The quality of perception without attention

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Introduction

CHAPTER 1

The statement that *more is seen than can be remembered* implies two things. First, it implies a memory limit, that is, a limit on the (memory) report. Such a limit on the number of items which can be given in the report following any brief stimulation has, in fact, been generally observed; it is the span of attention, apprehension, or immediate-memory (cf. Miller, 1956b). Second, to *see more than is remembered* implies that more information is available during, and perhaps for a short time after, the stimulus can be reported.

- Sperling, 1960

Anything that we are aware of at a given moment forms part of our consciousness, making conscious experience at once the most familiar and most mysterious aspect of our lives. - Velmans & Schneider, 2007

We experience the world in a rich and detailed manner no matter where we look. As you are reading the first sentences of this thesis, you most likely also experience some details that are not in the focus of your attention, such as the size and color of the pages of this book, or the colors and materials of objects present in the background. Together, the objects in the focus of your attention and the details outside your attention form the perception of a world that is complex and integrated. You don't have to continuously move your eyes and focus your attention on all of these aspects for this sensation of richness to occur. Although we feel as if we perceive the whole visual world at once, it has been argued that attention is necessary to consciously process information: under this assumption, unattended information is only implicitly, or unconsciously, processed. In this thesis, I will investigate whether attention is indeed necessary for conscious visual processing to occur.

One of the hallmarks of visual consciousness is that it is qualitative in nature. An example of perceptual quality is depicted in Figure 1.1. On the left, an illusory triangle lying on top of three disks can be perceived: it is defined by illusory contours and an illusory contrast difference between figure and background. In comparison, on the right of Figure 1.1, a triangle can be cognitively inferred from the layout of the inducers, but the perception of this triangle is not accompanied by an added visual percept. Thus, an additional visual quality is present in the

left figure compared to the right figure. To gain insight in the necessity of attention to create a perceptually qualitative - and thus visually conscious - world, I examined whether visual qualities such as these can arise under conditions of inattention as well. Below, I will first discuss how one can measure the richness of our perception using a cueing paradigm, and how these measurements can tell us something about the relation between attention and consciousness. I will explain how we can investigate unattended perception behaviorally by looking at different stages of visual memory, and how I examined whether various characteristics that are associated with consciousness - such as the integration of information to create perceptual inference (Fig. 1.1) and explicit information processing – are present during these different stages of memory. Last, I will elucidate how we may further our knowledge of what types of processing can occur outside the scope of attention by using neural measurements to investigate the perceptual processing of unattended, and even unreported, visual stimuli.
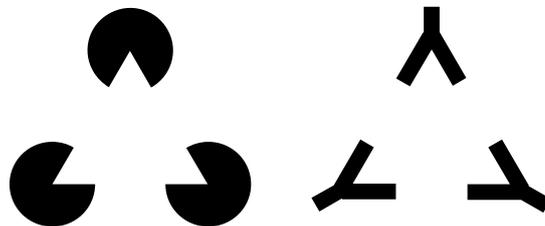

Figure 1.1. **Illusory versus non-illusory triangle.** *On the left, an illusory triangle can be perceived that lies on top of three black discs, and is defined by illusory contours and an illusory contrast difference between figure and background. On the right three 'twigs' have the same inner outline as the inducers on the left. Although a triangle can be cognitively inferred, this figure does not result in an illusory percept.*

Attention and its link to consciousness

While the sensation of perceiving a rich and detailed visual world is familiar - and perhaps even self-evident - to most of us, it has proven challenging to probe the richness of our perception empirically: when subjects are asked to freely report about a scene they have just perceived, they can only report about 4 objects from this scene, suggesting that the rich perception we experience is an illusion. In 1960, however, George Sperling performed an experiment that possibly touched upon our introspective feeling of rich perception. He briefly presented subjects with a picture containing rows of letters and asked them to remember as many letters as possible (Fig. 1.2). When asked to report any letter they could remember, participants were able to report 4 items on average, even when up to 12 items were presented (Sperling, 1960).

Intriguingly, however, if within a few hundred milliseconds after offset of the memory display a cue was presented indicating which row of letters should be recalled, performance was boosted up to 3 out of 4 items *per row*. Because subjects never knew in advance which row would be cued, it was inferred that they had the potential to remember 9 out of 12 letters from the whole array. Crucially, the cue was presented after disappearance of the memory items, thus the cue must tap into a mechanism that can maintain a large amount of information for a short period of time. This fleeting form of memory was referred to as sensory memory: the capacity to shortly maintain the first information that flows from our senses.
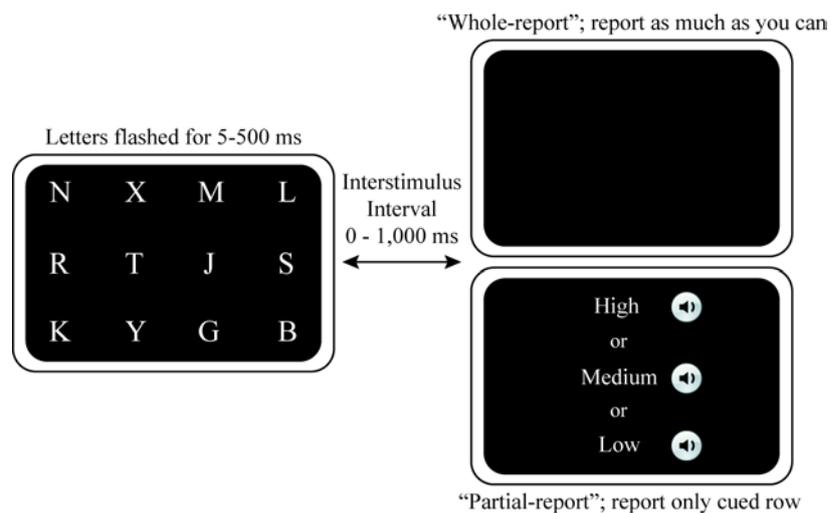

Figure 1.2. Partial report paradigm as used by Sperling (1960). *Subjects see an array of letters which they try to remember to the best of their ability. In the Whole-report condition (above), subjects have to report as many letters as they can remember from the whole array. In the Partial-report condition (below), subjects get an auditory cue that indicates which row they should report. This figure is based on the Sperling (1960) manuscript and copied with permission from Sligte (2011).*

You can experience the high capacity of sensory memory yourself: briefly look at an unfamiliar image, then close your eyes and try to report as many objects in the scene as possible. You will probably be able to recall around four objects. When you do the task again (looking at a different scene), and now, after closing your eyes, try to think of only those objects in a specific part of your visual field (don't cue before you close your eyes, that's cheating, let someone else say what part to report on). You will probably find that you are, again, able to remember about four objects, but now tied to the specific area. This phenomenon should repeat itself even if you do this task over and over again (looking at different scenes of course). What is so intriguing

about this phenomenon is that, apparently, after closing your eyes, much more information was available than you could report, because you could have decided to focus on any particular part of the scene and still be able to recall around 4 objects in that area. However, as soon as you have recalled the objects in a specific location, the objects in the other locations are no longer available. Their representations have decayed.

Our limited capacity to report about everything we see is proposed to lie with our limited attentional capabilities. Sensory memory has been taken as evidence that we perceive more than we can attend to, and thus more than we can report about; it is proposed to underlie the rich visual world we experience (Block, 2005, 2007, 2011; Crick & Koch, 1990; Koch & Tsuchiya, 2007; Lamme, 2003, 2006, 2010; Tononi, 2008). Unfortunately, this large memory capacity decays quickly, and when subjects freely report about what they remembered, the information contained in sensory memory has largely perished. Under conditions of free report, subjects can on average remember 4 items (Luck & Vogel, 1997; Sperling, 1960). This capacity corresponds to a robust form of short-term memory, also termed working memory. The bottleneck of our working memory system thus seems to lie with attention (Awh, Vogel, & Oh, 2006; Chun & Turk-Browne, 2007; Fougnie, 2008; Gazzaley & Nobre, 2012; Postle, 2006). It has been shown that indeed, attention facilitates items to be transferred to working memory (Gazzaley, 2011; Griffin & Nobre, 2003; Matsukura, Luck, & Vecera, 2007; Awh & Jonides, 2001). In addition, diverting attention during encoding (Vandenbroucke, Sligte, & Lamme, 2011; Vogel, Woodman, & Luck, 2005) and maintenance (Allen, Baddeley, & Hitch, 2006; Awh, Jonides, & Reuter-Lorenz, 1998) impairs working memory performance. Also, the number of items that can be tracked in a multiple object tracking task is limited to about 4 objects, corresponding to the average short-term memory capacity (Cavanagh & Alvarez, 2005). It is therefore proposed that sensory memory represents all the information that can be processed outside attention, while working memory reflects our attentional capabilities (Block, 2005, 2007, 2011; Crick & Koch, 1990; Lamme, 2003, 2006, 2010; Sperling, 1960).

Not only does the transfer from sensory memory to working memory depend on attention, lapses of attention have been shown to influence reportability in a range of other tasks. For example, when subjects focus on a stream of pictures or letters in which they have to detect two targets, they miss the presence of a second target when it is presented close in time to the first target (Raymond, Shapiro, & Arnell, 1992). This phenomenon is called the *attentional blink*, and is thought to occur because the first target captures attention, thereby leaving little attention (or faulty placed attention) for the second target, which then cannot be reported about (Di Lollo, Kawahara, Shahab Ghorashi, & Enns, 2005; Olivers & Meeter, 2008; Slagter,

Johnstone, Beets, & Davidson, 2010). In a similar fashion, *inattentional blindness* occurs when a subject focuses on a particular task (for example, counting the number of passes of a basketball team dressed in white, while they are standing in the midst of a team dressed in black), thereby missing certain obvious events (such as a man dressed up in a gorilla suit walking through the field). These events are not missed when subjects are informed about their occurrence in advance (Rensink, 2000; Simons & Chabris, 1999). This shows that specifically, a lack of attention for stimuli outside the focus of attention and not our perceptual capabilities causes obvious events to be missed.

What happens then to visual information that is not attended? Previous studies have shown that stimuli that are missed due to inattention can be processed up to a semantic level leading to priming effects (Luck, Vogel, & Shapiro, 1996). Also, figure-ground segregation and binding can take place (Moore & Egeth, 1997; Pitts, Martínez, & Hillyard, 2012; Scholte, Witteveen, Spekreijse, & Lamme, 2006). Similarly, although we don't have the capacity to attend to every letter in the Sperling paradigm (Fig. 1.2), when using an attention-guiding cue, one can retrieve almost all items of the display, showing that unattended information stays available for a short period of time. This then suggests that attention does not determine perceptual processing itself, but rather determines which perceptual processes are strengthened in order to be maintained for a longer period of time.

However, controversy remains whether perceptual processing that occurs outside the scope of attention, and therefore outside the scope of report, should qualify as conscious processing (Baars, 1997; Cohen & Dennett, 2011; Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006; Dehaene & Changeux, 2011; Kouider, de Gardelle, Sackur, & Dupoux, 2010; Lau & Rosenthal, 2011). Some argue that stimuli that are not reported about due to attentional lapses are not part of our conscious experience. Of course, this is an intuitive notion: if you can't report about what you saw, you must have never been aware of it. But where does that leave our rich visual experience? We can't report about everything we see, unless we are cued in the right direction. Does cued recall count as conscious report? Or does report only count as evidence for conscious processing when it is 'free'?

Although at first sight, it makes sense to equate conscious experience with the ability to freely report about the contents of our experience, problems start to arise when we want to define what counts as 'proper' report. Consider, for example, the case of split-brain patients, in which the connection between the two hemispheres - the corpus callosum - is severed (often as treatment to severe epilepsy). If these patients view something in their left visual field, this information is only processed by the right hemisphere and cannot be transferred to the left

hemisphere as it is in non-patients (Gazzaniga, 2005). Importantly, the left hemisphere is where, for most people, processing of language is dominant. As a result, these patients are unable to verbally report about objects seen in the left visual field. If one considers verbal reportability as crucial evidence for consciousness, these patients do not have awareness of stimuli that are perceived in their left visual field. However, if patients are asked to draw what they saw, or to pick the object from a group of concealed items using their left hand, they are perfectly able to do so. Should we now discard drawing and feeling from the list of behaviors that count as conscious report, simply because patients cannot talk about what their right hemisphere 'sees'? What is the criterion for including one form of report and excluding another? And if we do concede that their right hemisphere has conscious experiences even though a patient verbally insists he did not see anything, how do we go about establishing what counts as conscious experience? Perhaps we could come closer to a unified theory of consciousness when we step away from relying on forms of report, and instead investigate the perceptual processes that underlie our conscious experience; the conscious percept that forms the basis of our report (Kanai & Tsuchiya, 2012; Lamme, 2010).

To investigate conscious content (e.g. in Fig. 1.1, the illusory triangle) independent of the cognitive processes that enable report, we must first verify that the perceptual processes underlying conscious content similarly take place in the absence of report. Attention is a key mechanism underlying report. During inattentional blindness and the attentional blink, stimuli cannot be reported due to a lack of attention. Likewise, most items in sensory memory cannot be reported about, unless they are transferred to working memory by means of internal attention or external attention guided by a cue. In this thesis, I will investigate the quality of perception during inattention by examining which processes occur in sensory memory and during inattentional blindness. I will compare unattended processing to attended processing to see whether perceptual characteristics change from one condition to another. If unattended processing turns out to be qualitatively different from attended processing, we should conclude that attention alters our perceptual states, thereby influencing our conscious experience. This would imply that attention is necessary for conscious processing to occur. However, if perceptual processing does not differ between attended and unattended processing, the reasonable conclusion would be that attention itself, and therefore one of the main mechanisms supporting report, does not influence the contents of our experience, but only our ability to report about this experience. If this is the case, perhaps we should not focus consciousness research on investigating the mechanisms that are linked to report, but on the perceptual

processes that form the content of our report (Block, 2005, 2007, 2010; Lamme, 2003, 2006, 2010).

Investigating the behavioral characteristics of unattended processing

Sensory memory versus working memory

The best way to compare unattended and attended processing behaviorally is by comparing sensory memory and working memory. Sensory memory and working memory can be investigated using the partial-report paradigm as first designed by Sperling (1960). However, in his paradigm, the influence of purely visual representations and verbal representations are hard to disentangle, because here report itself depends on the verbalization of the memory items, and thus the memorized items might be verbal instead of visual in nature. To specifically measure the contribution of visual memory, it is best to combine a partial-report paradigm with a change detection task (Becker, Pashler, & Anstis, 2000; Landman, Spekreijse, & Lamme, 2003; Landman, Spekreijse, & Lamme, 2004; Phillips, 1974; Pinto, Sligte, Shapiro, & Lamme, 2013; Sligte, Scholte, & Lamme, 2008; Sligte, Scholte, & Lamme, 2009; Sligte, Vandenbroucke, Scholte, & Lamme, 2010; Sligte, Wokke, Tesselaar, Scholte, & Lamme, 2011). In a change detection task, subjects are presented with a memory display containing stimuli that they have to remember to the best of their ability (Fig. 1.3). A test display is presented after offset of the memory display, in which on 50% of the trials one of the stimuli has changed compared to the memory display. The subjects' task is to indicate whether a change occurred in the test display compared to the memory array (two-alternative-forced choice). To measure sensory memory capacity, a cue (termed retro-cue) is presented in between the memory and test display. The retro-cue indicates which stimulus might change in the test display. To measure working memory, the cue is not presented in the interval between memory and test display, but after onset of the test display. This way, sensory memory representations are overwritten, and only the items that are robustly stored in working memory remain available for detecting a change.

Using the partial-report change detection paradigm it was shown that the retro-cue can boost performance up to 4000 ms after stimulus offset (Sligte et al., 2008, 2009), which is considerably longer than the partial report benefit originally reported by Sperling, lasting about 500 ms. Within that 4000 ms interval, two stages of sensory memory can be distinguished (Sligte et al., 2008). The first stage corresponds to classical iconic memory (IM; Neisser, 1967). This
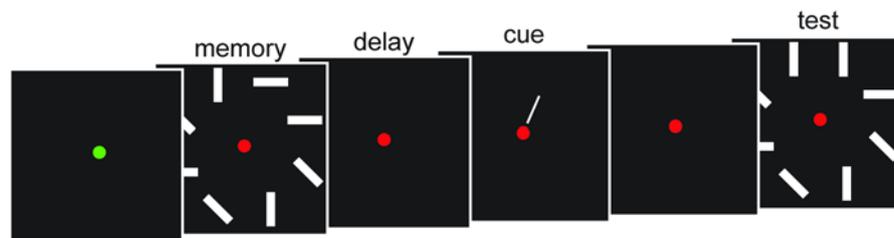
Figure 1.3. **Change detection combined with a partial-report paradigm.** *Subjects have to remember as many items as possible from a memory display (in this case containing oriented rectangles). A retro-cue can be presented after memory display offset, indicating which of the items might change. Subjects report whether a change occurred for the test display compared to the memory display.*

stage only lasts for a few hundred milliseconds and when stimuli are made isoluminant with respect to their background (instead of white stimuli on a black background), or a light mask is presented after stimulus offset to abolish any retinal afterimages, IM performance drops considerably (Fig. 1.4A). The second stage of sensory memory is not erased by a light mask or isoluminant stimuli, but is still easily overwritten by the presentation of similar stimuli (Makovski, Sussman, & Jiang, 2008; Pinto et al., 2013). Moreover, representations in this memory stage are supported by processing in visual area V4, and the strength of activity in V4 can distinguish between representations that are supported by late sensory memory or by WM (Sligte et al., 2009). Therefore, a tri-partite division of visual short-term memory is proposed (see Fig. 1.4): the first stage encompasses early sensory memory, or IM, that depends on retinal afterimages and only lasts for about 100 milliseconds; the second, late sensory memory stage is termed fragile memory (FM; Sligte et al., 2008). It has a cortical basis and lasts up to a few seconds, but is not (yet) made resistant against interference from similar item presentations; the third stage, WM, comprises a form of short-term memory that is maintained over longer periods of time, is robust against interference, and depends on attentional selection.

Because sensory memory representations (IM and FM) last for a shorter period of time than WM representations and are easily overwritten by similar stimuli, it is hypothesized that sensory memory reflects a stage in visual memory that is formed independently of focused attention. Comparing the characteristics of sensory memory to WM therefore gives us insight into the characteristics of unattended versus attended processing. Especially FM is an interesting stage in sensory memory, since it lasts longer than IM and has a cortical basis. The question remains, however, whether such a relatively long-lasting, cortically based storage can indeed represent a separate, unattended, stage of processing, or rather represents a weak form of WM. Although

behavioral evidence suggests that FM can be distinguished from WM, its representations at least partly rely on the same brain area (Sligte et al., 2009). To support the hypothesis that FM represents a separate, unattended form of memory, it should first be distinguished from WM based on its underlying attentional and cortical mechanisms. In Chapter 2, I therefore set out to dissociate FM and WM to confirm that FM is an unattended and separate stage in visual memory compared to WM. I investigated the dependence on attention for FM and WM by diverting attention during encoding of the memory displays using three different attentionally demanding tasks. Furthermore, in Chapter 3 I related individual differences in FM and WM capacity to their EEG time-frequency characteristics to investigate whether the neural underpinnings of FM and WM can be separated.
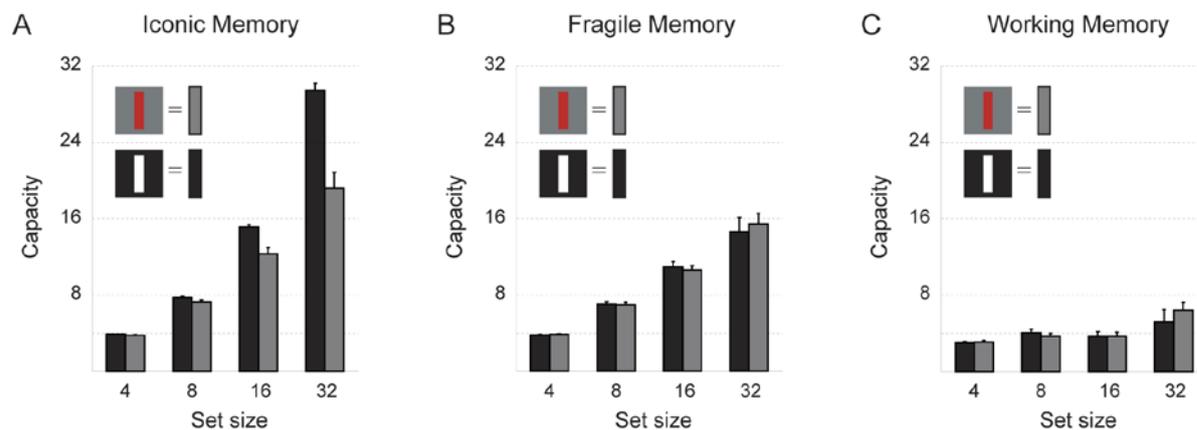

Figure 1.4. Capacity of three stages in Visual Short-Term Memory. *Copied and edited with permission from Sligte et al. (2008). A) Iconic Memory (IM) capacity increases with set size and is very high for white stimuli presented on a black background (black bars), but decreases when the afterimages are weakened by presenting isoluminant red on grey stimuli (grey bars). B) Fragile Memory capacity also increases with set size, but capacity is smaller than IM and is not affected by manipulating the strength of afterimages. C) Working Memory capacity is limited to about 4 items and does not increase with increasing set size.*

The nature of sensory memory representations

If FM indeed reflects an unattended form of memory, it is a likely candidate for unattended conscious processing. To establish that FM represents conscious processing, one must show that the perceptual characteristics of FM are similar to the perceptual characteristics of WM. Previous experiments investigating FM mainly used oriented line elements as memory items (Sligte et al., 2008, 2009; Vandenbroucke et al., 2011) but see Landman et al., 2004). However, orientation can be processed unconsciously as well (Boyer, Harrison, & Ro, 2005; Clifford &

Harris, 2005). To determine whether FM representations consist of bound and integrated percepts, one can investigate whether processes such as perceptual inference take place. Landman et al. (2004) already showed that perceptual grouping takes place in FM: in their experiment, they used line elements that were defined by an orthogonal orientation compared to their background. When in the interval before the retro-cue, the line elements were redefined by switching around the orientation of the figures and the background, performance in the partial-report paradigm decreased. This suggests that segregation of figures versus their background, and thus the perceptual grouping of local elements, plays an important role in change detection. To investigate whether higher-level perceptual inference in which elements are bound over different objects takes place in FM, we used the Kanizsa illusion as objects in a change detection task (Fig. 1.1 - left; Kanizsa, 1976). In the Kanizsa illusion perceptual inference produces the perception of an illusory figure - defined by illusory contours and an illusory contrast difference between figure and background - through the integration of elements. What is special about this stimulus is that we do not only know that a pentagon can be formed out of the inducing elements (cognitive inference, Fig 1.1 - right), but that the inference of the pentagon is accompanied by a visual experience. This corresponds to the difference between knowing that a car has moved when you see it in two different locations versus actually seeing the car move (Pylyshyn, 1999). Perceptual inference thus alters the perceptual characteristics of a stimulus. If stimuli like the Kanizsa illusion can be represented in sensory memory, this suggests that perceptual inference occurs, making sensory memory a likely candidate for unattended conscious processing. In Chapter 4, I explored the perceptual characteristics of sensory memory (including iconic memory - IM) and compared these to WM. Instead of reporting a change in orientation of a rectangle, subjects now indicated whether a change in orientation for an illusory Kanizsa triangle occurred.

Does sensory memory represent explicit or implicit processing?

Another important feature of conscious processing is that it is supported by explicit processing (Baars & Franklin, 2003; Lau & Rosenthal, 2011). When you make a decision and afterwards can argue why you made this decision, the process underlying the decision was explicitly available to you. Many unconscious processes, however, occur implicitly. This makes us behave according to events or decisions that we cannot retrieve, for example when we learn grammar and decide whether a sentence is grammatically correct (Knowlton, Ramus, & Squire, 1992) or slow down to stop signals that we did not perceive (van Gaal, Ridderinkhof, Scholte, & Lamme, 2010). Therefore, investigating whether sensory memory relies on explicit or implicit processing is a

second important step in answering the question whether sensory memory could reflect conscious processing. In Chapter 5, I compared the degree of explicit processing for IM, FM and WM by evaluating their level of metacognition. Metacognition reflects the degree to which subjects can accurately reflect on the correctness of their decisions (Fleming, Weil, Nagy, Dolan, & Rees, 2010; Metcalfe & Shimamura, 1994). It is calculated by combining objective performance on the change detection task (change/no-change response) with subjective confidence ratings (sure/not-sure) that a subject gives for the objective decision. When correct responses are accompanied by high confidence and incorrect responses by low confidence, subjects have good knowledge about the correctness of their perceptual decisions, or high metacognitive performance. Vice versa, when there is no relationship between confidence ratings and the correctness of perceptual decisions, metacognition is low. Comparing metacognitive performance for IM and FM to WM tells us whether sensory memory representations are explicitly processed to the same extent as WM representations.

Investigating unattended processing using neural measurements

Behavioral studies give insight in the way people perceive and remember visual scenes. When the behavioral characteristics of unattended processing are better understood, one can investigate what happens to unreported items on a neural level. The advantage of taking a neural approach is that neural measurements are independent of report, because the timing of these stimuli, and thus the timing of their processing, can be investigated in a controlled setting. During inattentional blindness for example, unexpected stimuli are not reported about because subjects are engaged in an attentionally demanding task and task-irrelevant stimuli are missed (Rensink, 2000; Simons & Chabris, 1999). However, we can still see what kind of processing occurred for these events, because we can analyze the activity evoked during presentation of these stimuli. This way, perceptual processing of unreported stimuli can be investigated without relying on behavorial measurements.

Determining the level of visual integration during unattended processing

Several studies have looked at the difference between unreported and reported stimuli using either the attentional blink (Kranczioch, Debener, Schwarzbach, Goebel, & Engel, 2005; Luck et al., 1996; Marois, Yi, & Chun, 2004; Sergent, Baillet, & Dehaene, 2005) or inattentional blindness (Pitts et al., 2012; Scholte et al., 2006). The main goal of these studies is often to show which mechanisms support the reportability of a target. However, visual processing of the unreported target has been found to occur just as for the reported target.

Chapter 1

During the attentional blink the Parahippocampal Place Area (PPA) is selectively activated when the missed target is a house (Marois et al., 2004), Lateral Occipital Cortex and Fusiform Gyrus might even show more activity for unreported than for reported letters, and the Inferior Superior Lobe (ISL) and the Anterior Cingulate Cortex show a small increase for unreported targets compared to when no target is presented (Kranczioch et al., 2005). In addition, early ERP components such as the P1 and N1 (occurring around 100 ms) are present for unreported targets (Luck et al., 1996; Sergent et al., 2005), and unreported targets can elicit both letter and semantic priming (Shapiro, Driver, Ward, & Sorensen, 1997), suggesting that perceptual processing for unreported targets proceeds as with reported targets, the only difference being that these targets are not accessed due to a lack of attention.

Similar results were found for inattentional blindness. Unreported stimuli have been shown to elicit activity associated with figure-ground segregation (Scholte et al., 2006), and feature grouping (Pitts et al., 2012). However, it has also been shown that when line-drawn pictures are presented superimposed on words, these words do not elicit word-specific activity compared to scrambled letters, suggesting that words are not processed when they are unattended (Rees, Russell, Frith, & Driver, 1999). This is in contrast with findings on processing of words during the attentional blink (Shapiro et al., 1997), and further research on the depth of processing during different manipulations of attention is necessary.

Although it thus seems that perceptual processing occurs during lapses of attention, the question remains whether perceptual inference through integrative processing takes place. Integration of information has been proposed to be a key factor in conscious processing (Fahrenfort et al., 2012; Tononi, 2008). Moreover, types of perceptual inference that depend on interactions between higher-level and lower-level visual areas do not occur when stimuli are masked such that they are not perceived, even when attended (Fahrenfort, Scholte, & Lamme, 2007; Harris, Schwarzkopf, Song, Bahrami, & Rees, 2011). Therefore, if perceptual inference that depends on integrative processing occurs during inattentional blindness, this shows that attention is not necessary for complex integrative processing to occur. In Chapter 6, I studied whether this type of perceptual inference occurs for unattended, and therefore unreported, stimuli by measuring functional Magnetic Resonance Imaging (fMRI) while subjects were rendered inattentionally blind to the same type of visual illusion (Kanizsa, 1976) as used in Chapter 4. In addition, in Chapter 7 I investigated the neural correlates of the influence of object knowledge on subjective color perception using fMRI. I presented subjects ambiguously colored prototype objects that could either shift towards the color red when presented on prototypical red objects (such as tomatoes) or towards green when presented on prototypical green objects

(such as clovers). When this effect is found to operate on a visual level, we can use it in future research to look at subjective color perception for unattended items.

Investigating the quality of perception without attention – Thesis outline

In this thesis, I have investigated the quality of unattended and unreported stimuli using different methods and tasks. In the first four experimental chapters (2-5), I compared the characteristics of sensory memory, a form of visual short-term memory that does not depend on attended processing, to working memory, a stage in visual short-term that depends on attention to be maintained. In the last two experimental chapters (6-7), I investigated the perceptual characteristics of unattended, and therefore unreported, objects by using fMRI, and explored the possibility of using fMRI to study subjective color perception. In Chapter 8, I will summarize the results of these studies and discuss whether unattended processing could qualify as conscious processing, which might lead to a shift in the focus of consciousness research.