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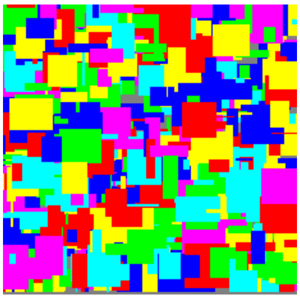
Do goals facilitate conscious awareness of goal-related information?



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Declaration

I, Irina Rochal, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Prior research suggests that people's behaviour and perception can be strongly biased by their current goals. This can occur without people being necessarily consciously aware of that. This idea implies that at least some information would have to be preconsciously processed to a specific degree, in order for the brain to decide what is goal-relevant and what is not. With this theory in mind, I investigated whether motivation could exert a top-down influence on what type of information would enter conscious awareness first and in particular, whether goal-related information would have conscious priority. This was done by using a state of mind technique called continuous flash suppression (CFS). I proposed that motivation affects perception and behaviour by top-down influences that occur via accessibility. In my first experiment, I tested motivational top-down effects of goals on goal-related materials (EXP 1), by inducing deprivation that should create a goal to fulfil. After sobering results I took a few steps back on the motivational – behaviour chain and tested a) top-down effect on a low-level basis (EXP 2), b) top-down effects of accessibility of concepts (EXP 3, EXP 4), and c) top-down effects on semantics (EXP 5). My results suggest that expected information, which is instrumental for the task at hand, is prioritized in conscious awareness (EXP 2). Moreover, these findings can be extended to accessible concepts that are not instrumental for the task but are simply accessible for goal pursuit (EXP 3,4). Lastly, the results of experiment 5 imply that previously found accessibility effects of concepts, are not due to familiarity but could be possible due to higher-level preconscious processing. This gives rise to the possibility that semantic processing might be possible. The meaning and implication of those results will be further elaborated on in the general discussion.

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Chapter 1: General Introduction

1.1. Theoretical Background

Most human behaviour is goal-directed. That is why, apart from reflexes and perhaps habits, we engage in behaviour that is aimed at producing specific outcomes. We may study to obtain a PhD or walk to the cafeteria for a cup of coffee. While many animals share this capacity, it is perhaps one of the most remarkable features of evolution and uses almost every function that the brain has to offer. First and foremost, it requires us to envision a state of the world beyond the here and now that we want to attain (Gilbert & Wilson, 2007; Liberman & Trope, 2008). Then, based on associations or knowledge of the world, actions have to be selected and executed to approach this state. Crucially though, as theorists have pointed out, this process requires perceptual feedback to tune behaviour to make sure that the discrepancy with the desired state is effectively reduced (Powers, 1973a, Powers, 1973b).

Many studies have revealed perception is guided and even biased by goals that are on our mind (e.g. Balcetis, Dunning, & Granot, 2012). For example, thirsty people are more likely to perceive ambiguous stimuli as more transparent – presumably a characteristic of water - than not water-deprived people (Changizi & Hall, 2001; Balcetis & Dunning, 2006). Hence, goals seem to exercise a top-down influence on how we perceive the world around us. Extensive literature on attention has also shown that goals help us to select relevant information from our environment, prioritizing some information over others. This thesis focuses on the question of whether goals directly affect our conscious experience of the world: Do goals determine what we become aware of?

If goals exert such a top-down influence on what information we perceive or prioritize for conscious awareness, wouldn’t that therefore imply that at least some of the given information surrounding us would need to be processed preconsciously? While goal-directed behaviour has been predominantly considered as a process that relies on consciousness, literature over the last decades has revealed that goals seem to operate outside of conscious awareness, directing perception and behaviour. For instance, people start acting more competitively once they perceive a leather briefcase laying on a table (Kay, Wheeler, Bargh, & Ross, 2004) or just perceiving the scent of cleaning products can lead people to behave in a “cleaner” way like leaving less crumbles around when eating a cookie (Holland, Hendricks, & Aarts, 2005). Given the evidence that goals affect behaviour outside of conscious awareness, goals could affect our perception outside of awareness as well. This, in turn, may determine what we become consciously aware of.

While preconscious selection has been studied extensively in literature on attention, evidence for effects on conscious awareness has always been indirect. In dichotic listening tasks for example, it has been demonstrated that when two different streams of words are presented in the two ears of participants, words that are relevant to the person shift attention from the attended to the unattended channel, revealing that this channel is preconsciously processed. Recently developed techniques such as the continuous flash suppression make it possible to measure the timing of conscious awareness directly rather than indirectly. I applied the continuous flash suppression technique to address the question of whether goals can influence conscious awareness of goal-relevant stimuli directly.

1.1.1 Goal Systems

Human behaviour is driven by goals and the motivation to fulfil them. For instance, we are confronted with many different chores in our everyday lives, such as going to work, picking up the dry cleaning, exercising regularly, as well as being able to resist numerous temptations that interfere with our personal goals, e.g. declining a piece of cake while being on a diet (Fishbach, Friedman & Kruglanski, 2003; Shah, Friedman & Kruglanski, 2002; Shah, Kruglanski, & Friedman, 2003). The reason why people are able to go through with their chores and not fall into temptation is due to the way that goals are mentally represented (Shah & Kruglanski, 2000). Goals are represented as mental knowledge structures in memory (Monsell & Driver, 2000;

Kruglanski, 1996; Shah & Kruglanski, 2000), which enable flexibility to adapt to different means to pursue the same goal under varying circumstances (Custers & Aarts, 2010; Powers, 1973a; Marien, Custers, Hassin & Aarts, 2012). A goal representation consists of the goal's content, i.e. knowledge of what is desired, and methods how to achieve that goal (Custers & Aarts, 2010; Moskowitz & Grant, 2009). Through repeated activation, the association between the content and means grows stronger (Marien et al., 2012). The stronger this association gets, the more automated a goal pursuit can become (Marien et al., 2012).

While goals are described as mental representations, they should not be confused with mental representations of simple concepts. Crucially, goals are representations of outcomes that contain desirability (Custers & Aarts, 2010). Moreover, once a goal is rendered accessible its accessibility is maintained until the goal is fulfilled, whereas the accessibility of simple concept priming wears off with time. Goals and their representations are part of a bigger structure.

Shah and Kruglanski proposed that goals and their corresponding means are organized in a hierarchical network in their goal systems theory (Shah & Kruglanski, 2000; Shah, Kruglanski, & Friedman, 2003). That network can only hold a few abstract goals and the means to achieve those can be identified as concrete subgoals, which again are served by lower level means and so on (Shah & Kruglanski, 2000). In addition to the connections between means and goals, goals can have associations amongst each other. This could be either of a facilitative or inhibitive nature (Fishbach et al., 2003). Summarizing and returning to one of the initial examples, our behaviour is motivated by the pursuit of our goal that comprises an ideal state, e.g. wanting to get fit. When this goal and its necessary means such as exercising and dieting, are activated, they enable people to decline for example a piece of cake, as it stands in an inhibitive association with the active goal of getting fit and its means.

Importantly, while our behaviour is directed towards goal attainment there is one crucial component worth mentioning – the "perceptual feedback" (Powers, 1973a, 1973b). In order to successfully reduce the discrepancy between a current state and the ideal goal state the brains needs to continuously monitor made progress and when necessarily attune (Powers, 1973a, 1973b). Perception plays another important role in goal pursuit and will be elaborated on further in the following section.

1.1.2 Perception

Perception plays a crucial part in human behaviour. People need to perceive something in order to act on it. Contrary to ordinary belief, perception is not an accurate and objective representation of the environment (Balcetis & Dunning, 2006), but is biased and selective to a person's individual cognition and motivation (Balcetis & Cole, 2013). Some supporters of the New Look approach (Bruner & Minturn, 1955) argued that perception is "an active and constructive process influenced by many top-down factors" (Balcetis & Dunning, 2006, p.613). For instance, many studies have shown that when people are given ambiguous drawings, e.g. the "Nader" drawing, that depicts simultaneously a saxophone player and a woman's face; or the "Liar" drawing, that can be interpreted either as a man's face or the actual word "liar" (see figure 1.1), people identify such drawings in line with their currently accessible concepts (Balcetis & Cole, 2013, Balcetis & Dale 2003; Balcetis & Dale, 2007). People who were given stories to read about the music industry or deception, identified the drawing as a saxophone player (Balcetis & Dale, 2007) rather than a face, or the word "liar" rather than a face, respectively (Balcetis & Dale, 2003). These effects can be explained by the situated inference model by Loersch and Payne (2011), which argues that cognitive constructs, which are rendered more accessible by priming, are more likely to be used to disambiguate information in the environment. This, in turn, affects perception, motivation and behaviour.

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To see example images please view Balcetis and Dale, 2003, page 110, page 112.

Figure 1.1. Ambiguous Pictures. Left: saxophone player vs. woman's face; right: word "liar" vs. face (as used in Balcetis and Dale, 2003).

Similarly, perception can also serve motivation. In a very interesting set of studies, Balcetis and colleagues investigated the influence of cognitive dissonance on perception (Balcetis & Dunning 2007). Cognitive dissonance occurs when one's behaviour is not in sync with one's thoughts (Festinger, 1957). Festinger (1957) argued that the human mind would do everything to resolve this discrepancy, which leads to psychological discomfort (Elliot & Devine, 1994; Balcetis & Dunning, 2007). In a study by Balcetis and colleagues (2007) participants had to push themselves up a hill while kneeling uncomfortably on a skateboard. In the high choice condition it was pretended that participants had a choice on whether they want to do this test or rather choose another one, although it would be preferable for the examiner if they'd help out with this particular study. In the low choice condition participants were told that they were assigned to this task without any other alternatives. As it was expected, people in the high choice condition perceived the hill to be less steep than people in the low condition (Balcetis & Dunning, 2007). This is due to the fact that in the high choice condition people were motivated to reduce their dissonance, i.e. steep hill and uncomfortable method of moving, as they had chosen this uncomfortable task themselves by perceiving their environment as less strenuous (Balcetis & Dunning, 2007).

Additional studies have shown that momentary goals can influence perception. For example, thirsty people were more likely to perceive ambiguous stimuli as more transparent, presumably as transparency is a characteristic of water (Changizi & Hall, 2001; Balcetis & Dunning, 2006) or women that are in their high fertility periods are faster in recognizing photographs depicting men (Macrae, Alnwick, Milne & Schloerscheidt, 2002; Balcetis & Dunning, 2006). Thus, there is a great amount of literature supporting the notion that goals and motivation can influence what we perceive, but can goals also influence what we become consciously aware of?

1.1.3 Attention

Literature focusing on attention had already made attempts to unravel the mysteries of consciousness; whether stimuli can be processed to a high cognitive level and then be selected to reach consciousness (late selection), or whether the selection happens before the processing (early selection) (for a review see Shapiro, Caldwell & Sorensen, 1997; Lavie, 1995). However, most attention paradigms never tested consciousness directly, but only implied that results could be due to awareness e.g. attentional blink (Broadbent & Broadbent, 1987) or dichotic listening task (Moray, 1959; Cherry, 1953). In the dichotic listening task, people are presented with two different audio streams in each ear and are asked to attend to only one of them. However, when personally relevant words, e.g., one’s name, are played in the unattended ear, the person’s attention swiftly changes from the attended ear to the unattended one. This attention shift used to be regarded as an indication for preconscious processing, however, the generalization of such findings is very limited, as one’s own name seems to be the exception to the rule. Any other word stimuli usually do not break the attentional threshold if they are presented in the unattended stream (Moray, 1959). Moreover, further research suggests that working memory capacity (WMC) can affect the probability of whether a person can detect one's name in an ignored audio stream (Colflesh & Conway, 2007). Only 20% of people with a high WMC noticed their name in the unattended channel, compared to 65% of people with low WMC. This study proposes that with increasing WMC people can focus their attention better to the task at hand (Colflesh & Conway, 2007).

Attention could be regarded as a gate-keeper for what stimuli get processed. Due to limited cognitive capacity people can neither process nor attend to everything around them (Schmid & Maier, 2015; Dijksterhuis & Aarts, 2010). Attention selects which information is processed and which is ignored (Koch & Tsuchiya, 2007; Dijksterhuis & Aarts, 2010), and active goals can exert a top-down effect on what stimuli will get attended to (Koch & Tsuchiya, 2007; Dijksterhuis & Aarts, 2010). However, this does not automatically imply consciousness awareness.

There is a growing body of literature proposing that attention and consciousness are two distinct entities (Koch & Tsuchiya, 2007). In their critical review paper, Koch and Tsuchiya (2007) point out different constellations of top-down attention and consciousness. For example, people can consciously become aware of the gist of a picture within 30 milliseconds of presentation, but this time frame would be insufficient for top-down attention to play a role. Besides, attention can be directed to a location without people becoming consciously aware of it. In Jiang and colleagues' study, participants were presented with erotic images that were interocularly masked – this will be explained later in further detail – which made the images "invisible" to the participants (Jiang, Costello, Fang, Huang & He, 2006). Performances on a subsequent orientation task were significantly better at locations that were preceded by invisible erotic images (Jiang, et al., 2006). Thus, attention does not seem to be a prerequisite for what enters conscious awareness, and therefore the question of whether motivation affects what people become consciously aware of still stands unanswered.

1.1.4 Unconscious Goal Pursuit

Thus far, it has been shown that active goals can have a significant influence on how people perceive the world around them. Goals can exert top-down processes on perception (e.g. Balcetis & Cole, 2013; Balcetis & Dunning, 2006) and attention (Dijksterhuis & Aarts, 2010; Koch & Tsuchiya, 2007). Importantly, all those influences can occur without conscious awareness (Dijksterhuis & Aarts, 2010; Bargh, Gollwitzer, Lee-Chai, Barndollar, Trötschel, 2001). The predominant view used to be that goal-directed behaviour was the result of conscious processes, as it requires amongst others, planning and decision-making (Custers & Aarts, 2010). Yet, a lot of recent research has undermined this view by showing that much of goal pursuit can occur under the threshold of conscious awareness (e.g. Bargh et al., 2001; Kay et al., 2004). Preconscious goal pursuit can occur because goals are mentally represented as knowledge structures, as discussed earlier (e.g. Shah & Kruglanski, 2000; Shah et al., 2003). Due to their mental representation and many linked associations, (see hierarchical goal system theory: Shah & Kruglanski, 2000; Shah et al., 2003) goals can be rendered accessible through many different ways, be it through traditional priming of words such as the names of significant others or by just perceiving distinct objects in one's surrounding. For instance, Shah (2003) found that priming people with the name of a person they know can affect subsequent task performance as a function of closeness and importance of the relationship. While in Kay and colleague's (2004) study, participants acted more competitively after they saw a leather briefcase lying on a desk (Kay, et al., 2004). In contrast to just simple concept priming, motivational priming grows stronger the longer the primed goal stays unfulfilled.

At this point it is a good opportunity to take a closer look with what is meant by accessibility. The term was first introduced by Higgins (Higgins, Rholes, Jones, 1977; Higgins 1996) and has been widely used in social psychology literature. Researchers refer to concepts being accessible, such as memory structures or stereotypes in order to form impressions. Moreover, accessible knowledge structures help to disambiguate situations, (e.g. adventurous versus reckless, Higgins et al. 1977) and increase the probability that the accessible structure will be used in decision-making and behaviour. In neuroscience on the other hand, brain regions that hold those mental representations get activated. Those activated brain regions then in turn affect our perception and behaviour. It could be regarded as the neurological equivalence to knowledge accessibility.

It is important to point out that only because a concept is accessible it is not necessarily expected. Memory structures and concepts can become accessible subconsciously and prime a person to perceive their environment biased towards that accessible structure, however people do not expect to see their environment that way. On the other hand, when people form expectations, the expected concept will in turn be accessible on their minds, one could even argue that this could be the strongest form of accessibility (this will be further elaborated in chapter 6).

Besides accessibility, another requirement for preconscious goal pursuit is the positive affect. The end state of attaining a goal needs to be desirable (Custers & Aarts, 2007a; Custers & Aarts, 2007b). There are two sources of motivation to attain a goal. One is to resolve deprivation of resources that are required for survival (i.e. water, food) and the other is an action that has been associative with positive affect (i.e. eating chocolate, ice cream) (Custers & Aarts, 2005; Veltkamp, Aarts & Custers, 2009). By repeatedly selecting one specific action to successfully fulfil a goal, that chosen action gets linked to a state associated with positive affect. (Custers & Aarts, 2005). This positive affect becomes in a way a “common currency” (Aarts, Custers, Veltkamp, 2008, p.571) that allows the brain to quickly and subconsciously evaluate a situation and weigh a goal’s value against the effort to achieve it (Custers & Aarts, 2005; Custers & Aarts, 2010). Several studies have shown that increasing the positive valence of a certain state can automatically increase a person’s effort to pursue that goal (Custers & Aarts, 2005; Pessiglione et al., 2007).

In summary, goals can direct perception and attention towards goal attainment without any conscious awareness and goal pursuit itself can occur without conscious awareness. This in itself implies that goals must be able to drive at least some preconscious selection. But does that also imply that goals can directly affect what enters our conscious awareness without being bound to means such as attention? Can it directly bias what information breaks the threshold to conscious awareness? In the past, there have been no real direct measures to test this question. As we reviewed, the attention literature attempted to answer the question of what breaks the threshold to conscious awareness, but most measurements have been very indirect and relied on verbal self-report. Moreover, the relationship between attention and consciousness is rather complex and manifold. More direct measures have emerged in recent years, such as dichotic rivalry - especially continuous flash suppression (CFS) - that allow direct time measurement of conscious awareness.

1.2. Borders of Consciousness

Before I delve into the CFS technique, a few words should be mentioned about consciousness, as this plays a significant role in this thesis. Currently, there is a prominent view that distinguishes two systems that govern perception and behaviour: a conscious, reflective processing stream and an unconscious, impulsive processing stream (Strack & Deutsch, 2004; Kahnemann, 2011). Both streams are thought to work together in parallel (Strack & Deutsch, 2004; Kahnemann, 2011). The reflective processing stream is based on rational decisions and consciously weighs different options. Its execution is slow but at the same time quite flexible (Strack & Deutsch 2004; Evans, 2008). The impulsive processing stream on the other hand, relies on learned associations like habits and is fast and automatic, but is based on slow changing representations (Strack & Deutsch, 2004; Evans, 2008). The reflective stream requires cognitive resources and effort, while the impulsive stream is automatic and effortless.

Focusing on just the consciousness part of the theory due to the limited cognitive resources, the impulsive stream is believed to be the default system people operate on (Evans, 2008). In other words, as some researchers call it, people function on an autopilot most of the time (Gayet, Paffen & Van der Stigchel, 2013; Koch & Tshuchiya, 2007). Due to those limited resources, consciousness is primarily used for higher functioning such as making inferences, planning and setting goals (Gayet et al., 2013; Koch & Tshuchiya, 2007). This is only a small excerpt of how conscious and unconscious processing streams can exert an influence on our daily lives. While there is a lot of work exposing the neural correlates of consciousness, other theories focus on consciousness as prerequisite for behaviour and perception. For the scope of this thesis, I focus on the latter theories and their findings.

Amihai and colleagues (Amihai, Deouell & Bentin, 2011) proposed a hierarchy within the cognitive processing stream, with the subconscious processing being the base of all information input. Once filtered, selected information is passed on to a subsequent conscious processing that provides a more complex picture of the input (Amihai et al., 2011). This is in line with the global neuronal workspace (GNW) theory (Dehaene & Naccache, 2001), which proposes that information needs to be amplified and maintained for a certain amount of time in order to enter consciousness (van den Bussche, Segers & Reynvoet, 2008; Dehaene & Naccache, 2001). The GNW theory also suggests that only consciously perceived information has the potential to be used strategically and consequently improve performance on a given task (van den Bussche, et al., 2008; Dehaene & Naccache, 2001). Therefore, it is suggested that while stimuli, which people are unaware of can trigger all kinds of processes, they cannot be the base for conscious decisions (van den Bussche, et al., 2008; Dehaene & Naccache, 2001).

Research literature focusing on consciousness is broad; some focus on its effects on behaviour (e.g. Strack & Deutsch, 2004; Kahnemann, 2011) while others on the more theoretical neurological part (e.g. Dehaene & Naccache, 2001). Nevertheless, understanding the factors that affect what enters consciousness is still in its early stages. In this thesis I address the question of whether goals can influence conscious awareness, specifically the awareness of goal-related stimuli.

An early attempt to answer this question was undertaken by Balcetis and colleagues (Balcetis, et al., 2012). The researchers argued, that as people's perceptions are influenced by their current attitudes and beliefs – as discussed in detail previously – that kind of "wishful thinking" should already start with perception, and stimuli which match people's current motivation should gain priority in conscious awareness. Applying a binocular rivalry (BR) technique – in which different images presented to each eye compete to be consciously perceived while the other is suppressed (Arnold, Law & Wallis, 2008; Alais & Blake, 2005) - they observed that images that had been explicitly outlined as rewarding reached consciousness more often than neutral or cost related pictures (Balcetis, et al., 2012). Hence, explicit task-goals appear to facilitate perception of goal-related stimuli.

The BR technique has a few shortcomings, however. While BR renders a stimulus invisible by temporarily preventing its access to conscious awareness (Yang, Zald, Blake, 2007, Alais & Blake, 2005; Tsuchiya, Koch, Gilroy & Blake 2006) and therefore offering a potential tool for studying consciousness, it is not an optimal technique for studying preconscious processing. The suppression duration usually only lasts for a few seconds (Tsuchiya et al., 2006; Arnold et al., 2008) and the swaps in perceptual dominance between eyes are hard to control (Arnold et al., 2008; Tsuchiya et al., 2006). Sometimes, fragments of both images can be consciously perceived at the same time (Arnold et al., 2008). Those perceptual uncertainties make it quite difficult to use BR as a reliable technique and to make substantial causal inferences (Tsuchiya et al., 2006). The successor, CFS, has proven to be a more compelling design to investigate motivational influence on conscious awareness.

Chapter 2. CFS

Continuous flash suppression (CFS) is based on the idea of BR, yet in CFS only one eye is presented with a static image while the other is presented with a flashing mask (Tsuchiya et al., 2006; Barbot & Kouider, 2012). The flash consists of a series of counter-rich, high contrast patterns, also known as Mondrian pattern (Tsuchiya et al., 2006; Barbot & Kouider, 2012; Yang & Blake, 2012). The flash initially dominates conscious perception, but the static picture eventually breaks through into conscious awareness in the other eye. Figure 2.1 shows a schematic setup for both BR and CFS (Lin & He, 2009).

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To see schematic illustration please view Lin and He, 2009, page 196.

Figure 2.1. Sequence Illustration of CFS and the mirror stereoscope participants look through (graph align to Lin & He, 2009).

In contrast to BR, CFS allows a stimulus to be completely invisible for a long period of time, ranging from a few seconds up to minutes (Yang et al., 2007; Laptate, Rokers & Davidson, 2013; Lin & He, 2009). Another advantage of CFS is that all target stimuli are presented against the same mask and do not compete against each other as in BR (Costello, Jiang, Baartman, McGlennen & He, 2009). This increasingly controlled setting allows one to make more accurate and more sustainable inferences about the time the suppressed stimulus needs to emerge into conscious awareness (‘time to emerge’: TTE) (Costello et al., 2009). To summarize, CFS has great control regarding timing (Barbot & Kouider, 2012) and due to its increased efficiency and reliability it has been repeatedly named the best method so of yet to study processing outside conscious awareness (Zabelina, et al., 2013; Arnold, et al., 2008; Yang et al., 2007; Yang & Blake, 2012).

2.1 CFS Bottom-Up Processing

CFS has grown massively in popularity in recent years and with it researchers’ desire to finally demystify the subconscious – how much can be processed outside of awareness? Is higher-level processing possible without conscious awareness? Questions over questions, however, the main focus of this dissertation lies in whether motivation can affect what enters conscious awareness. The literature is very mixed when it comes to the extent to which TTEs are influences by preconscious processing (see review by Gayet, Van der Stigchel & Paffen, 2014). Some argue that higher-level processing is possible (e.g. Mudrik, Breska, Lamy & Deouell, 2011; Sklar et al., 2012), whereas others believe that many of the positive CFS findings on higher-level processing can be traced down to alternative explanations (Gayet, et al., 2014; Stein, 2012). Gayet and colleagues (2014) have produced an extensive review paper examining all 30 CFS studies that had been conducted up to that point (Gayet et al., 2014).

One possible way to distinguish between different TTE effects is to look at bottom-up and top-down effects. By bottom-up I refer to effects that have been influenced by bottom-up processes and features, such as low-level visual features, salient stimuli attributes as well as stimuli that enjoy specialised processing, e.g. face processing. Top-down effects, on the other hand, are guided by having a mental representation accessible. For example, when people look for their house keys before leaving home, they create an inner picture of how those keys look and scan their environment for them. Thus, looking for house keys would be guided by top-down processing. Moreover, as mentioned before having information or an image of a concept accessible on one's mind, helps people to disambiguate information around them (e.g. Loersch & Payne, 2011; Higgins et al., 1977). This effect is also governed by top-down processes. In the next chapters I will illustrate how top-down effects can influence CFS.

One observation that led to agreement across research literature is that interocular suppression is very susceptible to low-level visual features of the suppressed stimuli. These include variations of spatiotemporal properties, spatial frequency, contrast, brightness, number of pixels of the suppressed stimuli, and for word stimuli; the length of words as well as the amount of ascenders and descenders (Yang & Blake, 2012; Tsuchiya & Koch, 2005; Mudrik, et al., 2011; Gayet et al., 2014). Therefore, differences in TTE derived from such low-level properties can hardly be regarded as evidence for preconscious processing.

CFS has been used intensively in the face and gaze literature. Many studies found that upright faces gain prioritized access to conscious awareness, i.e. break suppression faster, over inverted faces (Jiang, Costello & He, 2007, Zhou, Zhang, Liu, Yang & Qu, 2010). Similar TTE advantages have been found with familiar faces compared to strangers' faces (Gobbini et al., 2013b; Gayet et al., 2014), and for faces from the same age groups compared to faces from different age groups (Stein, 2012; Gayet et al., 2014).

Additionally, it was found that faces bearing fearful expressions gain conscious awareness faster than neutral or joyful expressions (Yang et al., 2007) and direct gaze is faster detected than averted gaze (Gobbini, Gors, Halchenko, Hughes & Cipolli, 2013a; Chen & Yeh, 2012). Those effects strongly suggest that familiarity and stimuli bearing social relevance can influence what information emerges into conscious awareness. Yet, due to the unique position that face perception has in the brain – neuroimaging and lesion studies have found that there are specialised brain areas, such as the fusiform face area (FFA) designated for face perception (Kanwisher, McDermott & Chun, 1997; McCarthy, Puce, Gore & Allison, 1997; McNeil &

Warrington, 1993) – it is difficult to make general claims of preconscious processing.

2.2 CFS Top-Down Processing

More generalizable insight comes from recent cross-modal priming studies. Zhou and colleagues (2010) observed that when participants were performing a CFS task while simultaneously being presented with different olfactory stimuli, e.g. the scent of a rose, images that matched the scent, e.g. a rose, broke CFS suppression faster than non-matching images, e.g. marker pen (Zhou, Jiang, He & Chen, 2010). Similar cross-modal effects were also found with auditory cues. For instance, Alsius and Munhall (2013) observed a TTE advantage for faces that depicted lip movements in sync with supraliminally presented auditory sentences, compared to faces with non-matching lip synchronisation (Alsius & Munhall, 2013). Similar advantages were found in Lupyan and Ward’s study (2013) in which preceding valid auditory cues, e.g. the word “pumpkin”, facilitated detection of matching targets under CFS, e.g. image of a pumpkin, while invalid cues, e.g. the word “kangaroo” interfered with the detection. Those studies strongly suggest that consciously accessible information, such as for example olfactory or auditory cues, influence what type of information is prioritized for access into conscious awareness.

Some researchers decided to manipulate the content of visual working memory directly, in order to see whether information that is kept active in the visual working memory (VWM) can also affect what type of information breaks into conscious awareness (Gayet et al., 2013; Pan, Lin, Zhao & Soto, 2014; Soto, Mäntyla & Silvanto, 2011). In one study, participants were asked to memorize a colour patch on every trial for a subsequent memory test (Gayet, et al., 2013). After seeing and memorizing the presented colour patch, the patch disappeared and a CFS trial followed. Targets that matched the stored colour patch in VWM emerged faster through the suppression into conscious awareness (Gayet, et al., 2013). Same results were achieved with other stimuli such as orientation of a Gabor patch (Soto et al., 2011) and faces (Pan et al., 2014). Generally, working memory (WM) is defined as a storage facility for information relevant for “imminent” goal directed behaviour, thus it would be beneficial for stimuli that are relevant for such goals to be prioritized for conscious awareness (Gayet, et al., 2013; Soto et al., 2011; Soto & Silvanto, 2014).

Even though neither of the two lines of research - cross-modal priming (e.g. Zhou, Jiang et al., 2010) and working memory experiments (e.g. Gayet et al., 2013) – specifically claim to test the effects of accessibility, they demonstrate how keeping certain information active at different processing levels can affect what type of stimuli enters conscious awareness.

There is some evidence proposing that even semantic processing can occur via top-down processing without conscious awareness. Words from one’s own native language break suppression quicker than words from a foreign language (Jiang et al., 2007). A similar effect occurs for words that are semantically related to previously shown words or words that share subwords (Costello et al., 2009). This prioritization into conscious awareness can also be found for entire sentences. Sklar et al. (2012) observed that semantically incorrect sentences emerged faster into consciousness than correct ones.

Equivalent semantic processing effects were found with numerical stimuli (Sklar, et al., 2012; Bahrami et al., 2010). One study investigated whether numerical properties could be processed outside conscious awareness. In this regard arithmetic equations (e.g. 9-3-4 =) were first presented as primes in the CFS flash and later the equation’s correct or wrong answer was presented to the other eye (Sklar, et al., 2012). Participants were not aware of the equations and had to only verbalize the visibly presented number. Digits mismatching the equation’s answer were perceived consciously faster than matching ones (Sklar et al., 2012). It should be noted that research on numerical properties is yet to reach a consensus due to some mixed results (see Hesselmann, Darcy, Sterzer & Knops, 2015), some of the possible drawbacks onto why some of the CFS literature is mixed will be elaborated in a more general approach in the discussion.

Another higher-level property, the integration of different perceptual stimuli into a comprehensive scene, used to be accredited to the functions of consciousness. Mudrik, and colleagues (2011) tested this property and found that incongruent scenes, such as two people playing basketball with a watermelon instead of an actual basketball, broke CFS suppression faster than congruent scenes (Mudrik et al., 2011). The researchers concluded that consciousness is not necessarily needed for object-background integration as long as the integration runs smoothly as it is supposed to be. The moment a novel situation or obstacle arises however (e.g. using a watermelon as a basketball), consciousness is needed to deal with the situation (Mudrik, et al., 2011).

In addition to being able to detect single stimuli, the latter mentioned studies of arithmetic (Sklar et al., 2012), sentence comprehension (Sklar et al., 2012) and scene integration (Mudrik, et al., 2011), point to the possibility that people might be able to perceive and comprehend stimuli embedded within different contexts, e.g. sentence or scene. Moreover, people might be able to preconsciously process that type of information without necessary conscious awareness. Some authors have voiced the possibility that consciousness may only kick in when the preconscious registers that something is not right (see Bongers, Djiksterhuis & Spears, 2010). Simultaneously, this explanation stands in contradiction with the familiarity findings (Gobbini et al., 2013b; Gayet et al., 2014; Stein, 2012; Jiang et al., 2007) that were described earlier; where familiar faces, upright faces, same age faces and words from a familiar script break suppression into conscious awareness faster. So, how do the aforementioned contradictory results, which found that sentences and scenes that are incomprehensible and thus unfamiliar and novel, emerge faster into consciousness, fit in? One possibility is that at higher cognitive levels, the respective cognitive processing – be it conscious or preconscious – gets more complicated and cannot be explained by only one generic theory. Participants in all familiarity studies were presented with only one stimulus at a time (e.g. Gobbini et al, 2013b), whereas in the other studies they were presented with an integrated scene composed of many visual items (Mudrik et al., 2011) or strings of stimuli (Sklar et al., 2012). Thus, it is possible the brain uses different processing strategies once the suppressed target is embedded within a changing context on a trial level.

Another factor to consider is that opinions on whether semantic processing on a preconscious level is actually possible in the first place, differ strongly. It is argued that if no semantic processing was observed under other interocular suppression paradigms such as BR – on what CFS is based - (Cave, Blake & McNamara, 1998; Zimba & Blake, 1983; Hesselmann, et al., 2015), how should any semantic processing be possible under CFS? Some researchers use BR's limitation as an explanation, and propose that any missing effects under BR can be traced back to "insufficient suppression times to keep stimuli invisible" (Lin & Yeh, 2016 page 29; Lo & Yeh, 2008). At the same time, it should be noted that it is not entirely clear whether BR and CFS operate under the same mechanism. While Shimaoka and Kaneko (2011) claim that CFS is an optimized version of BR, Tsuchiya and colleagues (2006) believe that CFS is an entirely separate mechanism, therefore missing effects under BR should not be a benchmark to compare CFS results to (see also critical review paper Sterzer, Stein, Ludwig, Rothkirch & Hesselmann, 2014).

Another reason as to why some people are sceptical of the possibility of semantic preconscious processing is rooted in neurological studies that failed to detect any N400 signal when participants had to judge the semantic relatedness between stimuli that were presented under CFS (e.g. Kang, Blake & Woodman, 2011). The N400 is a commonly used index in event related potentials (ERPs) for detecting semantic processing and semantic mismatch to be exact (Kang et al., 2011). While this can appear as evidence dismantling the existence of semantic preconscious processing, the mere absence of signals only cannot be taken as evidence that such processing does not occur (Sterzer, et al., 2014). In this regard, the authors of the missing N 400 paper stated that there could be other neurological activity signals that occur in response to processing semantics, which might have not been picked up by the chosen machine (Kang et al., 2011). Moreover, McNamara (2005) argued that the occurrence of semantic processing has already been demonstrated in a variety of tasks under many other masking paradigms before.

To summarize, CFS appears to be a promising paradigm to test preconscious processing due to its long suppression times, amongst other paradigms. Research on CFS has demonstrated that bottom-up as well as top-down processes influence TTE. Firstly, low-level properties such as the saliency of the suppressed stimuli (e.g. brightness) can prioritize access to conscious awareness. Secondly, consciously accessible information (e.g. VWM content) seems to exert a top-down influence on TTE. Higher-level processing such as arithmetic and sentence processing appears to occur without conscious awareness. Whether this preconscious higher-level processing can extend into semantics is a delicate topic. Apart from behavioural studies that test the limits of preconscious processing, neurological studies are essential in order to understand what occurs on a neurological basis while people view suppressed stimuli.

2.3 Neurological Evidence

In 2014, Sterzer and colleagues (2014) produced an elaborated and insightful review of neural processing under CFS (Sterzer, et al., 2014). The first stage that processes most of the incoming visual information from the retina is the primary visual cortex V1 (Sterzer et al., 2014). Many believe that the interocular competition is resolved in the early visual areas such as V1 and lateral geniculate nucleus (LGN) (Sterzer et al., 2014; Gayet et al., 2014; Yuval – Greenberg & Heeger, 2013) as neural activity of the suppressed stimulus decreases gradually along the visual hierarchy (Gayet et al., 2014). The mechanism under which CFS operates is believed to be via changing contrast gain of neurological responses (Yuval-Greenberg & Heeger, 2013). “The idea of normalization model is that the response of a neuron to its preferred stimulus (i.e. target) is suppressed by the pooled (summed) activity of a population of neurons (the normalization pool) that are responding to the surrounding context (i.e. mask)" (Yuval-Greenberg & Heeger, 2013, p.9641). Thus, superimposing the mask reduces the neural signals of the target (Yuval-Greenberg & Heeger, 2013). Importantly the signal is reduced, not fully knocked out. After the visual processing areas many believe that any neural activity of the suppressed stimuli is abolished in higher processing areas such as fusiform face are (FFA) and parahippocampal place area (PPA) (Gayet et al., 2014; Sterzer et al., 2014).

This however, is challenged by previous masking studies that found neural activity in the extrastriate, fusiform and precentral areas when people were presented with masked words (Dehaene & Naccache, 2001; Costello et al., 2009). Many studies have also found higher neural activity in the amygdala when the suppressed stimuli were of an emotive nature (Almeida, Pajtas, Mahon, Nakayama & Caramazza, 2013; Jiang et al., 2006). Neural activity as a result of masked stimuli could be exclusive to processes that support action (Fang & He, 2005; Lin & He, 2009, for review Hesselmann, Darcy, Ludwig & Sterzer, 2016). In a study where participants were presented with images of tool and animals under CFS, it was found that only images of tools evoked neural activity in the dorsal stream, also known as the "vision-for-action" pathway (Almeida, Mahon, Nakyama & Caramazza, 2008; Hebart & Hesselmann, 2012). This result was explained by the idea that the dorsal stream is processing action-relevant input, while the ventral stream is important for processing the identity of stimuli. As tools can be acted with and manipulated, the authors concluded that the processing of suppressed stimuli is intact in the dorsal stream (Almeida et al., 2008). However, those findings were also replicated with images of vegetables (Sakuraba, Sakai, Yamanaka, Yokosawa & Hirayama, 2012), as long as the vegetables were in an elongated form like the tools that had been used in Almeida's et al. (2008) study. This means that those findings could not be explained with the manipulation explanation. Sakuraba and colleagues (2012) concluded that the dorsal stream might be more specific for shape processing rather than categorization (Sakuraba et al., 2012).

Another possible reason that had not been considered by the researchers could have been aligned with Gibson's theory of affordances (1979). Gibson (1979) argued that the study of perception should always consider the meaning of the perceived stimuli in the environment. With "meaning" Gibson referred to the personal experience perceived stimuli can offer people. The elongated stimuli in the previous experiments were all "graspable"; that is the way people would interact with those stimuli in their environment. Thus, this could be the reason why both elongated tools and elongated vegetables showed the same results due to their affordances.

In contrary to some previous findings, Sterzer and colleagues (2008) found neural activity in the neural ventral stream, also known as the "vision-for-perception" pathway, even when the stimuli were suppressed under CFS (Sterzer, Haynes & Rees, 2008; Hebart & Hesselmann, 2012). More specifically, the neural activity recorded in the high level visual areas allowed the researchers to predict whether a participant had viewed a suppressed face stimuli or building stimuli. The reason for the conflicitng positive intact ventral processing findings is that Sterzer and colleagues (2008) used high-resolution fMRI and multi voxel pattern analysis. This increases the sensitivity of the fMRI signals in the fusiform face area and parahippocampal place area, which are normally significantly reduced in the BOLD signals.

Therefore, the reason behind so many contradictory neurological studies can be attributed to the sensitivity of neural activity measurements. A missing neural signal does not automatically conclude that no processing occurred, rather it may be that the signal was simply too weak. Another reason could be traced back to the depth of interocular suppression. If it is not deep enough, false positives can occur. If it is too deep, no processing will occur (Sterzer et al., 2014).

Bearing this in mind, to quickly reiterate in the beginning I reviewed literature showing that goals can direct perception and attention outside conscious awareness. This in itself implies that goals must be able to drive some of the preconscious selection. CFS offers a great method to test this hypothesis and assess whether goals can influence what breaks through suppression and into the palm of conscious awareness.

Chapter 3. Overview of Present Research

The present research investigates whether motivation can exert a direct top-down effect on preconscious processing tested via CFS. The underlying working model of this dissertation is the idea that goals can exert an indirect influence on perception and behaviour through top-down processing. It is assumed that this top-down processing occurs via accessibility of goal-related information (see figure 3.1). I, thus, argue that if a goal is accessible, it should then exert top-down influences on one's surrounding.

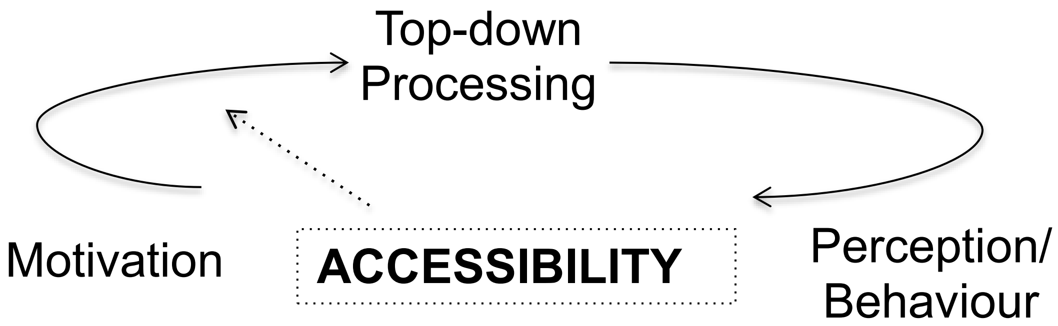

Figure 3.1. Simplified Motivational – Behavioural Chain.

This idea will be tested in the first experimental chapter 5, where I set out to investigate whether motivation influences goal-related stimuli to break CFS faster than goal-unrelated stimuli. Fluid deprivation will be used to induce motivation (see Veltkamp, Aarts, & Custers, 2008a; Veltkamp, Aarts, & Custers, 2008b). I would expect deprivation to cause goal-related stimuli to break CFS suppression faster into conscious awareness. This is based on research in the vision domain, which shows that consciously accessible information prioritizes what enters conscious awareness (Gayet et al., 2013), and on research in goal literature, which shows that after a goal has been primed, goal-relevant information gets activated subconsciously.

Due to quite "sobering" results, in chapter 6 I will take a few steps back in the motivational – behaviour chain in order to see whether the results from Chapter 5 are due to manipulation reasons or whether top-down influences cannot be tested under

CFS. Assuming that goals do influence our behaviour and perception via accessibility, the next step would be to target accessibility directly.

As pointed out earlier, it is assumed that having a goal in one's mind will render the goal's representation that consists of its content and the means to attain it, more accessible. This accessibility should consequently influence perception and behaviour. Before testing accessibility of concepts, I will take a step back in chapter 6 and test mere accessibility on a trial level under CFS. Manipulating the accessibility of individual targets on a trial level is supposed to induce expectancy. Every trial consists of a supraliminal cue and a suppressed target. The cues are predictive of the subsequent target most of the time. Therefore, I hypothesize that the instrumental and predictive nature of the cues should evoke expectancy, which in turn should result in congruent targets to emerge faster into consciousness. Inducing expectancy seems like the strongest possible manipulation for top-down processing. The next step would be to move on to an ecological paradigm that is more valid, such as inducing mere accessibility that is not necessarily instrumental for the CFS task at hand.

This is exactly what I will proceed to do in chapter 7, where it will be tested whether concepts that are kept accessible at all times can exert a top-down effect on preconscious processing. It is important to note that in this study I do not try to guide top-down processing, as I did in the previous study. On the contrary, I try to keep participants occupied by keeping a list of words active on their minds, which they have to report back to me after the completion of the entire CFS task. Therefore, there should be no reason for participants to start actively looking for those words in the CFS task, unless top-down processing occurs due to those stimuli being accessible in their minds.

In chapter 8 I will test whether higher-level processing can occur under preconscious processing. At the same time I will examine whether the previously found accessibility effect can be accounted for by familiarity, as participants might have become automatically more familiarized with the words they had to study. In this study participants will be presented with 2 lists from different categories and the rewarding category will only be indicated after participants have studied both lists. This way, participants should be equally familiar with the words from the rewarded and non-rewarded list. Furthermore, to test whether the reward effect generalizes across category members, novel words belonging to the same category as either the rewarded or non-rewarded list will be presented in the CFS phase.

It should be noted that the experiments will not be described in the chronological order they were conducted, but rather in an order that facilitates a clear presentation of how the individual experiments fit together, in understanding what types of top-down processing can occur under preconscious processing. Consequentially, different methodologies that were used in regard to this research, will jump back and forth throughout the order of describing the studies.

Chapter 4. CFS – Methodology

Continuous flash suppression (CFS) is a variant of dichoptic simulation in which each eye is simultaneously presented with different stimuli. As mentioned earlier in a typical breaking-CFS set-up, one eye is presented with a stimulus, e.g. word or image, whereas the other eye is presented with a mask. One of the most widely used methodology derives from the studies led by Tsuchiya and Koch (2005). In this original set-up flashing colourful Mondrian patterns were used as the suppressing flash (see figure 4.1).

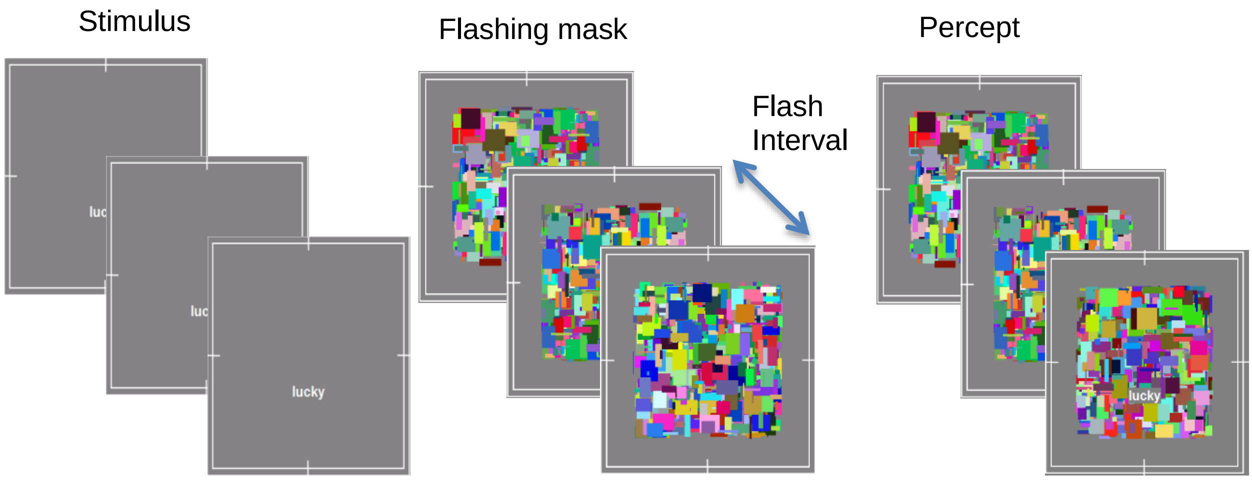

Figure 4.1. Illustration of a Typical CFS Trial.

However, a standardized set-up for CFS has not been developed yet, thus many researchers are free to decide upon many different experimental variables. Such freedom of choice can inevitably produce contrary results from similar CFS experiments, as it is known that CFS is very susceptible to slight low-level feature changes. This problem will be discussed in more detail in the general discussion of this thesis. In the following I will describe the methodological choices applied on this work.

First of all, there is a great number of different masks that can be chosen for an experiment. The mask can be colourful, black and white and can compromise different sized shapes often rectangles but not limited to that. Figure 4.2 shows some representative example of the wide range of different variations of masks. The flash and the suppressed stimuli are displayed side by side on the computer screen and fusion is reached by a mirror stereoscope (e.g. Pan et al., 2014; Costello et al., 2009; Tsuchiya & Koch, 2005). Refreshment rates of the masks can vary from 10 Hz (e.g. as used in Pan et al., 2014; Tsuchiya & Koch, 2005) to 20 Hz (e.g. as used in Yokomaya, Noguchi & Kita, 2013).

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To see examples of different CFS masks, please view Ludwig and Hesselmann, page 252.

Figure 4.2. Example of Different CFS Masks (Ludwig and Hesselmann, 2015).

The first possible obstacle is that not all CFS studies use Mondrians as a mask. Some researchers use monochrome high contrast noise patterns, as shown in box 2 in figure 4.2, and in order to reach fusion anaglyph glasses have to be used (e.g. Almeida et al., 2008; Lupyan & Ward, 2013). However, using anaglyph glasses allows crosstalk between eyes, which is a limitation (Hesselman, et al., 2016).

Another crucial variable is the calibration. In order to achieve the optimal suppression, contrasts need to be adjusted for each participant individually. It is up to each researcher to decide how conservative they make the calibration. Too fast suppression times could reflect a shallow suppression, as it has been suggested that the potency of suppression has to build up with a few successive masks (Yang, Brascamp, Kang & Blake, 2014; Tsuchiya et al., 2006). Too long suppression durations might have other confounding factors affecting the results such as partial awareness. It should be noted that some researchers use two computer screens, each for one eye (e.g. Heyman & Moors, 2014), this calibration might factor in differences between eyes. However, onset times of the computers could differ minimally, which could in turn have huge consequences on the entire CFS design. As most people have one dominant eye and one non-dominant eye, some researchers decide to present the suppressed stimuli only to the dominant eye, in order to circumvent the variance in data that is caused by eye differences (Gayet et al., 2013). While others do not mention how they tackle the problematic that arises from eye differences. To control for differences between eyes I z-score the TTE times per eye and then average those two z-scored eyes into one value.

There are also different ways of presenting the mask and stimuli. Some present the stimuli in full contrast to the suppressed eye while having the flash operating in full contrast, too (Tsuchiya & Koch, 2005). Some other authors use a ramping contrast display in that the stimulus contrast is gradually increasing from 0% to 100%. The ramping duration however is again variable across studies, some use 1s (e.g. Costello et al, 2009; Pan et al., 2014), 1.5s (Gayet et al., 2013), 2s (e.g. Salomon, Lim, Herbelin, Hesselmann & Blanke, 2013) or even 5s (e.g. Hung & Hsieh, 2015). Some set-ups decrease the contrast of the mask gradually while the stimulus contrast is increasing (e.g. Pinto, van Gaal, de Lange, Lamme & Seth, 2015), or decrease the mask contrast once the stimulus's contrast is to 100% (e.g. Mudrik et al., 2011). All those variables make it more difficult to make comparisons across the CFS literature.

For the initial set-up (static method) I leant on strongly on the original CFS version by Tsuchiya & Koch (2005). A colourful Mondrian mask that flashed at a 20Hz refreshment rate – this number was used after counselling with colleagues in my department that had used CFS before – was used. The stimuli were presented in full contrast while the mask continued to flash in full contrast in the other eye. I used mirror stereoscopes and tried to calibrate subjects so that stimuli were suppressed but the duration was not too long, in order to avoid fatigue or demotivation. This "static" method (as the stimuli were presented with full contrast) was used in chapter 5 and 7.

After reviewing newly published literature in my field, I critically assessed my set-up and improved my design. I changed the refreshment rate from 20 HZ to 10 Hz, as this seemed to be used more widely. Moreover, some people argued that the sudden full onset contrast of the stimuli could cause a change in the visual field and trigger awareness. Thus, to avoid abrupt transitions many authors nowadays advise to use the contrast ramping as described above. A contrast ramping of only the suppressed stimuli, but not the mask, was applied over the duration of 1 second. The ramping up technique allowed us to forego the calibration part of my study, as now all participants were presented with a spectrum of different contrasts in a rising manner. This at the same time prevents longer trials of individual participants and allows a more even TTE distribution, and makes log transformations redundant. As word stimuli would reach the highest contrast in the ramping up technique, I also increased the overall brightness of the mask, to match the increased stimuli contrast. Figure 4.3 shows the change in mask brightness. This methodology further referred to as the “ramping up” method was used in chapters 6 and 8.

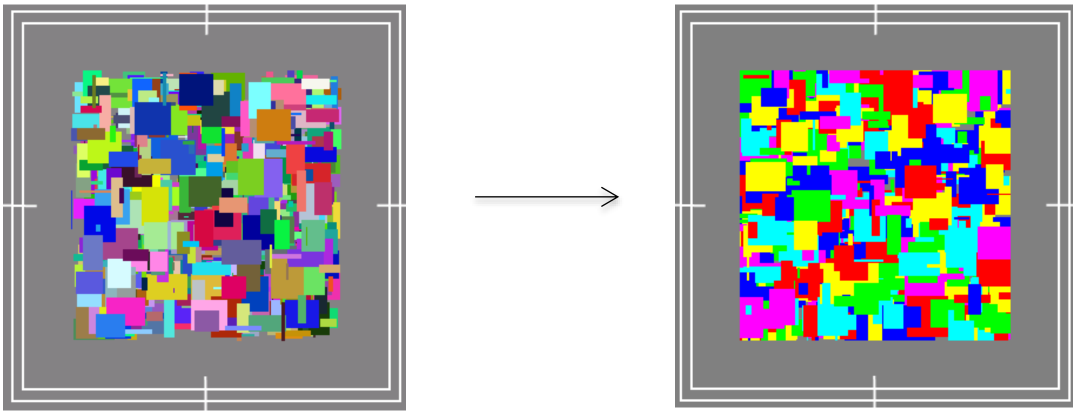

Figure 4.3. Illustration of CFS Mask Changes

Chapter 5. Does Thirst Affect What We See?

Abstract

Human behaviour is aimed at satisfying basic needs such as water, food and shelter. In this study, I was interested to test whether the motivation to satisfy such needs can exert a top-down influence on what people become consciously aware of. In particular, I wanted to test whether goal-related words would be prioritized in conscious awareness. People were deprived of water to induce thirst and used continuous flash suppression (CFS) to measure how fast drinking-related and unrelated words would break the CFS suppression (i.e., time to emerge; TTE). It was expected that drinking-related words would emerge faster into conscious awareness than control words. The results did not show significant prioritisation of drinking-related words. Possible reasons for the absence of this effect are discussed.

5.1 Introduction

We are all familiar with the stories of how thirsty men wandering in a desert can at some point, believe to see water on the horizon. This rare occurrence is called a mirage. A mirage, from French *mirage* or Latin *mirari*, is an optical phenomenon in with light travels through “cold air” to the ground and then gets refracted when it hits the heated air just above the ground. At the same time motivational forces can play an important role in perceiving a mirage. Due to the vehement water deprivation that people can face when travelling through the desert, it is possible that the motivation to clench one’s thirst can lead to misinterpreting the ambiguous stimulus as water, which is an existential resource needed for survival. People are not necessarily aware of this top-down influence on their perception.

A lot of research indicates that the core motivation for any human behaviour is the fulfilment of basic needs, which are defined as core substances needed for survival, such as water, food, shelter, as well as social needs, like the need to belong (Veltkamp et al., 2009; Maslow, 1943; Baumeister & Leary, 1995). Thus, it follows that if one is deprived, the brain would be scanning the environment for information and tools to engage in behaviour designed to reduce deprivation. As a result, goal-relevant stimuli may be more likely to reach awareness in a state of deprivation than in a state of satiation. In the present research, I set out to investigate whether the motivation to satisfy a need can indeed affect perception, and therefore cause people to become consciously aware of goal-relevant stimuli.

Needs can be defined as states that organisms have to be in, to ensure their survival. When deprived of resources that are needed to maintain this state, a discrepancy arises between the current state and the ideal state. All organisms are intrinsically motivated to reduce this discrepancy state (Powers 1973a, Custers & Aarts, 2010; Veltkamp et al., 2009). In early motivation theories, it was believed that deprivation reducing behaviour, e.g. drinking, was induced by the discomfort of feeling the deprivation, e.g. thirst, and wanting to lift this state of discrepancy (Hull, 1943;

Balleine & Dickinson, 1998). It was quickly discovered that deprivation on its own was not sufficient to induce deprivation reducing behaviour. First people have to learn what types of specific behaviour can reduce different discrepancy states (Veltkamp et al. 2008a). Incentive learning theory states that organisms learn what is desirable during the state of deprivation. Stimuli that are instrumental in satisfying a need will be evaluated as more positive in a deprived state compared to a satiated state (Balleine & Dickinson, 1998; Veltkamp et al., 2008b). This positive affect, rather than the discomfort of the deprivation, is believed to be the driving force in people's motivation to reduce a deprivation state.

In summary, needs create goals, which contain the representation of actions that have been learned to reduce the deprived state and that become more desirable during the state of deprivation (Custers & Aarts, 2010; Moskowitz & Grant, 2009; Veltkamp, et al., 2008a).

Several studies have shown that the motivation to reduce deprivation of a basic need, such as food or thirst, can affect automatic evaluations of stimuli (Hoefling et al., 2009). In particular, stimuli that are instrumental in satisfying the deprived need, i.e. goal-relevant, get evaluated as more positive (Hoefling et al., 2009). Automatic evaluations are thought to prepare people for imminent goal pursuing behaviour (Ferguson & Bargh, 2004). In addition to finding that thirsty participants evaluated drinking-related words as more positive than non-deprived participants, Ferguson and Bargh (2004) observed that those positive evaluations were exclusive to highly goal-related words, e.g. water, but not to weakly goal-related words, e.g. beer. The researchers argued that this depended on the degree of effectiveness different goal-related words have in satisfying the need, i.e. successful goal attainment (Ferguson & Bargh, 2004). For instance, water is more effective and more frequently used in quenching one's thirst than beer is.

Additionally to affective evaluation, Seibt and colleagues (2007) found that food deprivation can also affect spontaneous motivational reactions. In their study, participants had to respond to the position of different stimuli by pulling a lever either towards (i.e. approach) or away from them (i.e. avoidance) (Seibt, Häfner & Deutsch, 2007). It was observed that hungry people pulled the lever much faster towards them when they saw food items compared to not hungry people (Seibt et al., 2007). Seibt and colleagues (2007) proposed that their findings imply that next to favourable affective evaluation, deprivation can also exert a behavioural readiness for attaining a goal, or in this case satisfying a specific need. The essential factor is that for either effect to appear, the proposed goal needs to be accessible (Ferguson & Bargh, 2004; Seibt et al., 2007; Aarts, Dijksterhuis & De Vries, 2001). Only when people are in a state of deprivation <u>and</u> the representation of the related goal is activated, will this get translated into people being motivated to pursue the goal. In addition to the above-mentioned positive evaluation and motivational approach tendencies, accessibility of a need while people are in a state of deprivation, can increase perceptual readiness to perceive goal-relevant stimuli (Aarts et al., 2001).

Focusing on perceptual readiness, the New Look approach argued that perception in itself serves motivation (Bruner, 1957; Bruner & Minturn, 1955). In a very classical study of Bruner and Goodman (1947) children were asked to estimate different sizes of various coins and valueless discs of same sizes respectively. Children systematically estimated the sizes of coins to be bigger than their counterpart discs, despite them being the same sizes. The crucial factor was that the discs had no value. Bruner & Goodman (1947) argued that motivation to attain money caused the misjudgement. Support for this claim comes from neurobiological studies, which have shown that once stimuli pass the retina they compete for limited processing resources, and goal-relevant stimuli appear to be allocated more brain cells and therefore occupy more processing area in the visual cortex (Bundesen, Habekost, & Kyllingsbaek, 2005; Veltkamp, et al., 2008b). Focusing back on the behavioural and motivational literature, perceiving goal-related stimuli as bigger than they really are, is an illustration of perceptual readiness that people undergo in order to come closer in achieving their goals (Veltkamp, et al., 2008b).

It needs to be addressed that the early size estimation studies by Bruner and Godman (1947) received a lot of criticism for poor methodology and biased population sample. However, in recent years another research group went on and investigated whether deprivation can affect size perception (Veltkamp, et al., 2008b) and found favourable results. In their research, Veltkamp and colleagues (2008b) induced people with a momentary and personal goal of clenching one’s thirst. After varying the levels of fluid deprivation in their participants, they asked participants to estimate the sizes of different objects. They found that thirsty people would perceive goal-related objects such as a glass systematically larger than other goal unrelated objects (Veltkamp, et al., 2008b). This is in line with the previous research suggesting that motivation induces a perceptual readiness.

It is important to note that this effect is only possible when a) this goal gets activated, e.g. via subliminal priming, and b) this activation is sustained over time (Veltkamp et al., 2008b; Veltkamp, Custers and Aarts 2011; Bargh et al., 2001). In one of their studies, Veltkam and colleagues (2011) measured the water consumption of fluid deprived participants. All participants were primed with drinking-related words, that way rendering the goal of drinking accessible. One half of the participants were allowed to engage in thirst quenching behaviour, such as eating cucumbers, which contain 96% of water (Davidson, 1999; Veltkamp, et al., 2011). It was observed that participants who had eaten cucumbers consumed significantly less water at the end of the study than participants who had not. By engaging in thirst quenching behaviour, i.e. eating a cucumber, the goal of drinking had been satisfied, therefore was no longer accessible by the end of the study (Veltkamp et al., 2011). Thus, there was no need for them to drink any longer

Summarizing, numerous studies have shown that motivation to pursue a desired state can automatically activate associated constructs, i.e. necessary means, and in turn visually prioritize objects that can facilitate goal attainment without conscious awareness (Veltkamp, et al., 2008b). If this effect can occur outside conscious awareness it would seem quite likely that those stimuli can be processed without awareness as well. Thus, motivated by those results, I was interested to see what would happen if participants were presented with a variety of stimuli under CFS after having been induced with a deprivation, which also had been made accessible. If activated goal structures can prioritize associated constructs, I would expect those associated constructs – e.g. goal-related words – to be prioritized in their detection through the CFS mask. In CFS detecting a word means it has broken the interocular suppression and therefore emerged into consciousness. In other words, I was interested to see whether goal-related stimuli could reach consciousness earlier than unrelated stimuli.

5.2 Experiment 1: Fluid Deprivation Study

In the current research I will investigate whether real-life motives can indeed affect conscious perception of goal-related stimuli. This experiment leans strongly on the experimental set-up by Veltkamp's and colleagues (2008a) with the difference of using CFS as a dependent measure. As in Veltkamp's et al. (2008a) study, water deprivation was induced by asking people not to drink for two hours prior the study. In contrast to Veltkamp's et al. (2008a) study every participant was deliberately asked prior the study whether they had refrained from drinking or not, which consequently is more likely to render the concepts related to deprivation accessible (Veltkamp et al., 2009). Moreover, I expected that the frequent supraliminal presentation of drinking-related words in the CFS paradigm should additionally make the concepts related to deprivation accessible, which Veltkamp et al. (2008a) argued is vital in obtaining any effects. While, all participants arrived water deprived to the study, one group was allowed to replenish their thirst (drinking group) after a break during the CFS task, while the other half was not given any water (not – drinking group). I expected that deprivation would cause goal-related stimuli to overcome suppression into consciousness faster for everyone before the break during the experiment, if motivation to reduce deprivation in fact affects preconscious processing. After the break, I expected to see no TTE differences between goal-related and goal-unrelated stimuli in the drinking group, as their need for water and thus the goal of drinking had been successfully achieved. Contrarily, for the not drinking group, I still hypothesized to see a TTE difference, as their need for water was kept deprived throughout the entire study.

5.2.1 Method – "Static"

5.2.1.1 Participants. Sixty-two people were recruited via the UCL subject pool, but only data of 41 participants (14 male) with an average age of 27.37 years (*SD* = 8.57 years) were used for analysis (the administered exclusion criteria will be explained further in the results section). All participants had a normal or corrected-to-normal vision, no history of epilepsy and had not been drinking for two hours prior the experiment.

5.2.1.2 Design. This study was a mixed 4 (word type: negative, neutral, positive, drinking) x 2 (block: block 1 & block 2) x 2 (drinking manipulation: drinking group vs. not-drinking group) design. Word type and block acted both as within independent variables (IV) and water manipulation as a between IV. The dependent variables were accuracy and time needed for stimuli to break into consciousness (TTE).

5.2.1.3 Stimuli. The word stimuli consisted of six drinking-related words (water, drink, glass, soda, juice, quench). Each drinking-related word had a corresponding negative, neutral and positive word that was matched for frequency (updated Zipf values by Van Heuven, Mandera, Keuleers and Brysbaert, 2014), number of letters and pixel count. Furthermore, each negative and positive word pair was matched for hedonic value (distance from neutral).

On each trial, ten Mondrian patterns were generated, with each canvas consisting of 700 random rectangles with a random height and width between 1 and 35 pixels, a randomly selected colour presented in a random location on a 350 by 350 pixels canvas. Each value of the RGB parameters was randomly chosen between 0 and 255. These patterns were sequentially presented with a frequency of 20 Hz rate.

5.2.1.4 Apparatus. The study was conducted in a dark soundproof room using E-Prime (2.0 version) on a 17 in Dell CRT monitor (1024 x 768 resolution at 60 Hz refresh rate). All participants had to rest their heads on a chinrest 60 cm distanced from the screen. The chinrest was part of the mirror stereoscope (www.stereoaids.com.au – the Geoscope Standard), which allowed presenting a different image to each eye. In the present study Mondrian patterns were presented in one eye, while a word, in lower case Arial 32 point font, was presented in the other (height 0.29º to 0.48º, width 2.39º to 5.24º visual angle). These stimuli were presented on a grey background on the left and right side of the screen, each within a white frame (9º x 9º visual angle) in order to facilitate binocular fusion. Throughout the experiment a white fixation cross (2º x 2º visual angle) was displayed in the centre of each white frame. The brightness for the word stimuli was adjusted for each participant individually so that stimuli emerged within a number of seconds, but not immediately and varied from bright white to light grey tones. The words were presented either at the top or bottom half of the frame.

5.2.1.5 Procedure. At the beginning of the experiment, participants positioned their head on a chinrest while looking through the mirror stereoscope that was adjusted for each participant individually. Binocular fusion was achieved when participants perceived the two frames, presented on each side of the screen, as a single unit. At trial onset, flashing patterns were presented to one eye, followed by a subsequent presentation of a word in the other eye. Due to initial eye dominance of the flashing mask, participants could not immediately detect the presence of the word. Their task was to decide whether the word was displayed on the top or bottom of the square by pressing the “up arrow” or “down arrow”, respectively. Both accuracy and speed were emphasized.

Prior the experimental trials, I familiarized participants with the task and adjusted stimuli brightness for each participant in order to achieve optimal CFS suppression. The practice trial featured non-words rather than words as stimuli.

The subsequent study consisted of two blocks, each with 96 trials. There were 24 words presented each once at the top and once on the bottom of the frame in both the left and right eye, thus resulting in 96 trials (24 words x 4 locations) per block. There was a five-minute break between the blocks, in which participants in the drinking group were offered an unopened 0.5 liter Volvic water bottle, while participants in the not-drinking group were only allowed to rest their eyes. Where applicable the amount of water drunk was measured with a kitchen scale, while participants started the second block. At the end, participants filled out a questionnaire and were paid for their time.

5.2.2 Results

5.2.2.1 Exclusion criteria. Two participants were immediately excluded from the analysis for not finishing the study. For the remaining participants, each eye was inspected separately. Data from single eyes were excluded if the accuracy was below 80% or if the mean reaction time was below 600 milliseconds or above 30 000 milliseconds, as in the former case it could be strongly assumed that they had not experienced CFS (only for one participant the data from one eye was analysed). As the main manipulation was water deprivation, participants who had been initially assigned to the drinking group but declined water between blocks were excluded from analysis, as they were clearly not thirsty. Additionally, participants who indicated in the follow-up questionnaire that they were not thirsty upon arrival, were also excluded from analysis (these participants mostly overlapped with the ones who had refused to drink during the break).

5.2.2.2 Time to Emerge. Only correct responses were used for analysis. Due to the skewed nature of response times, each time response in milliseconds was first log transformed (10 lg) to normalize the reaction time distribution. Due to high variance between both eyes of each individual the data was furthermore standardized into z-scores per eye. The TTE score was then created by averaging the transformed times across both eyes. The means and standard deviations of the TTE_{zlog} are displayed in table 5.1. The average TTE across participants was 2.12 seconds, with a 1.29 seconds standard deviation.

Words	**Drinking Group**				**Not - Drinking Group**				**Total**	
	Block 1		Block 2		Block 1		Block 2			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Negative	0.06	0.33	-0.14	0.35	0.07	0.27	-0.24	0.32	-0.06	0.32
Neutral	0.17	0.3	-0.14	0.37	0.21	0.33	-0.23	0.23	0.003	0.31
Positive	0.13	0.35	-0.23	0.34	0.23	0.26	-0.18	0.25	-0.01	0.30
Drinking	0.29	0.34	-0.13	0.32	0.23	0.31	-0.09	0.24	0.08	0.30

Table 5.1. Means and Standard Deviations of Time to Emerge (TTE_{zlog})

A repeated measure ANOVA applied on the TTE_{zlog} scores showed that there was a significant main effect of block $F(1, 39) = 17.68$, $p = 0.001$, and significant main effect of word type $F(3, 117) = 5.69$, $p < 0.05$. Pairwise comparisons using a Bonferroni correction revealed that drinking words ($M = 0.077$, $SD = 0.13$) emerged slower into consciousness than negative words ($M = - 0.057$, $SD = 0.12$) $t(40) = 4.16$, $p < 0.05$. Those effects are visualized in figure 5.1. There was no significant main effect of drinking manipulation $F(1, 39) = 0.614$, $p = 0.438$, no significant interaction effect between word type and block $F(3, 117) = 1.84$, $p = 0.144$ and no significant interaction effect between block, word type and drinking manipulation $F(3, 117) = 1.33$, $p = 0.27$.

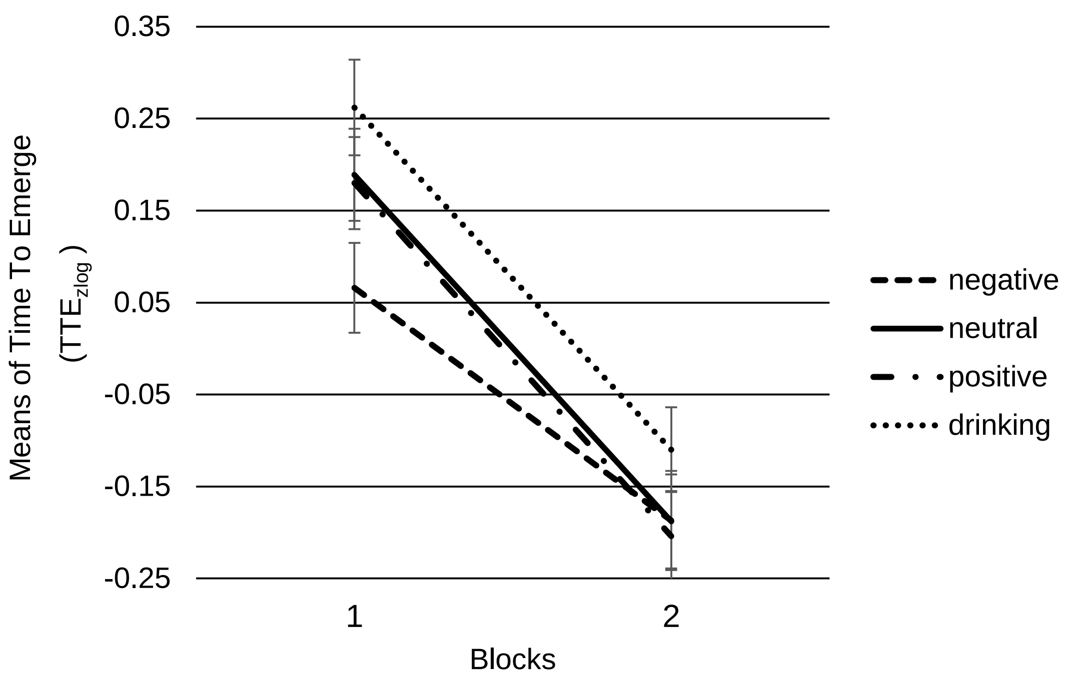

Figure 5.1 Means of Time to Emerge (TTE_{zlog}) of Each Word Type in Block 1 & 2

Additionally, an item analysis was conducted (Clark, 1973). A repeated measure ANOVA showed that there was a significant main effect of block $F(1, 20) = 441.18$, $p < 0.001$, as in the subject analysis. There was also a significant interaction effect between word type and block $F(3, 20) = 3.29$, $p < 0.05$ but no significant effect of drinking manipulation $F(1, 20) < 1$, *ns*. None of the 4 word types differed significantly $F(3, 20) = 1.13$, $p = 0.36$, *ns*. As the findings were not in line with the hypothesis, a follow-up analysis was conducted to test whether low-level features were predictive of the TTE_{zlog}. Pixel count was significantly correlated to TTE_{zlog} r (24) = - 0.50, $p < 0.02$. The amount of ascenders and descenders were neither significantly correlated to pixel count nor TTE_{zlog}, r (24) = 0.01, $p = 0.96$ and r (24) = 0.14, $p = 0.52$, respectively.

5.2.2.3 Accuracy. A repeated measure ANOVA applied on the percentage of accurate responses showed that there were no significant differences between the negative, neutral, positive and drinking words (overall $M = 0.99$, $SD = 0.03$) $F(3, 117)$ <1, *ns*.

5.3 Discussion

The current experiment was the first to test whether thirst, a deprivation of a need, could alter what people become consciously aware of, more precisely whether need-related stimuli would be prioritized in conscious awareness. The time stimuli needed to break into conscious awareness under CFS was measured. The results were not as expected.

The findings showed that there was no TTE advantage of goal-related words. Despite water deprivation, none of the participants perceived drinking-related words faster than control words. That one half of the participants were given refreshments did also not affect the results in any way. The block effect throughout the experiment could be interpreted as a consequence of training. A low-level visual feature effect was found; showing that the higher the pixel count is the faster a word breaks CFS suppression. This is in line with other studies showing low-level feature effects under CFS and suggests that the actual CFS set-up does indeed work (Gray, Adams, Hedger, Newton & Garner, 2013).

Low-level effect cannot explain the significant finding that negative words broke suppression faster than drinking-related words. Each drinking-related word had been matched on all low-level features, including pixel count, with each negative, neutral and positive word. When inspecting only the first block in figure 5.1, it appears that negative words differ systematically from all other categories, even though they are statistically speaking only significantly different from the drinking words. That finding has little to do with the deprivation manipulation, however, is in line with previous findings of negative words being processed systematically different than control. Sklar et al. (2012) found that word combinations that evoked negative associations such as “eternal rest” would break suppression faster than neutral combinations. While Yang and Yeh (2011) found that words that were related to negative feelings would break suppression slower than neutral ones. Such discrepancies have also been found in the face literature, fearful faces seem to break suppression faster than neutral ones (Yang et al., 2007; Gray et al., 2013), while angry faces break suppression slower (Gray et al., 2013). Although it should be mentioned that at least Gray and colleagues (2013) argue that some of their found effects are due to low-level feature differences.

There are a few explanations for the insignificant results of the need manipulation. Firstly, it could be that the drinking manipulation itself did not work. The study was run over the summer months, thus participants could have either misjudged the amount of time they refrained from water (2 hours before the study) or were not honest about it. Although this possibility exists, I had aligned my research to Veltkamp and colleagues (Veltkamp et al., 2008a, 2008b; Veltkamp et al., 2011) who had run an entire line of research with water deprivation as an experimental manipulation. They had indeed obtained significant differences in performance depending on water deprivation or replenishment. The current study had no way of verifying participants' truthfulness. While Veltkamp's and colleagues (2008b) also relied on self-report deprivation measures, they did not instruct participants beforehand not to drink. The researchers rather made use of some more natural set-ups, such as testing participants either before or after lunchtime as it was assumed that participants would be more deprived before lunch (Veltkamp et al., 2008b).

The observation that some people in the drinking group declined the offer to drink, could also point to a possible concern. Participants that declined to drink, were excluded from the analysis, as it was clear that they were not thirsty, thus were not experiencing the desired water deprivation manipulation. At the same time, people in the not-drinking group, might have been not thirsty either, but were still included in the data analysis, as they had no way of explicitly expressing their lack of thirst. Although this would affect the data, I still would expect goal-relevant drinking words to break suppression faster than goal irrelevant stimuli in the first half for the drinking group only.

Another possible explanation for the statistically non-significant results could be that the study was underpowered. After recruiting 62 people, we had to exclude many people (exclusion criteria is described in the methodology section), which left the data of only 41 people over two between subjects groups. This amount might not provide enough power to be able to detect a significant effect.

Lastly, the fluid deprivation manipulation might have not affected motivation per se. The experiment was based on the assumption that a deprived state induces a need state. When the deprived state is made accessible and the fulfilment of the deprivation is associated with positive affect, the need gets translated into a goal. Once the goal is activated together with its associated concepts and means, it stays accessible until it gets fulfilled (e.g. Bargh et al., 2001). It was expected that the motivation to fulfil this need would in turn also prioritize what people would perceive under CFS, and thus expect faster TTE. With that in mind, there could be two possible limitations for my methodology.

One could be, that only stimuli that are within the activated goal construct and that have been learned over time (see incentive learning theory) to reduce the need state would be expected to be prioritized in conscious awareness. The drinking-related words used for my experiment, such as *soda,* might have been not strongly enough related to the goal, and were, therefore, not perceived as goal facilitating. The degree of effectiveness of how the used stimuli can satisfy the goal at hand should have been closer inspected (Ferguson & Bargh, 2004).

The second limitation could be that even if I managed to successfully manipulate people's motivation to quench their fluid deprivation, it might have not gotten translated into increased accessibility. As pointed out earlier, the activation of a goal's concept and its sustained activation is crucial. In Veltkamp's and colleague's studies (Veltkamp et al., 2008a, 2008b), additionally to having high deprivation levels, they always primed participants with drinking-related words. It was assumed that seeing all stimuli supraliminally presented in the CFS design would be enough for the concept to get accessible. Maybe this was not enough of a prime to achieve deprivation and with it the associated goal accessible or maybe as mentioned earlier some of the used stimuli were too weakly related to the goal attainment, thus it did not contribute in activating the goal of quenching one's thirst.

In the next chapter, I will take a few steps back in the motivational – behaviour chain. I assume that once a need state, e.g. deprivation, is rendered accessible it gets translated into the goal of satisfying it. Once a goal is active, its associated concepts and means to achieve it become accessible, too. This accessibility is believed to be the link via what goals influence our behaviour and perception. Thus, in the next chapter, I am targeting accessibility per se. I do not want to induce motivation at this point in time, but test accessibility of specific targets on a trial-by-trial basis under CFS. In the following chapter, I will induce expectancy of what word could be expected under CFS by showing participants supraliminal cue words and instructing them that it is very likely that the same target word will appear under CFS. With this manipulation I expect people to keep the presented cue word accessible, and that accessibility should in turn translate into prioritized detection of the word under CFS. I believe that this is the strongest possible manipulation of accessibility and top-down processing. If I obtain positive results, the next logical step would be to go up in the motivational – behavioural chain and test accessibility of concepts and work my way up to motivation.

Chapter 6. Do Expected Words Reach Consciousness Faster?

Abstract

It is believed that goals can exert top-down influences on behaviour and perception. These effects are assumed to occur via accessibility and might be even amplified when the to be perceived goal-related stimuli are expected. This study induced expectancy on a trial level, as it seemed to be the strongest possible manipulation of accessibility and top-down processing. Each trial began with a presentation of a cue that predicted the subsequent target most of the time. Targets were presented under CFS. Results were as expected, matching target stimuli broke suppression faster than non-matching ones. This supports the theory that accessibility can influence what is prioritized in conscious awareness via top-down processing. The next step would be to test accessibility of concepts over a period of time rather than individual stimuli on a trial level.

6.1 Introduction

Many students will most likely be familiar with the phenomenon that when one sits till late at night in the common room of their university and hears a squeaky noise to expect to see a mouse in the corner of the room. When one, then, tries to localise the squeaky noise, one might misinterpret a grey sock on the floor for a mouse. Some argue that this can easily be explained by the fact that people's brains are "prediction machines" (Clark, 2013).

The predictive coding framework suggests that when our brains register sensory cues, e.g. squeaky noise, they try to anticipate the causality from previous knowledge, e.g. a) squeaky noise can come from mice and b) mice are often spotted in university common rooms (see Helmholtz 1860; Friston, 2005; Friston, 2010; Hohwy, Roepstorff & Friston, 2008; Kilner, Friston & Frith, 2007; Clark, 2013). In other words the brain is trying to predict what is going on around us, without having to accumulate a large number of low-level cues from the environment. Anticipating stimuli is enormously efficient, as on one hand it reserves brain capacity and on the other hand automatically prepares other senses for its detection. Returning to the example, when we hear a squeaky noise that matches the sound of a mouse in a common room – in where many mice have been spotted frequently before – our brains predict a mouse. Thus, we expect via top-down processing to detect a mouse when looking up, and therefore can misinterpret a grey sock for a mouse.

The social cognitive theory offers another explanation for the possible misinterpretation of a sock for a mouse. The social cognitive theory suggests that if the representation of mice becomes accessible beforehand, such as by watching a movie about mice, a person would be more likely to misinterpret the sock. However, in this case, the actual concept of mice would become activated and once it is accessible, people are more likely to use the construct to interpret their surrounding (Higgins, 1996). Importantly accessibility per se does not necessarily translate into expectation. Even though a person might misinterpret a sock for a mouse, they did not expect to see a mouse, but due to the accessible knowledge representation of mice, they are more likely to use the concept and make a misinterpretation.

In any case, both accounts, predictive coding and accessibility, can lead to a biased preconscious perception, as both times a concept and associated visual image becomes pre-active. If there are any top-down effects of accessibility on subconscious processing, the prediction route would be expected to be the strongest, as it incorporates both the accessibility and anticipation of a stimulus. Thus, the hypothesis could be rephrased into: Do expectations facilitate preconscious processing?

There is some evidence in the literature pointing to this possibility. Van den Bussche and colleagues (2008) found top-down expectancy effects in their studies. In their experiment participants had to categorise number targets as smaller or larger than five, while the targets were always preceded by subliminal primes (Van den Bussche et al., 2008). Both the primes and targets were presented in two varying formats, either in Arabic numbers or number words. The format proportion for the targets was manipulated (e.g. 25% Arabic numbers vs. 75% number words). They found that responses to the targets were significantly more influenced by the primes (faster reactions for congruent primes and slower reactions for incongruent primes), if the primes were presented in the same format, e.g. number words, that was the most frequent for the targets, e.g. 75% number words vs. 25% Arabic numbers. This suggests that people adopt a processing strategy based on the frequent target format, which in turn exerts a top-down effect on the perception of the masked primes (van den Bussche, et al., 2008).

In another related study, Pinto and colleagues (2015) tested what influence visible predictive cues can exert on TTEs in CFS (Pinto et al., 2015). Before each CFS trial participants were presented with a cue word, e.g. either FACE or HOUSE that would predict the subsequent target 3 out of 4 times. That way it was assumed that participants would form expectations, which would be instrumental for the CFS task at hand. Results showed that people were faster in detecting and identifying targets under

CFS if those were preceded by predictive cues (Pinto et al., 2015). This strongly suggests that expectation can influence preconscious processing, and therefore affect what information enters conscious awareness.

Interestingly, in a separate experiment, the same researcher group tested what would happen if they showed participants the same cue words with the difference that this time the cue words would not be predictive, but only associative to the targets presented under CFS (Pinto et al., 2015). In other words, after either cue word “HOUSE” or “FACE” both target images were as likely to follow, i.e. each target was presented to 50% of the time regardless of the preceding cue. The researchers found while in the first block there was still a beneficial effect of matching cue and target, e.g. an image of a house broke suppression faster than an image of a face if the cue word “HOUSE” had preceded, with an increasing number of trials this congruency effect disappeared. This suggests that participants learned with time that cue words were not predicting the targets, as targets were presented equally often independent to the cues, so they must have stopped forming expectations, and the TTE differences disappeared (Pinto et al., 2015).

The results from Pinto’s et al. (2015) study are promising, nevertheless, their choice of stimuli – faces and buildings – gives reason for some scepticism, as both faces and buildings have specific brain areas designated for their processing, the fusiform face area and parahippocampal place area, respectively (Kanwisher et al., 1997, McCarthy et al., 1997; Epstein, Harris, Stanley & Kanwisher, 1999; McNeil & Warrington, 1993). It is unclear whether the presented cues activated specific knowledge structures and associated concepts of the specific stimuli, or whether they merely activated the respective brain areas needed for processing faces and buildings.

In a similar vein of research Gayet, and colleagues (2013) investigated whether specific visual stimuli, this time not limited to two privileged stimuli, that are kept in visual working memory (VWM) can influence what type of information will break into conscious awareness (Gayet et al., 2013). Participants were firstly presented with a colour patch and were asked to memorise it for a memory test that would follow by the end of each trial. In between the colour patch presentation and the memory task, a CFS task was conducted. It was found that if the target stimulus under CFS matched the colour patch that had been previously presented and stored in the VWM, it emerged faster into conscious awareness (Gayet, et al., 2013). This supports the idea that stimuli that are kept accessible on a trial level can affect what type of stimuli break into conscious awareness (Gayet, et al., 2013). In contrast to Pinto et al. (2015) specific visual stimuli were used. Even though, it is a good approach, it uses basic visual stimuli that convey little conceptual information. I am interested whether such findings can be extended to more abstract stimuli, such as language, which is a step towards our main research of whether active concepts can have top-down influences on conscious awareness.

Summarizing, there has been some supporting evidence for the recent study investigating whether expectancy and accessibility can affect what people become aware of. The recent study leans on the design and findings of Gayet's, Pfaffen's and Van der Stigchel's recent study (2013). However, in contrast to them more abstract visual stimuli, such as words, rather than colour patches were used. Each trial consisted of a supraliminal presented prime and a subsequent target presented under CFS. It was pointed out to the participants that the prime would most likely be followed by the same word. That way expectancy was created on a trial-by-trial level that would facilitate detection of targets under CFS. It was expected that this type of set-up would maximise possible top-down effects. I hypothesized that if top-down processing indeed occurs under interocular suppression, I would expect target words that are identical to the previously presented prime (congruent condition) to break suppression faster than incongruent target words.

6.2 Experiment 2: Expectancy Study

In the previous experiment I attempted to manipulate motivation in order to see whether goals can affect what information people become consciously aware of. No

TTE advantage of goal-related words under CFS was found. Before continuing with any other motivational studies I decided to go to the very beginning of the behaviour – motivation chain and test whether top-down biases on low-level properties can affect preconscious processing. If I confirm an effect of top-down biases on lower-level properties, I will be able to test a higher-level processing hypothesis. In the following experiment, the effects of expectancy were tested, which were believed to be the strongest manipulation of accessibility per se. I presented participants with a supraliminal prime word that would most of the times predict the subsequent target word. I hypothesized that target words that were identical to the previously presented prime (congruent condition) to break suppression faster than incongruent target words if top-down processing occurs under interocular suppression.

6.2.1 Method - "Ramping up"

6.2.1.1 Participants. Forty-four people were recruited via the UCL subject pool. Two participants had to be excluded due to poor performance (accuracy < 80%), so only data of forty-two participants (11 male) with an average age of 22.62 years (*SD* = 4.40 years) was used for analysis. English language abilities were reviewed, 20 were native English speakers and on average all participants have been speaking English for 19.43 years (*SD* = 6.07) of their lives. All had a normal or corrected – to normal vision and no history of epilepsy.

6.2.1.2 Design. This study was a 2 (congruency: congruent & incongruent) x 2 (block: block 1 & block 2) mixed design. The dependent variables were accuracy and TTE.

6.2.1.3 Stimuli. Five stimuli were matched for frequency (updated Zipf values by Van Heuven et al., 2014), number of letters and pixel count. On each trial, ten Mondrian patterns were generated, with each canvas consisting of 700 random rectangles with a random height and width between 1 and 35 pixels, a randomly selected colour presented in a random location on a 350 by 350 pixels canvas. In contrast to the original design the values of each of the RGB parameters were no longer chosen randomly between 0 and 255. This time each of the RGB parameters could only take on the value 0 or 255, with the exception of the following combinations (0, 0, 0; black) and (255, 255, 255; white). Optimizing the design, the canvases were sequentially presented with a frequency of 10 Hz rate rather than 20 Hz as before in the “static” methodology. A contrast ramping of the suppressed stimuli was applied over the duration of 1 second until full brightness.

6.2.1.4 Apparatus. The apparatus was similar to the previous experiment 1 with the exception that this time the brightness for the word stimuli was not pre-adjusted for each participant individually. The word stimuli were ramped up in contrast.

6.2.1.5 Procedure. The procedure was similar to the previous experiment with the exception that this time, before each trial, participants were presented with a visible prime to both eyes for 5 seconds, after that a CFS trial started. Participants had to detect a target through the CFS mask, 50% of the time the prime predicted the target (congruent condition), and the other 50% of the time the prime was followed by completely different words (incongruent condition). Contrary to Pinto’s et al. (2015) experiment 3c this should still induce expectancy, because in this study each word was presented four times with the same subsequent word (congruent condition) and four times with different words (see figure 6.1 for better illustration). While Pinto et al., (2015) only had two stimuli where a 50/50 division would not induce expectancy. This set-up resulted in 8 trials (8 pairs) per word (see figure 6.1 for better illustration). Each pair was presented once at the top and bottom of the screen and both to the left and right eye, resulting in 160 trials (1 word = 8 trials; x 4 locations = 32 trials; x 5 words = 160 trials).

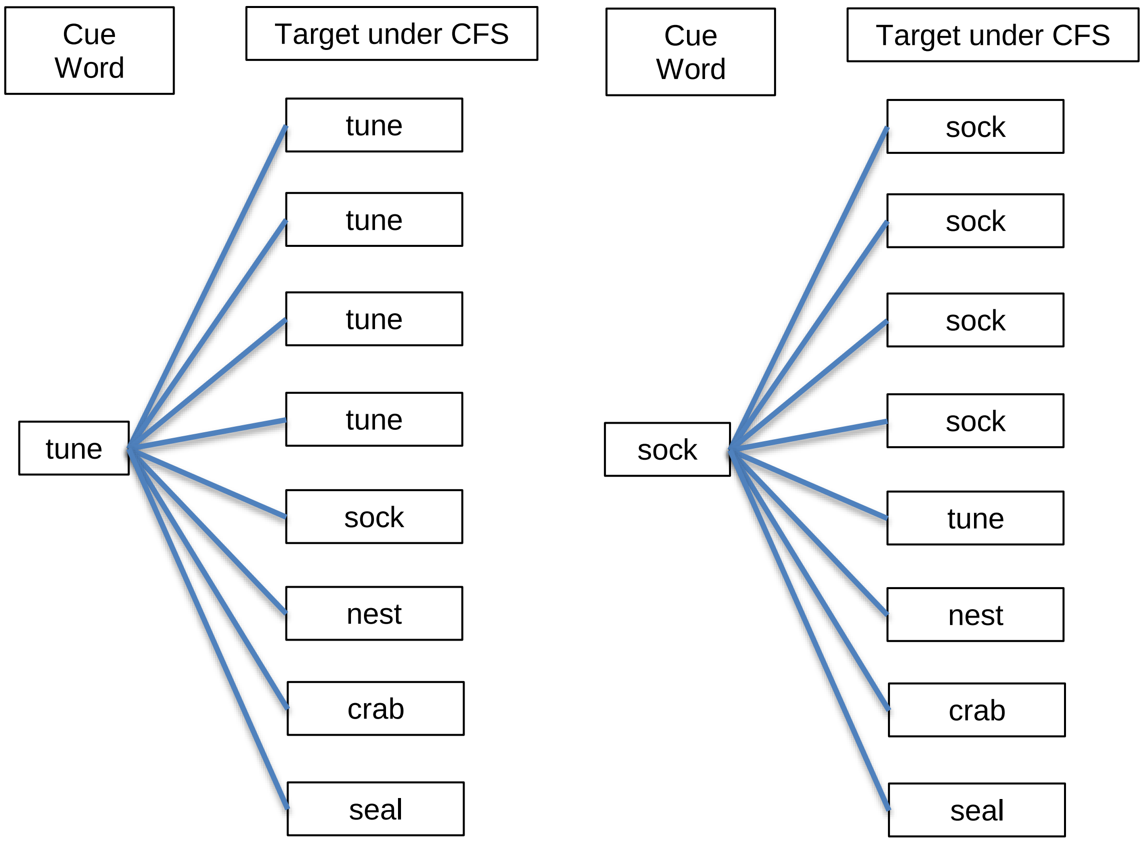

Figure 6.1. Illustration of Congruent and Incongruent Condition

Those 160 trials were broken down randomly into two blocks. The only prerequisite for breaking the 160 trials into two blocks was that all four incongruent pairs per word had to be presented once in the left eye and once in the right eye. Each incongruent pair per word was allocated a display combination, for instance if "tune-sock" received the allocation "left –up", it would be presented first to the left eye and the top of the screen (”up") in the first block, and then to the right eye and to the bottom of the screen in the second block. For each participant the program randomly decided whether a word pair was first presented up or down. This left us with 80 trials per block, with always presenting 40 trials to the left eye and 40 trials to the right eye. There were no breaks between the two blocks. At the end participants filled out a questionnaire and received monetary reward for their participation.

6.2.2 Results

6.2.2.1 Accuracy. A repeated measure ANOVA applied on the percentage of accurate responses showed that accuracy did not significantly differ between congruent (*M* = 0.98, *SD* = 0.04) and incongruent pairs (*M* = 0.98, *SD* = 0.05), $F(1,41) = 1.20$, $p = 0.28$, *ns*.

6.2.2.2 Time to Emerge. Only correct responses were used for analysis. In contrast to the pervious experiments, data was not transformed into log scores (10 lg) as changes in the design, such as presenting the stimuli by gradually ramping up the contrast, allowed me to use the raw TTE values in milliseconds. Individual trials that exceeded 30 000 milliseconds were excluded. As the variance between both eyes of each individual still differed, the data was still standardized into z-scores per eye. The TTE was measured from the onset of the stimulus until the stimulus broke through suppression. The average TTE across participants was 1.85 seconds, with a 0.50 seconds standard deviation.

A repeated measure ANOVA applied on the TTE_z revealed a significant main effect of block $F(1, 41) = 24.54$, $p < 0.001$ and a main effect of congruency $F(1, 41) = 5.24$, $p = 0.027$ (as seen in figure 6.2). There was no significant interaction effect between block and congruency $F(1, 41) = 1.02$, $p = 0.32$, *ns*.

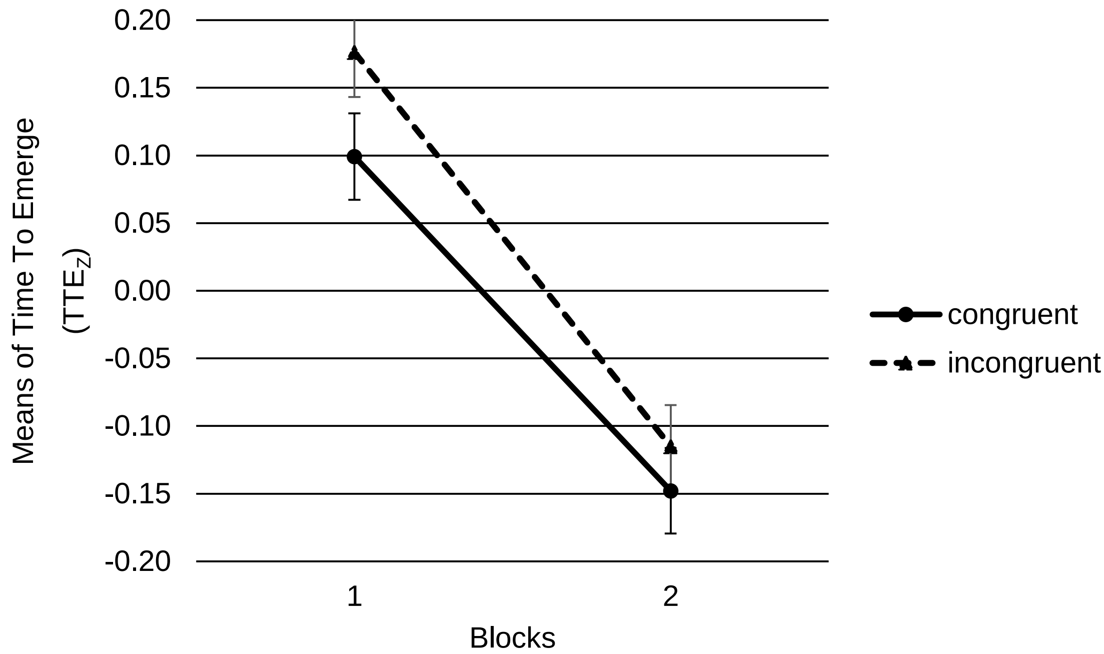

Figure 6.2. Means of Time to Emerge (TTE_z)

6.3 Discussion

The findings show that targets that match preceding primes break suppression faster than non-matching ones. The results are in line with Gayet's et al. (2013) findings, that showed that visual information that is kept accessible in VWM can effect what breaks through CFS and went one step further in showing that this effect can also be found with more abstract stimuli, i.e. words.

Low-level features cannot explain this effect, as all words were controlled for low-level features. The cue stimuli preceding each target stimulus were the only manipulated difference in all trials. In contrast to Gayet's et al. (2013) study the stimuli were not mere visual stimuli, but were abstract stimuli conveying semantic content. Moreover, the stimuli did not benefit of any specific designated brain areas for their processing, such as "face" and "house" stimuli did in Pinto et al.'s study (2015). Thus, the alternative explanation that had been propositioned to Pinto's et al. (2015) study, that the cue words had activated privileged brain areas that were exclusively designed for processing specific stimuli, can be ruled out. Therefore, my results suggest that expectancy exerts a top-down effect on preconscious processing that in turn can affect what information people become consciously aware of. Moreover, the found effects on abstract stimuli could indicate that my results could be generalized across most stimuli, not only simple visual stimuli

I speculate that this effect must be driven by top-down influences. In the set-up, all cues were mostly predictive and instrumental for the subsequent CFS task, therefore forming an expectation would facilitate the detection of words under CFS. Even though I used stimuli that convey semantic meaning I cannot claim semantic processing at this point in time. As expectation was induced on a trial level it would have been perfectly sufficient for participants to only remember the visual representation of the pattern of the words, or even more simplified just one or two distinguishing features of the cue word, e.g. "t" in the word "tune". This idea is supported by Lupyan and Ward (2013), who argued that top-down processing of words occurs due to an overlap of the visual representation of a stimulus and its visual image. In their experiment they found that when people heard the word “square” they were faster to detect an image of a square under CFS than a non-matching image. However, Lupyan and Ward (2013) went one step further and created a square – to – circle continuum, and varied the used visual stimuli in different degrees on that continuum. They observed that the top-down effects of detecting a visual stimulus that matched the auditory cue depended on the degree of correspondence, i.e. if the auditory cue was “square” and the shown image was on the extreme side of “square” of the continuum, the TTE benefit was strong. The more the visual image of a square started to overlap with the shape of a circle, the more the top-down effects gradually decreased (Lupyan & Ward, 2013). The authors argued that these effects strongly suggest that the cross-modal priming is not semantically driven but directed by the active visual representations of specific stimuli.

With both my chosen design and Lupyan’s & Ward’s (2013) design, it is hard to make any claims whether participants can or cannot access the concepts and meaning of the presented stimuli, as all tests were done on a trial level. A trial level set-up does not require participants to use higher-level processing, as they can accomplish the given task by taken up simple strategies, such as feature matching. Thus, predictability and accessibility are confounded at this moment. To come back to the initial example of falsely interpreting a grey sock for a mouse, with the current design it is not possible to differentiate whether a person believed to see a mouse because they expected to see a mouse or just because they were thinking of the concept of mice in general. In order to confirm whether just having a concept accessible on one’s mind without expecting it, can affect preconscious processing, I need to test accessibility in a more ecological way. In the next chapter, I will induce accessibility of a concept over the entire length of the study rather than on a trial-by-trial basis. It is investigated whether top-down processing effects will still be present in preconscious processing when seeing the stimuli is not instrumental for the CFS task at hand.

Chapter 7: Do Accessible Concepts Facilitate Awareness of Corresponding Stimuli?

Abstract

This paper investigates whether concepts that are on one's mind, and hence readily accessible to processes that drive the interpretation of incoming stimuli, can determine what we become consciously aware of. Using continuous flash suppression (CFS), in which stimuli presented in one eye are presented together with a continuous flashing mask in the other eye, the time stimuli needed to emerge from the mask (TTE) was measured. Several studies have shown that this time to emerge (TTE) is affected by information stored in visual working memory on a trial level. I present 2 studies in which participants had to study a list of words before entering the CFS task and were incentivized to recall the words by the end of the entire experiment. I found that words that participants had kept in minds emerged in awareness faster than control words. These findings suggest that concepts that we keep in mind determine what we become consciously aware of.

This chapter is based on: Rochal, I., Custers, R., Vinson, D., & Vigliocoo, G. (2017). *Accessible Concepts Facilitate Awareness of Corresponding Stimuli.* Manuscript under review.

7.1 Introduction

In our everyday lives, we are presented with more sensory information from our surroundings than we can possibly consciously process or even just attend to (Schmid & Maier, 2015; Yang et al., 2014). So, at any time we are only aware of part of it. Anecdotal evidence suggests that what we become aware of depends on what is currently on our mind. Notoriously, expecting women (and men) suddenly see prams and babies everywhere. It is furthermore well documented that concepts that are on our mind influence how we categorize ambiguous stimuli as these concepts are more accessible, that is, more likely to be used in the process of categorization and interpretation (Eitam & Higgins, 2010). My current project investigates whether accessible concepts do, as a consequence, also determine what we become aware of.

Evidence in line with this notion comes from Balcetis and colleagues (2012), who suggested that people are more likely to become aware of stimuli matching people’s current motivation, a process that they call “wishful seeing”(Balcetis et al., 2012). Using a binocular rivalry (BR) paradigm, in which different images presented to each eye compete for awareness, they observed that images that had been explicitly outlined as rewarding were more likely to “win” the competition and gain access to consciousness more often than neutral or cost-related pictures. Hence, the motivation to perceive a particular stimulus increased the likelihood that this stimulus reached conscious awareness first.

Although these results are compelling, they do not directly speak to the role of accessibility. In the Balcetis et al. (2012) study, perceiving the stimuli in the BR task was instrumental to their goal. That is, participants earned more if they became aware of the reward stimuli. Although great care was taken to rule out the possibility that participants would “cheat” in reporting what they were aware of, the results may pertain specifically to situations in which detecting stimuli aids goal attainment and strategic processes may be applied to aid perception of specific stimuli (e.g., looking for specific forms, colors, etc.).

Moreover, while BR was the first technique testing access to conscious awareness during dichoptic competition (Yang et al., 2007, Alais & Blake, 2005; Tsuchiya et al., 2006), continuous flash suppression (CFS) might be a more adequate tool to address the current research question. In CFS only one eye is presented with a static stimulus while the other is presented with a rapidly flashing mask (Tsuchiya et al., 2006; Barbot & Kouider, 2012). The flash initially dominates conscious perception, but the static stimulus eventually breaks through into conscious awareness, and the time it takes to break through the mask is measured (e.g. Tsuchiya et al., 2006). It is assumed that variations in this time to emerge (TTE) can be the result of differences in preconscious processing. That is, stimuli that are processed outside of awareness would subsequently be faster to reach consciousness.

One of the advantages of CFS is that all target stimuli are presented against the same mask and do not compete against each other as in BR (Costello et al., 2009). With this controlled setting, it is more likely that the TTE measurement will reflect only processes of interest (Costello et al., 2009). CFS also allows a stimulus to be completely invisible for a long period of time, ranging from a few seconds up to minutes (Yang et al., 2007; Laptate et al., 2013; Lin & He, 2009). Thus, while BR was a great first tool studying dichoptic competition, in light of the developments in the literature, CFS might be a more adequate method for studying awareness (Zabelina, et al., 2013; Arnold, et al., 2008; Yang et al., 2007; Yang & Blake, 2012).

Research on CFS has demonstrated that bottom-up as well as top-down processes influence TTE. First, validating TTE as a measure of awareness, it has been demonstrated that varying low-level visual properties of the stimuli such as brightness, number of pixels, spatial components of the suppressed stimuli, and for word stimuli importantly the number of ascenders and descenders, affect TTE (Yang & Blake, 2012; Tsuchiya & Koch, 2005, Gayet et al., 2014). Second, apart from these bottom-up effects on TTE, recent findings on visual memory suggest that top-down processes affect TTE as well. Various studies have demonstrated that stimuli that are kept active in visual working memory (VWM) can also influence what type of information breaks into conscious awareness (Gayet et al., 2013, Soto et al., 2011, Soto & Silvanto, 2014). For instance, target stimuli that matched a color patch that had been presented on a trial level and stored in VWM, emerged faster into conscious awareness under CFS (Gayet, et al., 2013).

Similar TTE effects have been found with more complex visual stimuli. Pan and colleagues (2014) presented their participants with a face cue at the beginning of each trial and asked participants to keep it in memory for a subsequent recognition test. In the meantime, participants had to perform a target localization task under CFS. Faces that matched the to-be-remembered face cue broke suppression faster (Pan et al., 2014). Together, these experiments on suggest that top-down modulation by visual working memory content affects perception before conscious awareness occurs (Pan et al., 2014). Moreover, in these paradigms consciously detecting the to-be-remembered stimulus was not instrumental to participants in reaching their goals (i.e., pointing out the correct stimulus at the end of the trial).

Although these findings provide evidence for the idea that working memory content can affect what we become aware of even when this is not instrumental in goal pursuit, these findings are limited to visual working memory. As such, the question of whether concepts that are on our mind influence what we become aware of is still open for debate. There is evidence suggesting, though, that more abstract conceptual information has top-down effects on TTE in CFS as well.

Studies on language and CFS have demonstrated that words written in a familiar script (e.g. one's own native's language), break suppression earlier than words from an unfamiliar script (Jiang et al., 2007) as well as words that are semantically related to previously shown ones (Costello, et al., 2009). The same has been demonstrated for entire sentences. Sklar et al. (2012) observed that semantically incorrect sentences emerged faster into consciousness than correct ones. Moreover, Pinto and colleagues (2015) observed that when participants were cued with a word e.g. “face”, images matching the word would break suppression faster than non-matching ones. These findings suggest that words can be preconsciously processed on a semantic level, making them an excellent candidate to investigate top-down influences of corresponding concepts that are kept in working memory.

In my current studies, I aimed to investigate the top-down influence of accessible concepts in an ecologically valid manner. I asked participants in the beginning of the study to memorize one of two lists of words that was presented for a fixed duration. They were told that they would receive extra money for each word they could still remember at the end of the study, after the CFS procedure. This is one of the strongest manipulations to make sure people keep information in mind, as keeping the words in memory is explicitly rewarded. In the CFS paradigm itself, words from the studied list as well as words from the non-studied list were used as stimuli. If keeping something in mind, or even actively rehearsing in WM, affects what emerges into consciousness words from the studied list should emerge faster into consciousness than non-studied words. Importantly, in this paradigm, performance on the CFS task is unrelated to people’s task goals (i.e. recalling as many words from the list as possible). Whereas, the first study was designed to demonstrate the basic effect of accessibility on TTE, the second experiment aimed to replicate this effect in an improved paradigm in which the number of to-be-remembered words was increased.

7.2 Experiment 3: Short Lists

7.2.1 Method – “Static”

7.2.1.1 Participants. Forty-three people were recruited via the UCL subject pool, but only data of 41 participants (10 male) with an average age of 24.78 years (*SD* = 6.64 years) were used for analysis (the administered exclusion criteria will be explained further in the results section). Additionally, I checked for language abilities, 15 were native English speakers but on average all participants, have been speaking English for 19.95 years (*SD* = 8.78) of their lives. All had a normal or corrected – to – normal vision and no history of epilepsy.

7.2.1.2 Design. This study was a 2 (list type: studied & non-studied) x 4 (block: block 1, block 2, block 3, block 4) within participants design. The dependent variables were accuracy and time for stimuli to break into consciousness (TTE).

7.2.1.3 Stimuli. Two sets of stimuli were created that consisted of five words each. All ten words were matched for frequency (updated Zipf values by Van Heuven et al., 2014), number of letters and pixel count. Which of the two sets of stimuli were assigned to the studied and non-studied condition was counterbalanced across participants.

On each trial, ten Mondrian patterns were generated, with each canvas consisting of 700 randomly rectangles with a random height and width between 1 and 35 pixels, a randomly selected colour presented in a random location on a 350 by 350 pixels canvas. Each value of the RGB parameters was randomly chosen between 0 and 255. These canvases were sequentially presented with a frequency of 20 Hz.

7.2.1.4 Apparatus. The study was conducted in a dark soundproof room using E-Prime (2.0 version) on a 17 in Dell CRT monitor (1024 x 768 resolution at 60 Hz refresh rate). All participants had to rest their heads on a chinrest 60 cm distanced from the screen. The chinrest was part of the mirror stereoscope, which allowed presenting a different image to each eye. In the present study Mondrian patterns were presented in one eye, while a word, in lower case Arial 32 point font, was presented in the other (height 0.29º to 0.48º, width 2.39º to 5.24º visual angle). These stimuli were presented on a grey background on the left and right side of the screen, each within a white frame (9º x 9º visual angle) in order to facilitate binocular fusion. Throughout the experiment a white fixation cross (2º x 2º visual angle) was displayed in the center of the white frames. The brightness for the word stimuli was adjusted for each participant individually so that stimuli emerged within a number of seconds, but not immediately and varied from bright white to light grey tones. The words were presented either in the top or bottom half of the frame.

7.2.1.5 Procedure. At the beginning of the experiment, participants positioned their head on a chinrest while looking through a mirror stereoscope that was adjusted for each participant individually. Binocular fusion was achieved when participants perceived the two frames as a single unit. At trial onset, flashing patterns were presented to one eye, followed by a subsequent presentation of a word in the other eye. Due to initial eye dominance of the flashing mask participants could not immediately detect the presence of the word. Their task was to decide whether the word was displayed on the top or bottom of the square by pressing the “up arrow” or “down arrow”, respectively. Both accuracy and speed were emphasized.

Preceding the experimental trials, there was a practice block to familiarize participants with the task and adjust stimulus brightness for each participant to achieve optimal CFS suppression. The practice trial featured nonwords rather than words as stimuli. Then, before beginning with the actual experiment participants were firstly presented with one list of five words for a minute and were asked to learn the words. It was emphasized that the more words from this list they would remember by the end of the study the more money they would receive. The subsequent trials were presented in four blocks. There were 10 words, each presented once on the top and once on the bottom half of the screen in both the left and right eye, thus resulting in 40 trials (10 words x 4 locations) per block. There were no breaks between the blocks. At the end participants filled out a questionnaire and received a monetary reward that depended on their memory performance.

7.2.2 Results

7.2.2.1 Exclusion criteria. Two participants were immediately excluded from the analyses for not finishing the study. For the remaining participants, each eye was inspected separately and data from single eyes were excluded if the accuracy was below 80% or if the mean reaction time was below 600 milliseconds, as in the latter case it could be strongly assumed that they had not experienced CFS (for four participants, only data from one eye were excluded).

7.2.2.2 Accuracy. A repeated measure ANOVA applied on the percentage of accurate responses showed that there was no significant differences between the studied (M = 0.98, SD = 0.03) and the non-studied list (M = 0.99, SD = 0.03), F(1, 40) = 2.42, p = 0.13.

7.2.2.3 Time to Emerge. Only correct responses were used for analysis. Due to the skewed nature of response times, each response time was first log transformed (10 lg) to normalize the reaction time distribution. Due to high variance between both eyes of individuals the data was furthermore standardized into z-scores per eye and averaged for the participant to get one measure for TTE (TTE_{zlog}). The average TTE across participants was 2.49 seconds, with a 1.64 seconds standard deviation.

A repeated measure ANOVA applied on TTE_{zlog} showed that there was a significant main effect of block, F(3, 120) = 14.67, p < 0.01, but no evidence that words from the studied list emerged faster, F(1, 40) = 2.16, p = 0.15, nor an interaction effect between block and list type F(3, 120) < 1, *ns*. was found (see figure 7.1).

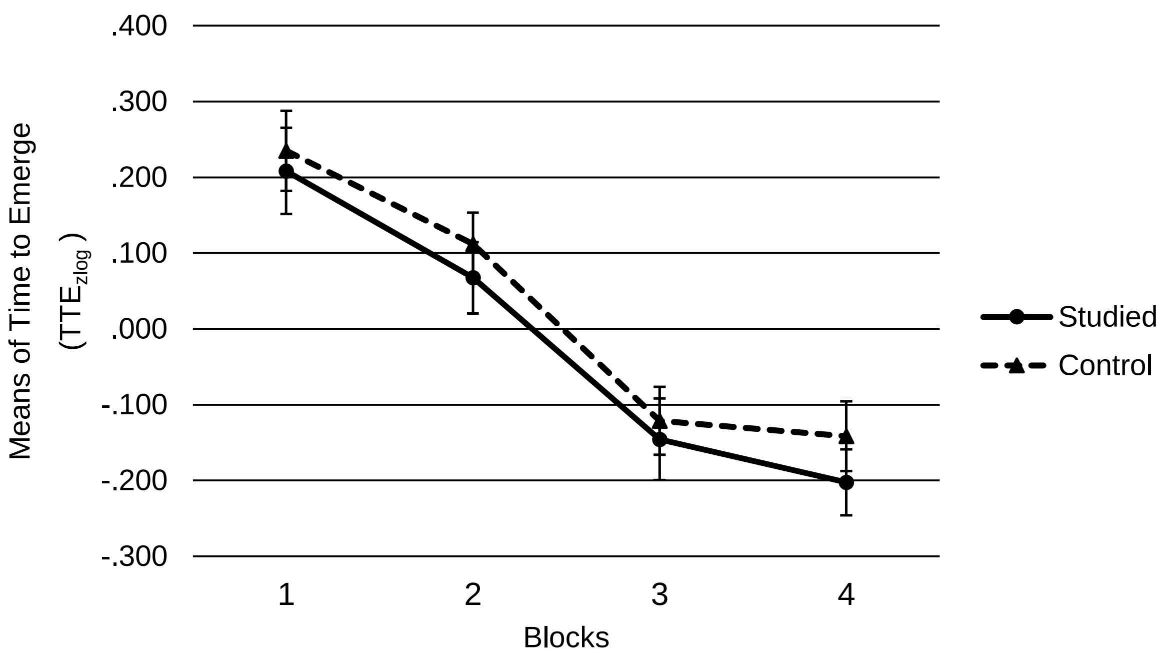

Figure 7.1. Means of Time to Emerge (TTE_{zlog}) throughout the 4 blocks as a function of list type. Error bars represent standard errors of the mean.

7.2.4 Memory Check. All participants remembered the studied words, and on average 2.93 words (*SD* = 1.60) from the non-studied list that they picked up during the CFS trials. As the recall of the non-studied list was quite high, it may have been the case that participants held items from both lists accessible and not only the studied one. Based on the memory check a follow-up analysis was carried out. Instead of analysing TTE_{zlog} differences between items from predefined list types such as studied and non-studied lists, the actual memory performance was taken into account. In this subsequent analysis TTE_{zlog} differences between items that participants actually recalled – regardless of previously defined list types – and items they did not remember, were analyzed**.**

7.2.5 Follow- up Analysis. As the remembered items made up about 80% of the data, while the not-remembered items made up 20%, I used paired t-tests rather than repeated measure ANOVA in order to assess the differences. Ten participants who recalled all non-studied words were excluded from the subsequent analysis.

The paired t-tests showed that averaged across the four blocks there was a significant main effect of memory. That is, words that participants remembered broke suppression faster than words participants did not remember, $t(30) = -2.48$, $p = 0.02$. Figure 7.2 illustrates the TTE differences.

In order to exclude that this positive finding is due to a difference in accuracy, a paired t-test applied on the percentage of accurate responses showed that there was no significant difference between remembered (*M* = 0.99, *SD* = 0.02) and not remembered words (*M* = 0.99, *SD* = 0.03), $t(30) = 0.84$, $p = 0.41$.

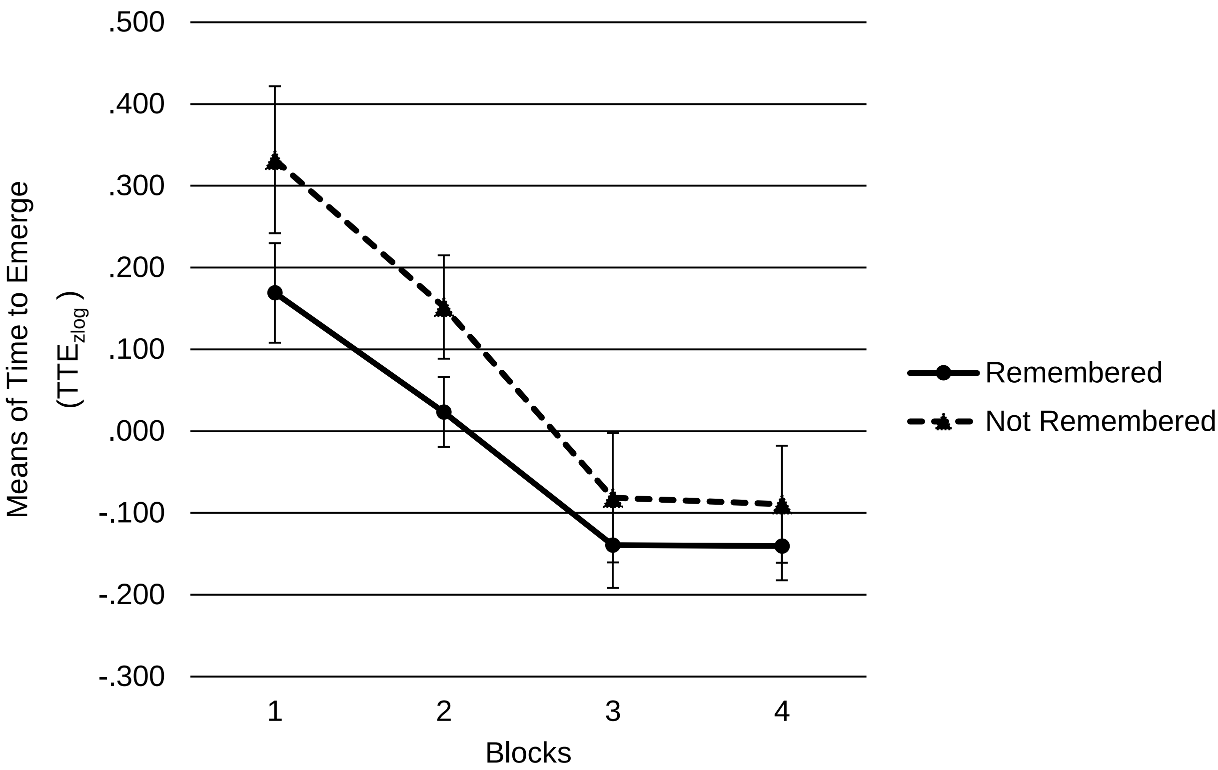

Figure 7.2. Means of Time to Emerge (TTE_{zlog}) throughout the 4 blocks as a function of list type. Error bars represent standard errors of the mean.

In anticipation to be able to compare results across this experiment and Experiment 4, the first two blocks and the last two blocks were averaged, (in this current experiment one block consisted of 40 trials, whereas in the subsequent experiment – described below in “Experiment 4: Long Lists”– one block consisted of 84 trials).

It was found that while in the first half of the experiment (block 1 & 2 averaged) items participants remembered emerged faster into consciousness than not remembered items, $t(30) = -2.63$, $p = 0.01$, there was no such effect in the second half of the experiment (block 3 & 4 averaged), $t(30) = -1.27$, $p = 0.21$.

7.3 Experiment 4: Long Lists

The previous study suggests that accessibility affects time needed to break suppression. However, the previous study also suggests that my predefined lists were too short, as participants remembered on average more than half of the non-studied list. As a result, I relied on a post hoc analysis, testing the effects of accessibility by looking at remembered versus not remembered items rather than the experimental manipulation. In the present experiment I increased the number of stimuli from five to seven words per list and introduced a third non-studied list containing non-words and acting as fillers. This way learning of non-studied words should be prevented and participants would actively try to only keep the studied list active, i.e. accessible. As in the previous study, it was hypothesized that words from the studied list would break faster into consciousness than non-studied words, as people have a motivation to remember as many words as possible for the subsequent monetary reward and thus keep them actively accessible.

7.3.1 Method – "Static"

7.3.1.1 Participants. Forty people were recruited via the UCL subject pool, but only data of 35 participants (21 female, 14 male) with an average age of 25.17 years (*SD* = 7.14 years) was used for analysis, the administered exclusion criteria is the same as in the previous study (three subjects did not finish the experiment, while for one participant only the data from one eye was analyzed, and two participants were completely excluded due to gross inaccuracy). As above language abilities were reviewed, 16 were native English speakers and on average all participants had been speaking English for 21.14 years (*SD* = 9.00) of their lives. All had normal or corrected – to normal vision and no history of epilepsy.

7.3.1.2 Design. This study was a 3 (list type: studied & non-studied & filler) x 2 (block: block 1 & block 2) within participants design. The dependent variables were accuracy and time stimuli needed to break into consciousness (TTE).

3.1.3 Stimuli & Apparatus. The word stimuli consisted of two lists, with each seven words as stimuli. Additionally, there were seven non-words presented to all participants as fillers to make the role of memory less conspicuous. All 21 stimuli were matched for frequency (updated Zipf values by Van Heuven et al., 2014), number of letters and pixel count. The apparatus was identic to the previous experiment.

7.3.1.4 Procedure. The procedure was similar to the previous experiment with the exception that this time participants were asked to learn seven instead of five words. The experiment consisted of two instead of four blocks. The 21 stimuli were each presented once on the top and bottom of the screen and both to the left and right eye, thus resulting in 84 trials (21 words & 4 locations) per block. There were no breaks between the blocks. At the end participants filled out a questionnaire and received monetary reward depending on their memory performance.

7.3.2 Results

7.3.2.1 Accuracy. A repeated measure ANOVA applied on the percentage of accurate responses showed that there was no significant difference between the studied (M= 0.98, SD = 0.03) and non-studied list (M = 0.98, SD = 0.03), $F(1, 34) < 1$.

7.3.2.2 Time to Emerge. Only correct responses were used for analysis. As in the first experiment TTE data was transformed into log scores (10 lg) and then standardized into z-scores, in order to normalize the reaction time distribution. The average TTE across participants was 2.79 seconds, with a 1.99 seconds standard deviation.

A repeated measure ANOVA applied on TTE_{zlog} revealed no significant main effect of block $F(1, 34) < 1$, *ns*., no main effect of list type $F(1, 34) < 1$, *ns.*, but a significant interaction effect between block and list type $F(1, 34) = 4.76$, $p = 0.04$. Figure 7.3 demonstrates this finding. As expected based on Experiment 3, studied words emerged faster than the non-studied words in the first $t(34) = - 2.07$, p = 0.02 (one-sided), but not in the second block, $t(34) = 0.87$, *n.s.*

For purposes of better comparison with the first study, I additionally carried out the follow up analysis that tested the effects of memory, regardless of the predefined listtypes (studied or non-studied list). As expected, words that participants remembered broke suppression faster than not remembered words in the first block $t(34) = -2.03$, $p = 0.03$ (one-sided), but not in the second, $t(34) = 0.64$, *ns*.

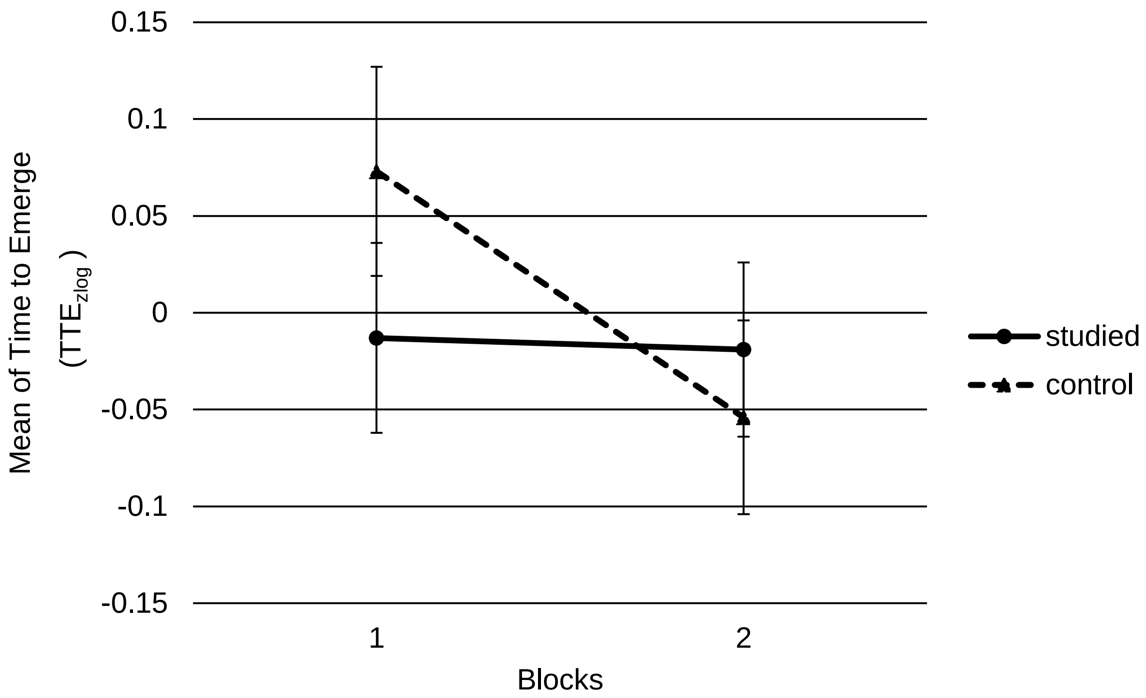

Figure 7.3. Means of Time to Emerge (TTE_{zlog}) throughout the 2 blocks as a function of list type. Error bars represent standard errors of the mean.

7.4 Discussion

In two experiments I observed that information that people kept on their minds emerged faster into consciousness in the CFS paradigm. In the first experiment, once the words that participants actually remembered were taken into account, rather than only those they were supposed to study, I found that accessible words emerged faster into consciousness. In the second experiment I improved the experimental design by increasing the number of studied words, and replicated the findings from the first experiment, but now as a function of our list type manipulation.

In both studies I found the hypothesized results of accessibility affecting TTE only in the first half of each experiment (Block 1 & 2 in Experiment 3, and Block 1 in Experiment 4). Such a block effect can have different possible explanations. For one it could be due to a CFS adaptation: Participants get used to the mask and therefore its effectiveness starts declining. Another alternative could be that halfway through each study every word would had been presented at least 8 times. This exposure may have been enough for all words to become accessible and not just the ones for which memory was incentivised, effectively leading to a floor effect in the second half of the experiment.

My findings suggest that information that is on one's mind emerges faster into consciousness, complements and expands the research by Balcetis and colleagues (2012). In their studies they showed that stimuli that are explicitly tagged as rewarding are prioritized in conscious awareness (Balcetis et al., 2012). My research goes one step further by suggesting that people do not only become consciously aware of concepts "they want to see" (Balcetis et al., 2012) but also of concepts that are just on their minds, without seeing them as instrumental in attaining their goal. This is not to say that goals cannot influence what people become aware of through accessibility. There is ample of evidence suggesting that information related to active goals remains accessible for longer than other information as long as the goals are not achieved (Bargh et al., 2001; Custers & Aarts, 2005; Förster, Liberman & Higgins, 2005). Hence, as active goals are on top of people's minds, they may cause us to become aware of related stimuli in the environment faster.

My study also goes one step further than previous studies in vision (Gayet et al., 2013; Soto et al., 2014), that found that when people were asked to retain specific stimuli such as a color patch (Gayet et al., 2013) or a face cue (Soto et al., 2014) for later recognition tests, target stimuli matching those cues emerged faster into consciousness under CFS than non-matching ones. Importantly, those effects were all tested on a trial-by-trial basis, whereas in my study concepts were kept accessible over the length of the entire study. Moreover, in previous vision studies the effects of visual working memory were tested, while I used words as more meaningful stimuli. It is highly unlikely that participants were relying only on visual working memory in keeping the studied words in their minds. Indeed, it would be rather difficult to just remember the visual forms of a list or words without processing any of them. As such, our effects seem to be the result of semantic processes.

Although it has been claimed that semantic processing can occur under CFS (Jiang et al., 2007; Sklar et al., 2012, Mudrik, et al.,2011) and without conscious awareness (Hassin, 2013), I believe my studies do not provide conclusive evidence for this. That is, even though accessibility of concepts may have been the result of semantic processes, this does not mean that semantic processes necessarily operated outside of conscious awareness. It could, for instance, have been the case that semantic rehearsal of the to-be-remembered words caused visual templates of these words to become accessible as well. Hence, even if semantic processes played a role in keeping concepts accessible, less sophisticated processes like template matching may have caused these words to break suppression earlier.

To sum up, it is still largely unclear what factors make people become aware of certain information. My studies show that information that people are asked to keep on their mind in exchange for monetary reward, broke CFS faster than controls. I argue that the underlying mechanism is accessibility. Thus, when people come across matching information in their surroundings they become conscious of it through top-down effects, which may enable them to deal with the environmental cues more effectively. To return to our introduction example, when expecting women (and men) suddenly start seeing prams and babies everywhere it does not have to necessarily mean that they are super fond of babies (yet), but that the concept of babies is accessible in their mind, thus prioritizes conscious awareness. Whether this prioritization of information in consciousness proves adaptive is a topic for further research, although theories of consciousness emphasize that awareness allows for much richer processing of incoming information, facilitating distributed processing across the brain (Dehaene & Naccache, 2001; Baars, 1997).

Chapter 8: I say Raven You Think Eagle: Do Category Members of Accessible Concepts Reach Consciousness Faster?

Abstract

The previous studies have shown that when people are presented with a list of words and asked to memorize them, those words break interocular suppression faster. This effect was explained by accessibility, words that were memorized became accessible on people's minds. Therefore, it was concluded that accessibility influences what type of information enters conscious awareness. However, as people were exposed to a list of the to-be-remembered words at the beginning of the experiments, familiarity with those stimuli cannot be ruled out as an alternative explanation. In order to address this possibility, the current study presented participants with 2 lists from different categories and the rewarding category was only indicated after participants had studied both lists. This way, participants should be equally familiar with the words from the rewarded and non-rewarded list. Furthermore, to test whether the reward effect generalizes across category members, novel words belonging to the same category as either the rewarded or non-rewarded list were presented in the CFS phase. Results showed that words that belong to the rewarding category, no matter whether they have been studied before or were control words broke suppression faster into conscious awareness. This suggests that previously found accessibility effects are not driven by familiarity. Moreover, these results give rise to the possibility that semantic processing might be included in the realm of higher-level preconscious processing.

8.1 Introduction

In the beginning of the 20th century Sigmund Freud claimed that people's behaviour is driven by motives hidden in the subconscious. Although his theories were heavily criticized for not being falsifiable, the subconscious became a mystery seemingly waiting to be solved. Nowadays there are methods available allowing scientists to empirically test for subconscious influences on behaviour. Research has shown that goal representations can be activated (i.e., primed) outside of conscious awareness and guide perception and behaviour (Bargh, Gollwitzer, & Oettingen, 2010). However, little is known about the extent to which information can be processed without conscious awareness. Recently, Hassin (2013) proposed a very pioneering theory called “Yes it can” (YIC) arguing “unconscious processes can carry out every fundamental high-level [cognitive] function that conscious processes can perform” (p. 195). He argues that consciousness, as we know it, is a fairly new development (Hassin, 2013; Dennett, 1995). Viewing it from an evolutionary point of view it would be pretty unusual for fundamental cognitive functions to rely on consciousness that has only a limited processing capacity. Therefore arguing the subconscious must be able to carry out all the same fundamental cognitive functions that conscious processes can (Hassin, 2013). The critical point, though, is that only because the subconscious can carry out all functions, does not necessarily mean it always will. There are many factors that can affect when the subconscious will perform, e.g. practice or motivation (Hassin, 2013).

While it is a very intriguing, forward-thinking but possibly also controversial theory, this thesis is more focused on investigating factors that affect what type of information can gain prioritized access into conscious awareness. For instance, why do some people become conscious of specific stimuli in their environment, e.g., prams, while others do not? I argue that one of the main reasons for differentiated conscious awareness lies in the type of information people keep actively on their minds. It has not yet been tested whether such accessibility effects are only limited to the exact type of information that people keep on their minds or whether it can be generalized to the category that information belongs to.

Previous research in the vision literature shows that accessible information affects what emerges into conscious awareness, precisely stimuli that are kept active in visual working memory (VWM) (Gayet, et al., 2013; Soto et al., 2011; Soto & Silvanto, 2014). Gayet and colleagues (2013) showed that target stimuli that matched a colour patch that had been presented on a trial level and stored in VWM, emerged faster into conscious awareness under CFS. Similar effects were found with more complex visual stimuli such as faces (Pan et al., 2014). Pan et al. (2014) had presented their participants with a to-be-remembered face prime at the beginning of each trial, they observed that faces that matched the initial prime would break suppression faster than incongruent targets. Both of those studies provided strong evidence suggesting that working memory content can affect what people become aware of even when detecting those targets is not instrumental in the actual goal pursuit (i.e. remembering the to-be-remembered colour patch/face). Nevertheless, both studies were limited to the visual working memory.

In my own research, I attempted to replicate the VWM results and additionally extend the results beyond the use of simple visual stimuli onto accessible concepts. Moreover, the accessibility effect was tested over the length of the entire study rather than just trial-by-trial basis. I conducted two studies (Rochal, Custers, Vigliocco & Vinson, 2017), in which participants were given a list of words at the beginning of the experiment and were asked to memorize them for a later recall. In the subsequent CFS paradigm words that had been previously studied broke suppression faster than control words (Rochal et al., 2017). Those results go beyond previously found expectancy and accessibly effects (Pinto et al., 2015; Gayet et al., 2013; Pan et al., 2014) on a trial level and simple visual stimuli, and provide supporting evidence that information related to what is currently on one’s mind gets prioritized access to conscious awareness. As with the visual working memory research those stimuli did not have to be instrumental in attaining the goal. Furthermore, when using abstract stimuli such as words the question of the degree of processing can arise, in particular whether the semantic content of a word needs to be processed for a specific task at hand. Rochal et al. (2017) argued that it seemed very unlikely that participants would have relied only on visual features of the studied words when memorizing them, without processing any of the meaning of the words.

Yet, familiarity could pose as a confounding factor in all aforementioned studies. Although Rochal's et al (2017) results suggest that information that is actively retained in WM, and therefore actively rehearsed, emerges faster into consciousness than information that had no incentive to be memorized, familiarity with the incentively studied words could offer an alternative reason for the TTE advantage. People were given sufficient time to memorize a set of words, that time might have been enough to evoke familiarity that then caused TTE benefits in the CFS paradigm.

That familiarity per se can account for differences in TTEs between different stimulus categories under CFS has already been shown in previous research (for review see Gayet et al., 2013). Much familiarity research has been conducted with faces, for instance upright faces break the threshold into consciousness quicker than inverted faces, which has been attributed to the fact that people are more familiar to see upright faces than they are to see inverted ones (Jiang, et al., 2007; Zhou, Zhang et al., 2010). More evidence lies in findings that familiar faces emerge faster into consciousness than unfamiliar faces (Gobbini et al., 2013b), faces that match the participant's age or faces that belong to the same racial in-group gain priority in conscious awareness than different aged faces, or faces from different cultural groups (Stein 2012). Those are all very good illustrations of how familiarity affects TTE under CFS, however it should be noted that those results should be considered carefully, as previously mentioned faces enjoy a privileged processing areas, such as the fusiform area (e.g. Kanwisher et al., 1997, McCarthy et al., 1997). However, similar effects have also been found with complex abstract stimuli – such as language. Jiang and colleagues (Jiang et al., 2007) observed that words that are from a familiar script (e.g. one's own native language) emerge faster into consciousness than words from unfamiliar scripts.

In light with familiarity research one could argue that my own previous results might not reflect the finding that information relevant to concepts that are currently on one's mind are prioritized in conscious awareness, but previous presentation and therefore possible familiarization caused them to break interocular suppression faster. Stripping it down to an even more basic level, people might have learned the visual representations of the to-be-studied words and were matching the visual form they studied with the ones that were presented under CFS, without necessarily remembering the semantic content of the words.

The question of whether semantic processing under CFS is actually possible is very controversial. There are a few contradicting views upon the level of processing possible under CFS. Some believe that semantic preconscious processing can indeed occur, for example Costello et al. (2009) showed that target words broke suppression under CFS faster if they are semantically related to previously shown prime words, or just shared a subword. Pinto and colleagues (2015) found similar effects in one of their studies (Exp. 3c) they presented participants with not predictive but associative cues, i.e. after presenting the cue word “FACE” or “HOUSE” either target stimulus “face” or “house” would equally often follow. Their findings showed that as targets were presented equally often independent of the cue word, no TTE differences arised (Pinto et al., 2015). This seems to stand in odds with Costello's et al.'s (2009) findings of semantic, i.e. associative, influences on TTEs. The authors addressed this issue themselves (Pinto et al., 2015), they pointed out that their experiments consisted out of almost four times as many trials as Costello's et al.'s (2009) study. When only using the first block of their study, not predictive but associative cues did indeed exert a top-down influence on CFS, i.e. target stimuli that were preceded by a matching prime would emerge faster into consciousness (Pinto et al., 2015). This supports the claim that associative, and thus semantically related stimuli have an advantage to break suppression. At the same time, it also suggests that this automatic semantic association can be “unlearned” over time when participants realize that presented cues are not predictive (Pinto et al., 2015).

On the other hand, other researcher argue that most of the supposedly semantic preconscious processing can be led back to lower-level features (see Gayet et al., 2014 for a thorough review). The only experiment to date that has tested top-down modulation of members belonging to the same categories used BR rather than CFS (Scocchia, Valsecchi, Gegenfurtner,& Triesch, 2014). Scocchia and colleagues (2014) tested whether images that were hold in WM would cause matching stimuli under BR to gain perceptual dominance. There were three different categories, face, house and plane, but only “house” and “face” were used as rivalry stimuli. The results suggested no top-down effects of WM content on BR. The authors argued that this would suggest that WM cannot affect interocular suppression, but attention could. As previously mentioned there is a lot of evidence in the interocular suppression literature, mainly with CFS, that WM at least VWM does indeed influence perception. A few possible reasons for Scocchia’s et al. (2014) null results could be that firstly, they had a very small sample size 7-12 people. Secondly, despite a non significant effect, it appeared on the graph that the “house” stimulus was perceived above chance level first no matter what stimuli had been memorized. This could point to the possibility that low-level features such as pixel count could have affected dominance. Thirdly, as mentioned in previous chapters BR has a few possible drawbacks, such as uncontrolled swaps in perceptual dominance between eyes (see Arnold et al., 2008; Tsuchiya et al., 2006). In Scocchia's and colleagues’ (2014) experiments exclusive dominance was only perceived at 31.84% (experiment 1) or 40.85 % (experiment 2) of the time during rivalry, which shows that more than the majority of times eye dominance was swapping.

8.2 Experiment 5: Semantically Matching Control Words

The present research intended to disentangle all those aforementioned confounding effects of possible low-level features, familiarity effects, template matching effects and possible semantics. Instead of presenting just one list, participants were presented with two lists each from one different category (“Birds” vs. “Vegetables). After studying and familiarizing themselves with both lists, they were told for which one and only one list they would get rewarded. This step allowed me to tear apart the confounding factors of familiarity and reward. If as previously argued motivation is a driving force, people are motivated to keep only that set of information active in their memory, in turn can affect what gains conscious awareness, it would be expected to find a TTE benefit for only the rewarded list. If however, familiarity is the driving factor I would expect both studied lists to break suppression faster than the control words under CFS. Another manipulation that was introduced, was that the control words were sampled from the same categories as the studied words. Thus, there were four different cells of words. First there was the studied and rewarded list, second the studied and not rewarded list, third the not studied, i.e. not previously presented, and rewarded, i.e. control words belonging to the rewarded category, list, and lastly the not studied and not rewarded list, i.e. control words that were neither previously presented nor belonged to the rewarded category (see figure 8.1). If semantics indeed play a role in preconscious processing, I would expect that words that had not been presented before the CFS but belong to the rewarding category would break suppression faster, too.

8.2.1 Method – “Ramping up”

8.2.1.1 Participants. Forty-four people were recruited via the UCL subject pool. One participants had to be excluded due to poor performance (accuracy < 80%), so only data of forty-three participants (9 male) with an average age of 21.01 years (*SD* = 4.02 years) was used for analysis. As in the previous experiments language abilities were reviewed, 16 were native English speakers and on average all participants have been speaking English for 16.79 years (*SD* = 6.58) of their lives. All had a normal or corrected – to normal vision and no history of epilepsy.

8.2.1.2 Design. This study was a 2 (list type: studied & not-studied) x 2 (reward: rewarded & not rewarded) x 2 (block: block 1 & block 2) x 2 (set: set A & set B) mixed design, with the first three variables being within participants factors, and set being a between subject factor. The dependent variables were accuracy and TTE.

8.2.1.3 Stimuli & Apparatus. There were two sets with each two lists of stimuli. Each list consisted of seven words from the category "birds" and seven words from the category "vegetables". All 28 stimuli were matched for frequency (updated Zipf values by Van Heuven et al., 2014), number of letters and pixel count. For each participant one set was assigned as the studied condition and the other as the not studied condition. It was counterbalanced between participants which set was assigned to the studied and not studied condition. The two lists within a set were fixed, though, meaning the "birds" list from set A would always be presented with the "vegetables" list from set A, while the "birds" list from set B would always be paired with the "vegetables" list from set B. Figure 8.1 presents a graphic illustration of the stimuli allocation. A contrast ramping of the suppressed stimuli was applied over the duration of 1 second until full brightness.

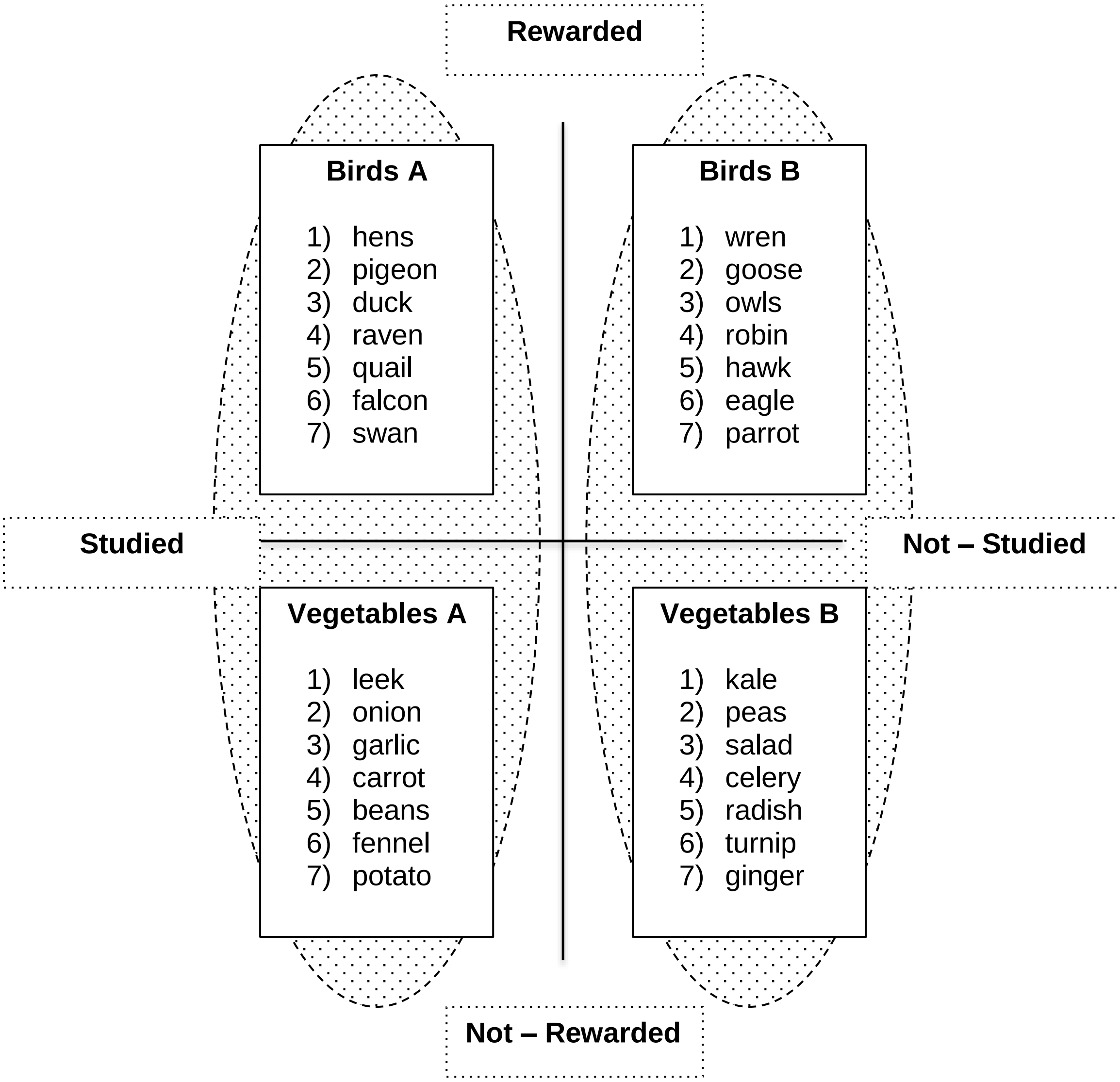

Figure 8.1. Stimuli Allocation. Set A on the left side and set B on the right side

8.2.1.4 Procedure. The procedure was similar to the previous experiments with the exception that this time participants were asked to learn two lists each consisting of 7 semantically related words. Immediately after presentation participants were told for which list they would receive monetary reward for by the end of the study. The 28 stimuli were each presented once on the top and bottom of the screen and both to the left and right eye, thus resulting in 112 trials (28 words & 4 locations) per block. There were no breaks between the two blocks. At the end participants filled out a questionnaire and received monetary reward depending on their memory performance.

8.2.2 Results

8.2.2.1 Accuracy. A repeated measure ANOVA applied on the percentage of accurate responses showed that accuracy did not significantly differ between studied (*M* = 0.98, *SD* = 0.03) and not studied words (*M* = 0.99, *SD* = 0.04), $F(1,41) = 1.15$, p = 0.29, nor between words that belonged to the rewarding category (*M* = 0.98, *SD* = 0.03) or not rewarding (*M* = 0.99, *SD* = 0.03), $F(1, 41) < 1$.

8.2.2.2 Time to Emerge. Only correct responses were used for analysis. Due to the improved CFS methodology (as in experiment 2) data was not transformed into log scores (10 lg) as changes in the design, such as presenting the stimuli by gradually ramping up the contrast, allowed me to use the raw TTE values in milliseconds. Individual trials that exceeded 30 000 milliseconds were excluded. As the variance between both eyes of each individual still differed, the data was still standardized into z-scores per eye. The TTE was measured from the onset of the stimulus until the stimulus broke through suppression. The average TTE across participants was 1.94 seconds, with a 0.73 seconds standard deviation.

A repeated measure ANOVA applied on the TTE_Z revealed a significant main effect of block $F(1, 41) = 40.15$, $p < 0.001$, but no main effect of list type (whether the items had been studied or not) $F(1, 41) = 1.5$, $p = 0.23$ *ns*., nor a main effect of reward (whether the stimuli were from the rewarding category, regardless of having been studied or not) $F(1, 41) <1$, *ns*. Importantly, there were no significant differences in response times between set A and set B $F(1,41) < 1$, *ns*. However, the effect of reward seemed to interact with block $F(1, 41) = 3.22$, $p = 0.08$ (2 sided).

A repeated measure ANOVA showed that there is a significant reward effect in the first block, meaning that words belonging to the rewarding category, regardless of whether they had been studied or not studied before, emerged faster than words from the not rewarding category $F(1, 41) = 3.24$, $p < 0.04$ (1-sided). There was no such effect in the second block $F(1, 41) < 1$ *ns*. Figure 8.2 shows the reward effect in the first block.

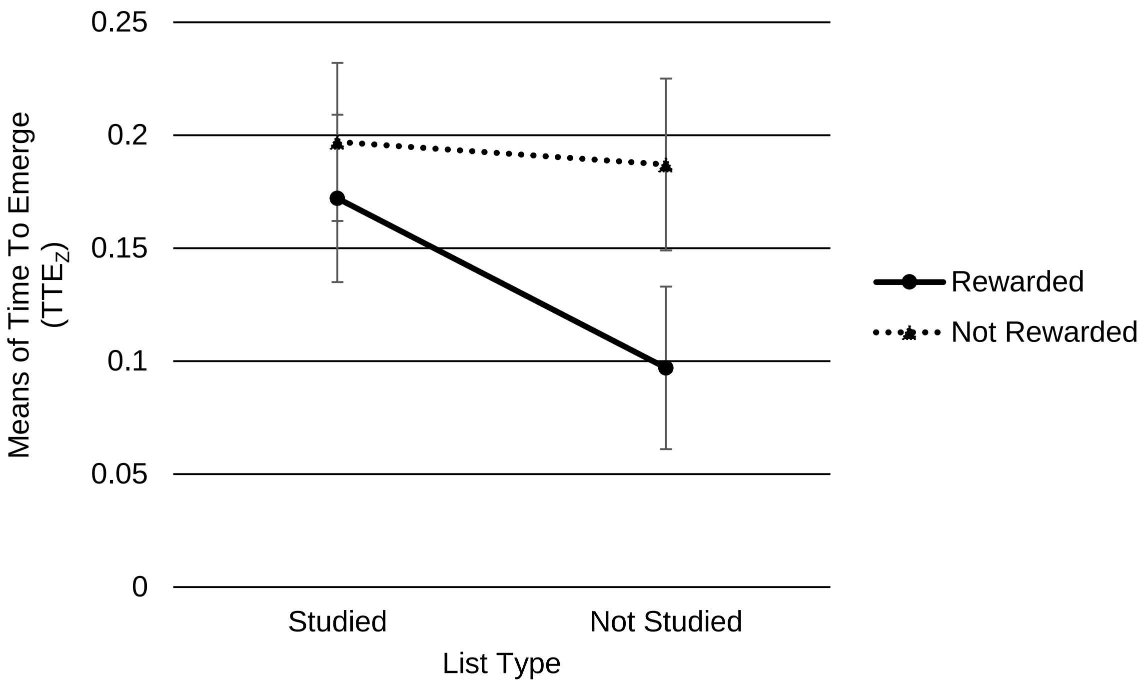

Figure 8.2. Means of Time To Emerge (TTE$_Z$) for the first block

8.3 Discussion

The present experiment aimed to unravel possible confounding effects of familiarity with reward and in addition to test whether preconscious processing can occur on a semantic level. For that, participants were presented with two semantically different lists of which they were explicitly only rewarded for one. The control words consisted of words that were semantically related to both studied lists. The results showed no general TTE benefit for previously presented and studied lists, meaning only because words were presented beforehand and could have become familiarized with, they did not emerge faster into consciousness. Moreover, an interaction effect between block and reward was found. As always the manipulated effect was present in the first half of the experiment, words that belonged to the rewarding category emerged faster into conscious awareness in the first block. It is important to stress that this effect of reward was found for all words that belonged to the rewarded category, both the control words and the previously studied words. Those findings imply that incentivising recall is the main factor affecting response times and not familiarity.

The tendency to find effects exclusively in the first block and not in the second block, could be due to the fact that each word is presented four times per block. This exposure may have been enough for all words to become accessible and not just the ones for which memory was incentivized, effectively leading to a floor effect in the second half of the experiment. In order to test this theory it would be advisable to add new stimuli into the CFS study in the second block. That way it could be seen whether the found TTE effects in the first block would withstand in the second block, too. Positive findings would strengthen any found effects in the first block. On the other hand, I do tend to find such positive results consistently in the first blocks and those findings are in line with previous studies, thus it should be possible to assume that these results are indeed real and substantial.

Assuming the validity and reliability of the findings, my research suggests that reward and motivation is the main factor affecting TTE and not familiarity. Furthermore the generalization effect, that all rewarded words were found to break suppression faster, and not only the specifically outlined seven words, seems in line with Costello's et al. (2009) study in which it was found that words that were semantically related to previously shown words broke suppression faster. Both findings give rise to the possibility that semantics might be able to be processed preconsciously. This study's results go one step further than Costello's et al. (2009) ones, who presented a prime and a target word on a trial-by-trial basis. Although the evidence is rather weak, it could be the case that once the rewarding category got activated. This activation spread to semantically related associations in the mind, facilitating the processing of these words, perhaps outside of awareness. In this case, this facilitation may still point to pre-conscious semantic processing.

Alternatively, it could be argued that it is not semantic preconscious processing per se, but that participants might have gotten confused throughout the CFS study and started actively rehearsing all words belonging to the rewarding category. This is quite possible, and would not support an actual semantic preconscious processing, however it would still support my other claim that what is accessible on one's mind and kept actively accessible gains priority in conscious awareness. This would be in line with my previous experiments in the previous chapters. Nevertheless, even though it is possible that participants started to actively rehearse all words instead of just the seven outlined ones, it would be expected to see this learning effect across both blocks and not only limited to the first block.

Nevertheless, this study has been very informative and has been the first of its kind to test accessibility effects over the duration of an entire study rather than a trial-by-trial basis (Gayet, et al., 2013; Pan et al., 2014). In addition it is unravelling the two confounding factors of familiarity and reward. Because of the nature of this design, some statistical power and some degree of experimental control were sacrificed for understanding the bigger picture. Testing accessibility and memory performance on a trial-by-trial basis as researchers like Gayet et al. (2013) have done, definitely provides a more controlled set-up. However, aim of my research was to test whether concepts and words that are semantically associated to concepts that are actively on one's mind would get prioritized access into conscious awareness. Most importantly, I wanted to test this question in an ecologically valid manner. Testing accessibility of rewarded concepts over the time frame of an entire study resembles much more a real-life scenario than a trial-by-trial design can, as when people form goals or have something on their minds those concepts do not usually change over minutes but stay active for a prolonged duration. Moreover, it is also a more real-life scenario that people would be confronted with several different concepts but only one would be of interest or adjacent to their goals, i.e. what is actively on their minds.

Thus, despite the results possibly not being as strong as one would hope for, it provides a very meaningful and important piece to the puzzle in demystifying the factors affecting the preconscious. More research is needed to expand my research and also to understand the limits of CFS. CFS has found a renewed interest a couple of years back, but to date there are no universal standardized versions of how it should be administered. This can lead to some difficulties comparing and at times replicating results obtained by different researcher groups.

Chapter 9: General Discussion

9.1. Prior Research

My research was based on the notion that most human behaviour is goal-directed and that perception can play a huge role in its attainment. Goals are thought to have a top-down influence on what people perceive around them in their environment, without necessarily requiring conscious awareness. If goals can exert a top-down influence on what is perceived and therefore prioritized in conscious awareness, it follows that at least some of the given information has to be processed preconsciously. I was particularly interested in whether goals and the motivation to fulfil them could exert a top-down influence on what information emerges into conscious awareness. To investigate this question I used a methodology called CFS. In CFS, one eye is presented with a stimulus while the other is presented with a flashing mask. The flashing mask initially dominates conscious perception, but the stimulus presented to the other eye eventually breaks through into conscious awareness. The time that is needed to break the suppression is measured and is defined as the time to emerge (TTE).

9.2. Overview of the Findings

In my first experiment, a basic need, thirst, was manipulated. I hypothesized that the motivation to fulfil this need would exert a top-down influence on what information thirsty participants would perceive. In particular, I expected water-related words such as “drinking”, to be prioritized in conscious awareness. However, results showed, thirst related words did not emerge to consciousness more quickly than non-goal related words as measured by time to emerge (TTE) in the CFS paradigm. I reason that the lack of a difference could have been linked to the fact that the manipulated need – water deprivation – was not accessible enough for participants (e.g. Veltkamp et al., 2008a, 2008b). As described many times before in the thesis, accessibility is thought to act as an essential prerequisite for top-down processing to occur (e.g. Veltkamp et al., 2008a, 2008b, Higgins, 1996; Custers & Aarts, 2010). As only when a goal representation is accessible, the associated constructs, i.e. means to achieve it, get activated and in turn visually prioritize objects that can facilitate goal attainment without conscious awareness (e.g. Custers & Aarts, 2010).

In order to test for the strongest form of accessibility manipulation, I manipulated accessibility on a trial basis in the following experiment. Moreover, accessible stimuli were made instrumental for the CFS task at hand. This manipulation was supposed to create expectancy for locating specific targets that matched previously shown cues. Indeed, a congruency effect was found, i.e. congruent – expected – targets broke suppression faster than incongruent – unexpected – ones. This suggests that accessibility exerts a top-down influence on what enters conscious perception. Next, I tested accessibility in a more ecologically valid manner; testing accessibility of concepts over a longer period of time, rather a trial-by-trial basis in order to see whether the found accessibility effects can go beyond visual features of words. Here I found that stimuli that were kept accessible in the WM broke suppression faster into consciousness than stimuli that were not made accessible.

My final study tested whether the found accessibility effects were limited to only stimuli that were specifically outlined and kept accessible, or whether such accessibility effects can also be extended to other members of the same category. I simultaneously tested whether previously found accessibility effects could have been partially attributed to familiarity effects as participants became familiarized with the accessible words while studying them. Therefore, I tried to disentangle possible confounding effects of familiarity and semantics. The results indicated that the driving factor for keeping words accessible was not familiarity but the motivation to receive a higher financial reward. Moreover, the results showed that the main effect of reward was not limited to only the studied words, a generalization effect was observed. Namely, all words belonging to the same semantically rewarded category emerged more quickly into consciousness, no matter whether the specific words had been presented before or not.

Thus, first I established that having a goal and a motivation to achieve it may not be sufficient to change prioritized awareness of stimuli related to the goal. This could have been due to insufficient accessibility of the goal. My experiments showed that once accessibility and motivation is increased it can affect the times that stimuli need to break through intercocular suppression into conscious awareness. Words that had been rendered accessible and were expected on a trial-by-trial basis were prioritized in conscious awareness, as well as words that were memorized over the duration of the entire study. The findings of my last experiment give reason to argue that semantic processing can be possible. After I manipulated one word category to become accessible, this accessibility and the prioritization into conscious awareness appeared to extend and generalize to other members of that semantic category.

As the CFS paradigm is relatively novel in the field, the input of every researcher working on it is necessary to optimise this methodology. Throughout my project I critically reassessed my used CFS set-up and believe that the changes I have applied will also benefit to further researchers in this field. Below I describe the limitations of CFS as a methodology and suggestions how it could be optimized in the future.

9.3. Limitations of the CFS paradigm

9.3.1. No Standardized Norms and Poor Transparency

As mentioned briefly in the introduction, the literature exhibits some contradictory findings, be it in behavioural or neurological studies. One substantial reason for that is that there is no standardized methodology when it comes to CFS. It is the individual researcher’s responsibility to decide upon a range of variables, be it the type of mask they use, the mask’s refreshment rate, or the duration of the target contrast ramping for example (e.g. Ludwig & Hesselmann, 2015; Pan et al., 2014; Tsuchiya & Koch, 2015). All those decisions are entirely up to the individual researcher. Yet, any change to the low-level features of the mask or stimuli, no matter how small, can influence the effectiveness of CFS (e.g. Tsuchiya & Koch, 2005; Mudrik et al., 2011; Gayet et al., 2014).

Similar concerns arise during data analysis; many researchers apply different methodologies to nullify noise or to account for differences in eye dominance. For instance, while I used z-transformation for each individual eye, other researchers calibrate eyes individually, by using two separate screens before running subjects under CFS (e.g. Heyman & Moors, 2014). Calibration in itself can be a very delicate process. An overly conservative calibration can result in TTEs, which are too long and therefore could affect participants' performance and their focus drastically. This in turn could introduce noise in the data. A liberal calibration, on the other hand, can make TTEs too fast. Therefore, the observed times might reflect mere word recognition times rather than the time needed to break interocular suppression. Crucially though, such adjustments are rarely reported in articles, despite them having a massive effect on CFS results. There is definitely a need for more transparency of how variables are chosen across different studies. I would even advocate an attempt to fuse all this knowledge together and create the best possible standardized form of CFS. Further research would benefit from such a development.

One methodological suggestion that has been voiced increasingly in recent years and is associated with the conceptual interpretation of TTEs - which will be discussed in more detail in a subsequent section - is the inclusion of a non-suppression condition (Yang et al., 2014). TTE is defined as measuring the different times different stimuli need to break through the CFS mask. The idea is that if TTE differs systematically between two varying conditions, although both types of stimuli are always physically presented, the TTE differences must reflect differences in preconscious processing. While I will discuss other possible interpretations of TTE later, some researchers have voiced concerns that in order for TTE results to truly support preconscious processing differences, all TTE results need to be held against a non-suppression condition, in which all stimuli are always fully visibly presented (see overview Yang et al., 2014). Many studies that included a non-suppression condition failed to find similar TTE differences as in the suppressed condition, i.e. typical CFS (Stein and Sterzer 2011; Yang et al., 2014). Such findings are usually used to support the notion that TTE in suppressed trials, do indeed reflect influences of preconscious processing (Yang et al., 2014). It should be noted that the absence of TTE differences in fully visible trials does not automatically imply that no preferential processing can occur under fully conscious trials. Similar mechanisms could be in place, but other conscious factors might be masking the findings. Many previous non-CFS studies have shown that in the presence of awareness, people start making much more controlled and intentional decisions, compared to more automatic reactions in absence of awareness (Merikle, Smilek & Eastwood, 2001). Nevertheless, the inclusion of a non-suppressed condition can still support found results and the notion that TTEs may indeed reflect processing differences that appear to occur outside of awareness.

9.3.2. Conscious Infiltration

Sometimes CFS receives criticism that by its own definition it operates on a thin line between consciousness and preconscious (Yang et al., 2014). While TTE gets interpreted as a measure of what is happening during preconscious processing, technically it measures variables after they have become consciously visible. Therefore, some argue that the driving forces behind TTE variance are differences in responses that might be governed by factors that play a role once a stimulus becomes consciously accessible (Yang et al., 2014) or at least partially aware. In order to rule out alternative explanations, many researchers began to include a non-suppression condition. A non-suppression condition still consists of a typical CFS mask and a target, with the difference that the target gets gradually blended into the mask. Both the mask and the target are presented equally in both eyes – nothing is suppressed. If the non-suppression condition fails to replicate CFS findings in a suppressed condition, the alternative explanations of partial awareness or that conscious factors are affecting TTE, can be ruled out.

9.3.3. Response Bias

Another frequently raised concern is whether CFS effects could be driven by response biases. If participants are too conservative with their answers, i.e. hold on with their response because they want to be extra certain of the target, even though they might have perceived it already, extremely long reaction times could be a consequence. Most of the time long reaction times are interpreted as lack of awareness, rather than a conservative criterion. The non-suppression condition could help to rule out this explanation. Another unique approach to this problem is to couple eye tracking with CFS. This could give a clearer indication of whether people actually look at the suppressed stimuli immediately or after a specific time. It would be interesting to see whether the eye tracking results would reflect TTEs.

9.3.4. Partial Awareness

Typically CFS is broken down in a dichotomous manner, with a participant being “aware” or “not aware” of a stimulus, as TTE measures the time needed for a person to become consciously aware of a stimulus. This gives rise to a possible “grey zone” where participants could become partially aware of a stimulus but are not fully capable to identify the stimulus (Yang et al., 2014). Some evidence suggests, “visual awareness of complex stimuli can vary in a graded manner” (Yang et al., 2014 page 6; Kang et al., 2011; Mudrik et al., 2011). In order to be able to rule out partial awareness as a confounding factor a control condition such as the non-suppression trials could be included. Amongst others Mudrik et al., (2011) and Salomon et al., (2013) were able to rule out partial awareness of their results by simply including a non-suppression condition.

Mudrik and colleagues (2011) included a control condition in which the target stimuli were blended in with the masks and presented to both eyes. The idea was that if partial awareness was the driving factor for the TTE results, it would be expected to find the same TTE benefits under non-suppression trials (stimuli blended in mask trials) as well as in the normal CFS trials. In the control condition, the stimuli were never suppressed and always presented to both eyes at all times. Interestingly, the researchers only found TTE benefits in the suppressed condition, thus they could rule out partial awareness being a confounding factor and concluded that the TTE results were strongly suggesting influences outside conscious awareness (Mudrik et al., 2011).

In my research I did not include a non-suppression condition, due to a few methodological constraints. The biggest constraint was time. As all stimuli and presentation combinations had to be randomized and equally often presented to different eyes and locations, the CFS study was always around 45 minutes long. If I had included a non-suppression condition, I would have needed to treat this condition to the same criteria as the suppressed trials, which meant randomize and equally often present the non-suppression trials for the same amount of trials. This could have easily increased the experiment time to 1-1.5 hours. There I would have run the risk of fatigue and participants not being actively engaged nor focused on the task. Therefore, the decision was made to concentrate on the suppressed condition. Nevertheless, due to the way of how participants were instructed before the study, it is highly unlikely that partial awareness was a biasing factor in our studies. The instructions clearly stated “Please press the up or down button <u>whenever</u> you see a word, you do not have to be able to read the word, just the mere detection of the word is enough for a response”.

9.4. Possible Conceptual Interpretations

9.4.1. Semantics Interpretation and Debate

It could be argued that the positive results throughout the experiments up to the semantic study (excluding the first thirst study) imply that semantic processing is indeed possible on a preconscious level. This is from the observation that when participants were told for example that “birds” would be the rewarded category, not only words that had been studied and that belonged to this category were prioritized in conscious awareness, e.g. “swan”, but also words that had not been studied but were members of the rewarded category e.g. “robin”. The fact that the TTE benefit was extended to all items of the rewarded category could be an indication that semantic associations can become activated preconsciously when a goal is involved. This is in line with Costello’s et al. (2009) work, in which semantically related words broke CFS suppression faster, Sklar’s et al. (2012) findings that semantically incongruent sentences would break suppression faster than correct sentences, as well as Mudrik’s et al. (2011)’s observation that semantically incoherent scenes were prioritized over semantically coherent scenes in conscious awareness. All these findings suggest that semantic processing must have occurred to a certain degree preconsciously, in order for the TTEs to systematically differ.

Additional support for the possibility of preconscious semantic processing comes from cross modal studies using different sensory modalities, such as Zhou and colleagues (2010) scent study. The authors exposed participants with different scents while they were participating in a CFS task (Zhou, Jiang et al., 2010). It was found that images, e.g. a rose, that matched the olfactory stimuli, e.g. scent of a rose, would break suppression faster (Zhou, Jiang et al., 2010). Similar results were found by Alsius and Munhall (2013) with auditory cues. Faces, in which lip synchronization matched the supraliminal presented auditory sentences, broke suppression faster than faces with non-matching lip synchronization (Alsius & Munhall, 2013). These studies suggest that some of the semantic content of the stimuli presented had to be extracted, in order for them to exert an influence on stimuli presented in a different sensory modality. Semantic information of an invisible stimulus may be encoded and consequently strengthen the neural signals associated with that stimulus enabling an advantage in emerging through CFS suppression (Yang et al., 2014).

However, as mentioned occasionally in this dissertation, this is a debatable claim. For example, one neurological study failed to pick up on an N400 signal, which is usually an indicator for semantic processing (Kang et al, 2011). Thus, arguing that perhaps no semantic processing can occur under the threshold to consciousness. Interestingly, a study was published last year that showed that people can process syntax subconsciously (Hung & Hsieh, 2015). Hung and Hsieh (2015) presented participants with two words subliminally and then suppressed the third under CFS. They found that if the third word was a syntactically incorrect word, e.g. subject – verb – verb format, this syntactically incorrect word would break suppression faster than a correct word. Crucially they replicated this result with pseudowords that did not convey any semantic meaning. Thus, while their research strongly suggests that high-level processing is indeed possible under preconscious processing, as language processing is regarded as one of the “most complex form of multistep rule based operation” (Hung & Hsieh, 2015 page 1), it shows at the same time that this can occur without the necessity of semantic processing. This interpretation does not necessarily rule out semantic preconscious processing, but does not imply it either. However, it does imply that higher-level processing is possible under the threshold of conscious awareness.

9.4.2. Pattern Matching Interpretation

An alternative account for my results could be that people were engaging in pattern matching during preconscious processing. Pattern matching in this context means that people have a given sequence of items accessible on their mind and test whether the given stimulus matches the pattern of the accessible sequence. This idea would be in line with the cross-modal priming study of Lupyan and Ward (2013), which found that when people heard the word “square” they were faster to detect an image of a square under CFS. Lupyan and Ward (2013) went one step further and created a square – to – circle continuum, and varied the used visual stimuli. They observed that the top-down effects detecting a visual stimulus that matched the auditory cue, depended on the degree of correspondence i.e. if the auditory cue was “square” and the image shown was on the extreme side of “square” on the continuum, the TTE benefit was strong. However, when the visual image was overlapping a little bit in its shape with a circle, the top-down effects were decreasing gradually as the overlap of the shape increased (Lupyan & Ward, 2013). The authors argued that these effects strongly suggest that the cross-modal priming was not semantically driven but by the active visual representations of specific stimuli. This would be a plausible explanation for our significant results reported in chapter 6 where I manipulated the accessibility of individual words on a trial level and in chapter 7, where I manipulated the accessibility of a list of words over the period of the entire study. It is possible that people remembered the visual representation of those words on a trial level or over the entire study, respectively. The same applies for my last study in chapter 8, where participants could have learned the pattern of the words they would get rewarded for, after initial learning of what all those words were. This would imply that no semantic processing is needed to explain all our findings.

It could be argued that this pattern matching could be broken down into a lower level, such as feature matching. In chapter 6, I presented people with words such as “crab” on a trial level, it is very possible that people just remembered that this word would have to have an ascender and match this strategy onto the suppressed targets. However, this logic cannot be applied that easily to chapter 7. Each list consisted of a row of words, it would had been impossible to only have one strategy for all the different type of words, thus feature matching is not an applicable interpretation for my research.

This leaves pattern matching as a plausible alternative account. Yet, it seems quite difficult for a person to learn and rehearse all rewarding words just based on their visual representation without extracting any of their semantic contents. I am not arguing that the CFS effects per se have to be of a semantic nature, but my evidence suggests that there are top-down effects that work under a preconscious threshold. Even if some of my results are marginally significant, they are nevertheless significant and I argue that they uniformly suggest that accessibility can exert top-down effects on preconscious processing.

9.5. Conclusion

To conclude, my research started with the broad question of whether the motivation to fulfil a goal can exert goal-related stimuli to break interocular suppression faster into conscious awareness, and therefore imply that goal-related information must be prioritized in conscious awareness. My line of research changed its course when I started to distance myself from manipulating an active goal, to manipulating the different components that need to be fulfilled in order for motivation to affect one’s behaviour and perception; in particular accessibility. My following experiments tested different variations of accessibility and its effect on conscious awareness. I found that expected and accessible stimuli would exert a top-down influence on detecting matching stimuli under an intercocular mask. Even more such an effect of accessibility on prioritized awareness could be extended to an entire list and the duration of an entire study. Being able to find these accessibility effects to sustain over a period of time is another step towards unravelling the bigger picture of subconscious goal pursuit. In general for goal pursuit to occur the motivation and its activation need to sustain over time. Thus, my findings that accessibility can indeed be kept active over a longer period of time and have an effect on conscious awareness are favourable results. In my last experiment I went one step further and tested how far those accessibility effects can go. Can those be extended to semantics? It is important to point out that my semantics category study was the first of its kind and I argue that semantic preconscious processing appears to be able to occur to some degree. Whether this finding is only restricted to word activation via a semantic associative network activation by accessible category members or whether these effects can be extended to sentence comprehension, is for future research to explore. For the scope of my research that was about whether motivation can affect what enters our consciousness, I argue that my findings strongly suggest that higher-level preconscious processing is indeed possible, especially when a motivational incentive is created.

Chapter 10. Implications

This set of studies expands our current knowledge and understanding of the possible depths information processing appears to undergo outside of conscious awareness. My line of research suggests that preconscious processing seems to drive what type of information is perceived in an abundance of stimuli around people, and not just selective attention. During the course of my research, attention was always focused on the same location on the screen. The type of information that was incentivised to be kept accessible affected what gained priority access into conscious awareness. Consciousness and attention are two distinct entities (Koch & Tsuchiya, 2007), even though their effects are sometimes hard to differentiate. Koch and Tsuchiya (2007) provided an ample review of the distinction and provided examples where attention and consciousness can occur independently of each other. For instance, a) for the formation of an afterimage, neither top-down attention nor consciousness is required, b) top-down attention is not required to get the gist of an image whereas it can give rise to consciousness, c) priming requires top-down attention but works best without conscious awareness of the prime, and d) last but not least, discrimination of unfamiliar stimuli requires top-down attention and can give rise to consciousness (Koch & Tsuchiya, 2007).

Attention is oftentimes regarded as a gate-keeper for what type of information gets processed. My research suggests that concepts that are accessible on one's mind affect what people become consciously aware of. This points to the possibility that the preconscious fulfils a similar function as selective attention, i.e. that it filters out what is relevant and directs attention towards certain objects and information in one's environment. The main difference is the process by which this happens. During selective attention, there is an abundance of visual stimuli, whereby people could theoretically become aware of everything they are presented with. Attention, though, selects what piece of the picture is relevant and that is what people become aware of. When using CFS in my studies, attention was always focused on one particular location and although stimuli were always physically presented, people failed to perceive the stimuli at first. The critical point was that even with focused attention, it depended on the type of information accessible for stimuli to be able to break suppression and emerge into consciousness. Thus, even though it is a very fine line, there is a difference in the manner that attention and preconscious processing seem to filter information into conscious awareness.

Some real life implications could be that despite focusing our attention on a particular scene we will only become aware of information and objects that are relevant to us, and that are related to information accessible in our minds. This appears to be a highly adaptive behaviour; it allows people to selectively perceive what is relevant to them individually. For instance, evoking a goal complemented with a monetary reward in a position of employment (i.e. the more clients one gets in the higher the bonus) will both motivate the employee and more importantly, on a psychological level, make the employee perceive goal-related information more consciously, thus allowing them to realize their full potential.

This feature of allowing people to selectively become aware of relevant information could have originated through evolution, or it could be a by-product of having information accessible in one’s mind. This is for future research to discuss.

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