-1350.

Heinze, H. J., Mangun, G. R., Burchert, W., Hinrichs, H., Scholz, M., Munte, T. F., . . . Hillyard, S. A. (1994). Combined Spatial and Temporal Imaging of Brain Activity during Visual Selective Attention in Humans. *Nature, 372*(6506), 543-546.

Henderson, J. M., & Hollingworth, A. (1999). High-level scene perception. *Annual Review of Psychology, 50*, 243-271.

Henderson, J. M., Weeks, P. A., & Hollingworth, A. (1999). The effects of semantic consistency on eye movements during complex scene viewing. *Journal of Experimental Psychology-Human Perception and Performance, 25*(1), 210-228.

Hidalgo-Sotelo, B., Oliva, A., & Torralba, A. (2005). Human learning of contextual priors for object search: Where does the time go? *Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 3*, 86-93.

Holcomb, P. J., & McPherson, W. B. (1994). Event-Related Brain Potentials Reflect Semantic Priming in an Object Decision Task. *Brain and Cognition, 24*(2), 259-276.

Hollingworth, A., & Henderson, J. M. (1998). Does consistent scene context facilitate object perception? *Journal of Experimental Psychology-General, 127*(4), 398-415.

Hollingworth, A., & Henderson, J. M. (1999). Object identification is isolated from scene semantic constraint: evidence from object type and token discrimination. *Acta Psychologica, 102*(2-3), 319-343.

Itti, L., & Koch, C. (2000). A saliency-based search mechanism for overt and covert shifts of visual attention. *Vision Research, 40*(10-12), 1489-1506.

Koch, C. (2004). *The Quest for Consciousness: A Neurobiological Approach*: Roberts & Company Publishers.

Koch, C. (2012). *Consciousness - Confessions of a Romantic Reductionist*. Massachusetts: MIT press.

Kosslyn, S. M. (1994). *Image and Brain*. Cambridge, MA: MIT Press.

Kouider, S., & Dehaene, S. (2007). Levels of processing during non-conscious perception: a critical review of visual masking. *Philosophical Transactions of the Royal Society B-Biological Sciences, 362*(1481), 857-875.

Kutas, M., & Hillyard, S. A. (1980a). Event-related brain potentials to semantically inappropriate and surprisingly large words. *Biological Psychology, 11*(2), 99-116.

Kutas, M., & Hillyard, S. A. (1980b). Reading between the lines: event-related brain potentials during natural sentence processing. *Brain and Language, 11*(2), 354-373.

Kutas, M., & Hillyard, S. A. (1980c). Reading Senseless Sentences - Brain Potentials Reflect Semantic Incongruity. *Science, 207*(4427), 203-205.

Lau, H., & Rosenthal, D. (2011). Empirical support for higher-order theories of conscious awareness. *Trends in Cognitive Sciences, 15*(8), 365-373.

Leopold, D. A., & Logothetis, N. K. (1999). Multistable phenomena: Changing views in perception. *Trends in Cognitive Sciences, 3*(7), 254-264.

Li, F. F., VanRullen, R., Koch, C., & Perona, P. (2002). Rapid natural scene categorization in the near absence of attention. *Proceedings of the National Academy of Sciences of the United States of America, 99*(14), 9596-9601.

Loftus, G. R., & Mackworth, N. H. (1978). Cognitive Determinants of Fixation Location During Picture Viewing. *Journal of Experimental Psychology-Human Perception and Performance, 4*(4), 565-572.

Loftus, G. R., Nelson, W. W., & Kallman, H. J. (1983). Differential Acquisition Rates for Different Types of Information from Pictures. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 35*, 187-198.

McPherson, W. B., & Holcomb, P. J. (1999). An electrophysiological investigation of semantic priming with pictures of real objects. *Psychophysiology, 36*(1), 53-65.

Merikle, P. M., & Joordens, S. (1997). Parallels between Perception without Attention and Perception without Awareness. *Conscious Cogn, 6*(2/3), 219-236.

Mudrik, L., Deouell, L. Y., & Lamy, D. (2011). Scene congruency biases binocular rivalry *Consciousness and Cognition, 20*, 756-767.

Mudrik, L., Lamy, D., & Deouell, L. Y. (2010). ERP evidence for context congruity effects during simultaneous object-scene processing. *Neuropsychologia, 48*(2), 507-517. doi: DOI 10.1016/j.neuropsychologia.2009.10.011

Mudrik, L., Lamy, D., & Deouell, L. Y. (2011). Integration without awareness: expanding the limits of unconscious processing. *Psychological Science, 22*(6), 764-770.

Neumann, D., & Gegenfurtner, K. (2006). Image retrieval and perceptual similarity. *ACM Transactions on Applied Perception (TAP), 3*(1), 31-47.

Nobre, A. C., & Mccarthy, G. (1995). Language-Related Field Potentials in the Anterior-Medial Temporal-Lobe .2. Effects of Word Type and Semantic Priming. *Journal of Neuroscience, 15*(2), 1090-1098.

O'Regan, J. K., & Noe, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences, 24*(5), 939-973; discussion 973-1031.

Oliva, A. (2005). Gist of the scene. In L. Itti, G. Rees & J. K. Tsotsos (Eds.), *Neurobiology of attention* (pp. 251-256). San Diego, CA: Elsevier.

Palmer, S. E. (1975). Effects of Contextual Scenes on Identification of Objects. *Memory and Cognition, 3*(5), 519-526.

Posner, M. I. (1980). Orienting of Attention. *Quarterly Journal of Experimental Psychology, 32*(Feb), 3-25.

Posner, M. I. (1994). Attention: The mechanisms of consciousness. *Proceedings of the National Academy of Sciences of the United States of America*(91), 7398-7403.

Rayner, K., & Pollatsek, A. (1992). Eye movements and scene perception. *Canadian Journal of Psychology, 46*(3), 342-376.

Rieger, J. W., Braun, C., Bulthoff, H. H., & Gegenfurtner, K. R. (2005). The dynamics of visual pattern masking in natural scene processing: A magnetoencephalography study. *Journal of Vision, 5*(3), 275-286.

Rousselet, G. A., Joubert, O., & Fabre-Thorpe, M. (2005). How long to get to the" gist" of real-world natural scenes? *Visual Cognition, 12*(6), 852-877.

Schendan, H. E., & Kutas, M. (2002). Neurophysiological evidence for two processing times for visual object identification. *Neuropsychologia, 40*(7), 931-945.

Schyns, P. G., & Oliva, A. (1994). From Blobs to Boundary Edges - Evidence for Time-Scale-Dependent and Spatial-Scale-Dependent Scene Recognition. *Psychological Science, 5*(4), 195-200.

Siegel, D. J. (2012). *Developing Mind: How Relationships and the Brain Interact to Shape Who We Are*: Guilford Press.

Sklar, A. Y., Levy, N., Goldstein, A., Mandel, R., Maril, A., & Hassin, R. R. (2012). Reading and doing arithmetic nonconsciously. *Proceedings of the National Academy of Sciences, 109*(48), 19614-19619.

Sterzer, P., Jalkanen, L., & Rees, G. (2009). Electromagnetic responses to invisible face stimuli during binocular suppression. *Neuroimage, 46*(3), 803-808. doi: DOI 10.1016/j.neuroimage.2009.02.046

Thorpe, C., Fize, D., & Marlot, C. (1996). Speed of processing in the human visual system. *Nature, 381*, 520-522.

Tononi, G. (2005). Consciousness, information integration, and the brain. *Prog Brain Res*, *150*, 109-126.

Tononi, G., & Edelman, G. M. (1998a). Consciousness and Complexity. *Science, 282*(5395), 1846.

Tononi, G., & Edelman, G. M. (1998b). Consciousness and the integration of information in the brain. In H. H. Jasper, L. Descarries, V. F. Castellucci & S. Rosignol (Eds.), *Consciousness: At the frontiers of Neuroscience, Advances in Neurology* (Vol. 77, pp. 245-279). Philadelphia: Lippincott-Raven Publishers.

Tsuchiya, N., & Koch, C. (2005). Continuous flash suppression reduces negative afterimages. *Nature Neuroscience, 8*(8), 1096-1101.

Tsuchiya, N., Koch, C., Gilroy, L. A., & Blake, R. (2006). Depth of interocular suppression associated with continuous flash suppression, flash suppression, and binocular rivalry. *Journal of Vision, 6*(10), 1068-1078.

Underwood, G., & Foulsham, T. (2006). Visual saliency and semantic incongruency influence eye movements when inspecting pictures. *Quarterly Journal of Experimental Psychology, 59*(11), 1931-1949.

Underwood, G., Foulsham, T., van Loon, E., Humphreys, L., & Bloyce, J. (2006). Eye movements during scene inspection: A test of the saliency map hypothesis. *European Journal of Cognitive Psychology, 18*(3), 321-342.

Van Petten, C. (1995). Words and Sentences - Event-Related Brain Potential Measures. *Psychophysiology, 32*(6), 511-525.

West, W. C., & Holcomb, P. J. (2002). Event-related potentials during discourse-level semantic integration of complex pictures. *Cognitive Brain Research, 13*(3), 363-375.

Yoon, K. L., Joormann, J., Hong, S. W., & Kang, P. (2009). Perception of Facial Expressions of Emotion During Binocular Rivalry. *Emotion, 9*(2), 172-182.

Zadbood, A., Lee, S. H., & Blake, R. (2011). Stimulus fractionation by interocular suppression. *Frontiers in Human Neuroscience, 5*.