Is Conscious Perception a Continuous or Dichotomous Phenomenon?

Henk Pretorius

PRTHEN001

University of Cape Town

Thesis Presented for the Degree of

DOCTOR OF PHILOSOPHY

in the Department of Psychology

UNIVERSITY OF CAPE TOWN

September 2014

Supervisors:

Colin Tredoux

Susan Malcolm-Smith

University of Cape Town

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Declaration

I declare that this thesis is my own unaided work, both in concept and execution, and that apart from the normal guidance from my supervisors, I have received no assistance. Neither the substance nor any part of the thesis has been submitted in the past, or is to be submitted for any other degree at this or another university.

Henk Pretorius Date

Acknowledgements

My consciousness has benefited greatly from the support of a number of people.

I extend my sincerest gratitude to my supervisors Colin Tredoux and Susan Malcolm-Smith. Their guidance and support were invaluable. This thesis is the result of an excellent working relationship between us.

I would also like to thank Elna, my fiancé and business partner for her unwavering support and understanding during this process. At various times throughout this project I had asked you to take over some (or all) of my responsibilities. You never said no. This would not have been possible without you.

The opportunity to undertake my PhD studies would not have occurred without the loving support of my family. Mom, Dad and Lize - my deepest thanks for always being such a great foundation.

To all the research participants in this project - thanks for making this research possible!

Finally, to everyone at Columinate, thanks for being such a supportive company throughout the creation of this thesis.

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Abstract

Is our conscious visual experience of the world characterised by events that appear suddenly or gradually in our awareness? This apparently simple question has proved difficult to resolve. Inspired by the global neuronal workspace theory, the dichotomous view (e.g. Sergent and Dehaene, 2004) proposes that visual experience is all-or-none, and that someone is always either fully conscious or fully unconscious of visual phenomena. Opposed to this is a graded view (e.g. Overgaard, Rote, Mouridsen, & Ramsøy, 2006) that argues for the existence of diluted states of visual consciousness. Contradictory introspective and theoretical accounts have not been settled in experimental investigations. It was the aim of this thesis to test the proposal that the form of consciousness is dynamic and dependent on the viewing conditions of the observer. To this end, the three experiments reported in this thesis investigated the effect of degradation technique, stimulus type and processing level on conclusions regarding the form of visual consciousness. Further, the possible confounding effect of awareness scale length in this area was examined. In Experiment 1 the effect of two types of visual degradation techniques (the attentional blink and masking) and two stimulus types (words and shapes) was investigated. The results revealed that shape stimuli and the masking technique lead to more degraded conscious experiences. The second experiment compared the findings about the form of consciousness from four different scale lengths, finding that all scales delivered degraded reports but that the degree of degradation reported on the scales differed significantly. The third experiment introduced face stimuli as a more natural, multi-dimensional stimulus set. Participants took part in two conditions, distinguishing between faces and other objects (categorisation) and identifying the exact face that was presented (identification). The findings showed many reports of degraded conscious states in both the identification and categorisation stages, but differences in the nature of degradation at different timing levels were evident. On the whole, the findings reported in this thesis suggest that visual consciousness can be degraded, and that the degree of degradation depends critically on the viewing conditions and rating scale employed. These findings challenge the predictions of the prominent global neuronal workspace theory of consciousness and prominent research approaches in consciousness studies that rely on the dichotomising of awareness state data.

Chapter 1

Introduction

Conscious visual experience appears to be both graded and dichotomous. When a subject stares directly at her pet cat, she is completely aware of the animal at that moment. At the same time the subject is completely unaware of the myriad other visual objects in her surroundings that she is not attending to, such as a slightly tilted picture frame in the corner of her field of vision. This scenario invites a simple solution: Visual consciousness is all-or -none. The subject is always either fully conscious or fully unconscious of the content of her surroundings. However, what happens when the subject, attending to dinner, gets only a glimpse of the cat leaping from one area to another? In this case her consciousness appears to have a graded character. She is neither fully conscious nor fully unconscious of the creature; instead some degraded state characterises her consciousness. These competing intuitions about our visual consciousness have proved difficult to reconcile, not only from the perspective of introspection but also in experimental investigations.

There is now a growing body of research that tries to determine empirically how to treat the variable of consciousness. Inspired by theoretical predictions from the global neuronal workspace theory (GNWT) (Dehaene, Kerszberg, & Changeux, 1998), evidence for all-or-none visual consciousness has been found in some studies (e.g. Sergent, Baillet, & Dehaene, 2005; Sergent & Dehaene, 2004), while other studies have supported a graded view of visual consciousness (e.g. Overgaard et al., 2006; Ramsøy & Overgaard, 2004). Recently there have also been attempts to integrate these disparate accounts through appeals to separable levels of visual consciousness (Kouider, De Gardelle, Sackur, & Dupoux, 2010; Windey, Gevers, & Cleeremans, 2013). These researchers argue that some levels of visual consciousness are graded while others are dichotomous. However, the two proposals of this kind offer different structures for this dissociation and lack strong empirical assessments of their main hypotheses. On the whole, a review of the literature reveals a debate that remains unresolved. Consequently, the question of the form of visual consciousness has been firmly established alongside other debates in the recently flourishing area of consciousness studies. It is this debate that is the central concern of this thesis.

The approach taken in this work relies on conceptual and empirical components to make progress on this central question. Conceptually, a critique of the current framing of debate is offered and the debate's seemingly single central question is recast into three distinct questions. It will be argued that while evidence for the *existence* of degraded states is accumulating in the literature, issues around the *generality* and *degree* of degradation should also be addressed. Further, a definition of degraded consciousness is put forward, derived from popular definitions of conscious and unconscious states. The empirical work advances the debate by testing the idea that the form of consciousness is dynamic and that viewing conditions influence how the visual world is presented to our consciousness. In addition, the potential bias introduced by variations in awareness scale length is examined. Finally, the reach of the debate is extended by investigating the form of consciousness when viewing human faces. The findings reported here suggest that visual consciousness can be degraded, and that the degree of degradation depends critically on viewing conditions, stimulus characteristics and the rating scale that is employed.

The thesis is structured as follows: The remaining part of this introductory chapter situates the debate in the broader area of consciousness studies, and reviews some of the foundational challenges in the wider field concerning definitions and measures of consciousness. An examination of the popular strategy of *contrastive analysis* is presented, in order to show how this prominent approach in consciousness studies may have been an obstacle to posing the question of whether visual consciousness can be degraded. Chapter 2 critically reviews the theoretical and empirical literature from both sides of the debate about the form of visual consciousness, and summarises the objectives and strategy that guided the experimental work reported in the thesis. Chapters 3 to 5 present the empirical material, reporting on the three experiments. The thesis concludes with a discussion in Chapter 6 on the implications of the findings, the limitations and promising avenues for further research.

Resurgence in Consciousness Studies

The debate about the form of visual consciousness is situated in a field of consciousness studies that has re-emerged after a long silence. For a large part of the 20th century consciousness was purposefully disregarded as a topic of study in psychology, due to the prevailing behaviourist paradigm. More than a century ago, Watson (1913, p. 158) expounded a manifesto that declared consciousness off-limits to the objective aims of behaviourist psychology:

> Psychology as a behaviorist views it is a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its method nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness.

Furthermore, “the time has come when psychology must discard all reference to consciousness; when it need no longer delude itself into thinking that it is making mental states the object of observation ...” (Watson, 1913, p. 163). For much of the 20th century Watson’s (1913) call was answered. The private and subjective nature of consciousness was considered at odds with the public and objective nature of scientific inquiry.

In the last few decades this situation has changed, and consciousness has resurfaced as a respectable and productive area of study. Zelazo, Moscovitch, and Thompson (2007a) trace the antecedents of this resurgence to a number of key factors. The first development was the cognitive revolution in psychology that started viewing human mental life in terms of information processing systems. Even though the initial formulation of these models did not include consciousness, the study of attention and memory opened the door for the addition of consciousness. A second development involved the clinical sciences, where conditions were reported that appeared to be explainable only with reference to consciousness. Blindsight is a famous example (e.g. Weiskrantz, 1996). In this condition patients with damage to the occipital lobe claim to have no phenomenological experience of visual events, but perform at above-chance levels when prompted to guess what they are observing. A third development that has contributed to the renewed interest in consciousness has been the development of sophisticated brain imaging techniques, such as magneto-encephalography (MEG) and functional magnetic resonance imaging (fMRI). These techniques provide an objective, observer-independent view into mental life and allow us to correlate reports of subjective experience with brain events.

The result of all of these developments has been the rapid elevation of the study of consciousness to a legitimate and significant scientific challenge. In fact, in its 125th anniversary edition *Science* magazine named consciousness as one of the biggest questions facing 21st century science (Miller, 2005). Various journals have been established that are dedicated to consciousness studies (e.g. *Consciousness and Cognition* and the *Journal of Consciousness Studies*), and a regular conference has been held by the Association for Scientific Study of Consciousness since 1997. Several handbooks (e.g. Banks, 2009; Bayne, Cleeremans, & Wilken, 2007; Zelazo, Moscovitch, & Thompson, 2007b) have also appeared in recent years, summarising the state of knowledge in the various branches of the field now generally titled *consciousness studies*. These and other general indications point to a flourishing field of investigation.

There are a number of significant questions being addressed in the broad domain of consciousness studies. The challenge identified by *Science* involves one of the most prominent of these questions, which is the attempt to find the brain states and areas that are uniquely associated with specific conscious experiences. This is often called the search for the neural correlates of consciousness (NCC) (e.g. Chalmers, 2010) and led to the famous proposal by Crick and Koch's (1990) that the NCC involve a 40 hertz neural oscillation.

However, the search for the NCC is by no means the only question being actively worked on in the area. Seth (2009) offers an overview of what he considers to be the greatest challenges, distinguishing between immediate and long-term aims for the science of consciousness. Regarding the immediate challenges, he observes that consciousness is multi-modal, with many sensory and non-sensory contents. He proposes that we need to understand how separable these states are, what their neural underpinnings are and how they integrate into our unitary experience of the world. The next challenge Seth identifies is related to the function of consciousness. Various proposals have been put forward to explain why natural selection would favour consciousness, including supporting voluntary action, enabling flexible responding and error correction (e.g. McGovern & Baars, 2007). The issue of measurement is also a core challenge for consciousness studies (e.g. Seth, Dienes, Cleeremans, Overgaard, & Pessoa, 2008). Seth observes that effective measures of consciousness are essential for advancement in all areas of the field. He suggests that the combination of objective (e.g. brain measures) and subjective (e.g. awareness ratings) measures are likely to yield better insights than a single measure alone. The issue of measurement is reviewed in more detail later in this chapter. Another fundamental challenge is understanding the disorders of consciousness, such as blindsight (e.g. Weiskrantz, 1996). Coma, the vegetative state and the minimally conscious state are being studied intensely with the hope of finding markers of consciousness and even potentially allowing communication with patients who have these conditions (e.g. Owen et al., 2006).

Three further challenges identified by Seth (2009) are likely to take longer to address. The first is understanding which non-human animals are conscious (e.g. Seth, Baars, & Edelman, 2005). This line of inquiry is made particularly difficult without the verbal report of conscious experiences available when studying adult humans. The second long-term challenge is understanding the development of consciousness across ontogeny in normal human development (e.g. Zelazo, 2004). Seth speculates on the potentially disruptive implications if we were, for example, to discover that babies are unconscious until several months after birth. The third long-term question is whether it is possible to engineer a conscious artefact (Gamez, 2008). While simulations of consciousness are being offered in various areas of study (e.g. Sun & Franklin, 2007), what has not yet been approached is the instantiation of consciousness in some physical material. At present this challenge appears a long way off and will rely on the accumulation of knowledge from study of the other questions summarised here. These challenges and various others are being approached from an interdisciplinary perspective. Researchers from psychology, philosophy, psychiatry, neuroscience, artificial intelligence, neurology, and computer science have been attracted to work on the various problems posed by consciousness.

Disagreements in Consciousness Studies

Perhaps it is unsurprising that there is much disagreement in the area, given the significant interest in the study of consciousness. In fact this field is pervaded with disagreements to the extent that Dennett (2005, p. ix) remarks it (consciousness studies) is "so rambunctious that several people are writing books just about the tumult"[1]. A few examples are warranted. In the area of conscious perception there has for several decades been disagreement on whether implicit perception has been and can be verified, or whether these states have been detected as artefacts of measurement (e.g. Simons, Hanulla, Warren, &

[1] Mischel (2008, para. 3), commenting on disagreements in psychology in general coined a term that is fitting in describing this debate. He calls it the "toothbrush problem" and noted that: "Psychologists treat other people's theories like toothbrushes – no self-respecting person wants to use anyone else's".

Day, 2007). Regarding neural research in consciousness, the exact nature of the NCC has been a point of contention for some time, and the ten proposals reviewed in Chalmers (2010) often conflict in their claims. Regarding methodology, there is also a strong debate about the value of introspective data (e.g. Hurlburt & Schwitzgebel, 2007), which some claim to be the most direct access to consciousness, while others claim reports of this nature are too unreliable to trust. While a thorough treatment of these and other debates is beyond the scope of this thesis, these examples are noted in order to show the wide-ranging scale of the disagreement.

Of considerable interest to this thesis is the debate about the graded or dichotomous form of consciousness. This question has been contested in a series of studies in visual perception (Nieuwenhuis & De Kleijn, 2011; Overgaard et al., 2006; Ramsøy & Overgaard, 2004; Sergent et al., 2005; Sergent & Dehaene, 2004). As will be demonstrated, this debate has ties to many of the leading debates in the area. Regarding methodology, there is disagreement about which awareness scales are most valid and reliable, and there is similar disagreement in other areas of consciousness studies. The debate also has implications for the search for the NCC, as the current search for consciousness predominantly follows the contrastive analysis approach of seeking two states (conscious and unconscious), but could require elaboration if degraded conscious states could be verified to exist.

As the next section reveals, the debates in consciousness have occurred in parallel with general disagreement and confusion about the conceptual and empirical tools of the field – in particular, about the definition and measurement of consciousness.

Foundational Issues: Defining and Measuring Consciousness

It is common practice for a thesis of this kind to include a clarification of terms at the outset. This is particularly challenging in consciousness studies. Sutherland (1996, p. 90) went as far as to say that: "The term 'consciousness' is impossible to define except in terms that are unintelligible without a grasp of what consciousness means … Nothing worth reading has been written about it". It is common for investigators in the area of consciousness studies to concede that defining consciousness poses a foundational challenge for the field. Fortunately, not all assessments of this issue are as bleak as the one offered by Sutherland. This section will review the variations in the meanings assigned to consciousness, and will show that the sense of consciousness involved in the current debate is the *visual contents of consciousness*. The measurement of conscious contents is considered and it is argued that *subjective behavioural report* is at present the most suitable way to assess this type of consciousness.

Meanings Attributed to "Consciousness"

A major reason for the difficulty in defining consciousness is the heterogeneous nature of the concept. The burgeoning literature on consciousness is characterised by various definitions and interpretations of the term "consciousness". More than 30 years ago, Natsoulas (1978) reviewed seven common-sense interpretations that appeared in the 1933 Oxford English Dictionary, and more recently Vimal (2009) has identified 40 different meanings attributed to the term, while pointing out that the list is not exhaustive. The multiple concepts in use prompted Block (1995, p. 227) to call consciousness a "mongrel concept".

Confusion arises when two or more of these distinct concepts of consciousness are used interchangeably in a specific line of argument (Block, 1995; Rosenthal, 2009). For this reason Nunn (2009) underlines the importance of being specific about the way in which the term is used and the context in which it is applied. This section is dedicated to emphasising the kind of consciousness that is being addressed in the debate on the form of visual consciousness. In order to do this two main types of definition will be considered below. Firstly, certain descriptions define consciousness in terms of to what the concept is applied (e.g. a species, a creature or a mental state). Secondly, there are those characterisations that use the properties of consciousness (experiential or functional properties) in defining the concept.

Consciousness level and conscious contents. One starting point for the definition of consciousness is to consider to what the term can sensibly be applied. Here we can distinguish between species, creatures and mental states that may or may not be conscious. Philosophical distinctions of this type are offered by, for example, Kriegel (2007) and Rosenthal (2009). At the broadest level of investigation we can ask whether a particular biological species is conscious. We can refer to this as *species consciousness*. Secondly, we can attribute consciousness to a particular creature if it is awake and responsive to external stimuli – a state that we can call *creature consciousness*. Finally, we can apply the term "consciousness" to mental states, in the sense that certain mental states are conscious while others are not. This final sense is referred to as *state consciousness*.[2]

The cognitive sciences employ a comparable distinction between a background *level of consciousness* and specific *conscious contents* (Hohwy, 2009; Overgaard & Overgaard, 2010; Seth, 2009). A creature has at any time a specific background *level of consciousness*: In humans this can range from complete unconsciousness (death, coma, general anaesthesia) to being fully awake and alert. The *content of consciousness* refers to changing conscious mental content such as perceptions, thoughts, memories and explicit beliefs that is present in conscious creatures.

[2] Relations appear to exist between the different concepts of consciousness described thus far so that we may analyse the different types of consciousness with reference to one another (e.g. Kriegel, 2007). A species is considered species conscious if a prototypical specimen of the species (a creature) is capable of having a non-zero level of consciousness. A level of consciousness is in turn only assigned to a creature if it is capable of having conscious contents. This argument leads us to assign primacy to conscious content as the most fundamental of all the notions of consciousness described thus far. It is also the focus of the debate on the form of visual consciousness.

Confusingly, similar concepts are referred to by different names in philosophy and cognitive science investigations. As Hohwy (2009) explains, the cognitive science concept of consciousness level is similar to Rosenthal's (2009) philosophical concept of creature consciousness. Furthermore, the idea of conscious content is conceptually similar to Rosenthal's (2009) concept of state consciousness. For clarity and consistency, the terms from the cognitive- and neurosciences are preferred here, given the focus of this thesis. In the rest of this thesis, *level of consciousness* is preferred over creature consciousness and *content of consciousness* is preferred over state consciousness.

In the central debate of this thesis, it is clear that the disagreement is not whether different forms of the background level of consciousness exist. There is little disagreement that conditions such as sleep, coma, the vegetative state and minimally conscious states constitute qualitatively different awareness states from normal waking consciousness (Overgaard & Overgaard, 2010). Instead, the debate is whether degradation of visual conscious contents occurs or not. The studies reviewed in Chapter 2 disrupt the visual awareness of participants while they look at a visual stimulus, with the aim of deciding whether the disruption eliminates (as expected from a dichotomous account) or degrades (as expected from a graded account) consciousness.

Functional and experiential aspects of consciousness. The contents of consciousness are often said to have two distinct classes of properties – functional and experiential – that pose two distinct challenges to investigations in the area. In this section popular proposals are reviewed that argue that the functional aspects of consciousness are all the current science of consciousness can study. Two useful frameworks in this regard are Chalmers' (1995) distinction between the easy and hard problems of consciousness, and the access and phenomenal consciousness description provided by Block (1995).

Chalmers (1995) distinguishes between two classes of problems of consciousness, labelling one the easy problem and the other the hard problem. The easy problems of consciousness are those problems that relate to the *functional* aspects of consciousness, such as the ability consciousness bestows on a creature to discriminate between, categorise and act on environmental stimuli, the accessibility and reportability of mental states, the control of behaviour and the focus of attention. Chalmers (1995) argues that the easy problems are amenable to the current methods of cognitive science, and that a standard reductive explanation in terms of computation or neural mechanisms will suffice to solve these types of problems. The hard problem of consciousness asks why we *experience* something when cognitive functions are conscious. This aspect of consciousness does not yield to the standard methods we typically employ, and Chalmers (1995) claims that the explanation is unlikely to be in terms of functional (computational or neural) mechanisms. The phenomenal and subjective nature of this class of problems points to an explanatory gap in our current methods and theories when we try to grasp a solution to the problem.

Another famous attempt at conceptual clarity in consciousness studies is introduced by Block (1995), who proposes a difference between access and phenomenal consciousness. Access consciousness (A-consciousness) refers to the ability to act on and report experiences. More formally, A-consciousness refers to a representation in a person's mind that can be used in reasoning and the rational control of action and speech. Phenomenal consciousness (P-consciousness) on the other hand refers to the subjective and qualitative nature of experience. There is a phenomenal feel to the experience of seeing, tasting or sensing in some other way. Whereas A-consciousness has representational content and a *functional* character, P-consciousness has phenomenal content and is not a functional notion but rather an *experiential* notion. The links between the categorisations by Chalmers (1995) and Block (1995) are evident. The easy problem of consciousness is *functional*, and relates to access consciousness. Chalmers' (1995) hard problem seems to be a match for Block's (1995) phenomenal consciousness with its *experiential* properties.

The experiential properties of consciousness highlighted by Chalmers' (1995) hard problem and Block's (1995) notion of phenomenal consciousness resonate together as a key element in the definitions of consciousness given by other authors in the area. Indeed, in reviewing common usages of the term Bogen (2007, p. 776) argues that the subjective, qualitative, phenomenal aspects of consciousness form a "central core" of the many "semi-synonyms" of usages. This aspect of consciousness also follows Nagel's (1974) famous argument that there is something "it is like" to be a conscious organism. Gallagher (2010) starts the process of defining consciousness with a phenomenological description of consciousness and identifies phenomenality as one of three key features of consciousness. Similarly, Velmans (2009, p. 8) uses a strategy of defining consciousness in an ostensive way and also arrives at a definition that favours the phenomenal and experiential aspects of the concept:

> A person, or other entity, is conscious if they experience something; conversely, if a person or entity experiences nothing they are not conscious. Elaborating slightly, we can say that when consciousness is present, phenomenal content (consciousness of something) is present. Conversely, when phenomenal content is absent, consciousness is absent.

While the experiential property of consciousness is arguably the defining and most interesting feature, it is also the most problematic for investigators and not amenable to study with current methods. In fact theorists such as Chalmers (1995) believe that the functional aspect of consciousness is all that the science of consciousness can hope to address in its current format. In this sense each cognitive- and neuroscience investigation into consciousness is an investigation into access consciousness. For example, varieties of workspace theories (e.g. Baars, 1989; Dehaene & Naccache, 2001) are considered to address this aspect of consciousness, and not the hard problem and its experiential properties (Rosenthal, 2009). Similar to all investigations in the area, the current debate and the focus of this thesis fall squarely in the category of easy problems of the functional aspects of consciousness.

Operational definitions of consciousness. Despite confusion about the definition of consciousness, the scientific study of consciousness has progressed mostly unabated. There exists a growing sentiment in this area that the concern with rigorously defining consciousness is premature and that the definition should follow, rather than precede, an understanding of the phenomenon (Atkinson, Thomas, & Cleeremans, 2000; Bogen, 2007; Cole, 2010). According to this view, deciding on a definition at the outset of this investigation may preclude us from discovering which of the various options has the most merit, a position that Nunn (2009, p. 7) summarises as follows: "… we should embrace the resultant diversity, say several authors, for that way lies progress". Koch (2009, p. 16) is more blunt: "Measure more, argue less" was the title of his regular article in *Scientific American Mind* magazine on this topic. This pragmatic stance on the matter had been proposed decades earlier by Natsoulas (1978).[3] Natsoulas (1978) also reasons that a comprehensive definition of consciousness is based on finding out, not on prior stipulation, and that we arrive at an understanding of consciousness through the study of the phenomenon. What we need are working definitions to get this project off the ground:

[3] Before expressing this point Natsoulas (1978, p. 907) warns us not to think that this practical manoeuvre solves all riddles posed by consciousness, but to "… realize that the factors responsible for the behaviorist revolution have not entirely disappeared; therefore, we run the risk of a sudden, narrow reorientation in the interest of a manageable methodology".

> In the meanwhile, we do make use in science, as a summary and guide to research, of that which mimics the ultimate, namely, a working definition in terms of a theory held to be the best available. Short of Utopian knowledge, all scientific definitions are of the working variety; they exist in order to be replaced with improvement in the respective theory (Natsoulas, 1978, p. 908).

In this regard there is generally agreement that the pragmatic index for consciousness is accurate behavioural report (Nunn, 2009; Seth et al., 2005). This operational criterion is already employed widely in cognitive science research. That is, if a mental state is reportable then that mental state is conscious. It is not only verbal report but any voluntary behavioural response that is used for this purpose, for example using voluntary eye-tracking movement or button pressing. According to this criterion if a mental state is not reportable, that mental state is unconscious.

More formally, McGovern and Baars (2007) describe a mental process as *conscious* if (a) it is claimed to be conscious, and (b) can be reported and acted upon (c) with verifiable accuracy (d) under optimal reporting conditions. In contrast, a mental event is *unconscious* when (a) it is not claimed to be conscious, and (b) it cannot be voluntarily reported, operated upon or avoided; however, (c) its presence can be verified (for example, through facilitation of observable tasks) (d) under optimal reporting conditions. This operational definition bridges the definition and measurement of consciousness by stipulating conditions under which consciousness is inferred in practical terms. The following section reviews measures of conscious content and identifies why behavioural report has become a widespread criterion for consciousness, including examining the advantages and limitations of two kinds of behavioural report.

Measures of Conscious Content

Measures of consciousness have evolved to address specific aims, based on the type of consciousness being investigated. Some measures aim to assess the level of consciousness, for example the Glasgow Coma Scale (Jones, 1979), which is a clinical behavioural scale that assesses the depth of coma in patients with brain trauma. Other measures are aimed at detecting the presence and degree of the content of consciousness (e.g. whether the person saw a digit that has been shown very briefly or how clearly they saw the digits shown). As shown earlier it is the form of conscious visual content that is being debated and therefore measures that aim to measure this kind of consciousness are reviewed here.

First-person and third-person measures of conscious content. Conscious visual contents can be studied from two perspectives: first-person data about subjective experience, and third-person data about behaviour and brain processes. These methods are also sometimes classified as *reports* or *signals*. First-person data is collected by means of verbal or behavioural reports, while signals are third-person data inferred from behavioural- or brain indicators. As described by Overgaard (2009, p. 16):

> A report is an intended communication from a conscious subject. That is, it involves a subject with metacognitive insight in their own conscious content and the intended, self-controlled giving of information about this content. A signal lacks this intention and is outside the control of the subject. A signal may be any kind of information obtained from the subject that previous research has indicated can be correlated with consciousness – typically, this will be data from technological measurement techniques such as brain scanners, EEG, eye tracking, galvanic skin response, or, more rarely, the observation of uncontrolled behaviours such as reflexes.

Researchers have assigned varying weight to these classes of data, often disagreeing about which is a more robust measure of consciousness. Still, there is an emerging view that sees both types of data as valuable in the search for an understanding of consciousness (Chalmers, 2010; Gallagher & Sørensen, 2006; Overgaard, 2009). In the extant studies on the debate behavioural reports have been the dominant data used to investigate consciousness.

Objective and subjective behavioural report. Behavioural report holds a privileged status in the methodology of consciousness research. While there are currently various brain and physiological measures that expose the brain events associated with consciousness, behavioural report is the most ubiquitous index of consciousness currently in use (McGovern & Baars, 2007; Overgaard, 2009). This is true of both consciousness research in general (Seth et al., 2005) and of the form of consciousness debate in particular. For this reason the review is limited to these measures and not other objective measures such as neurophysiology. Two types of behavioural report are employed in studies of conscious perception, commonly classified as objective and subjective report.

Objective report. When employing objective report the key test for a conscious mental state is the ability to choose correctly under forced-choice conditions. For example, a person could be prompted to pick the next item in a sequence learning task, or asked to accurately identify a target number in a rapidly displayed sequence of distractors. When performance is at below-chance levels for a discrimination or classification task then the states are presumed to be unconscious (Dehaene & Changeux, 2011). The advantage of the objective criterion is that it avoids some of the difficulties of privacy inherent in subjective report (reviewed later) and as such it is more congruent with the objective aims of the scientific method. However, there are some significant drawbacks with using this approach in studying consciousness, as outlined by Dehaene and Changeux (2011). A concern is that in many cases this approach overestimates conscious perception because performance may be above chance while the person still claims to be unaware of the stimulus. These cases of implicit perception are difficult to explain when using the objective criterion alone. Another drawback is that above-chance performance can only be inferred across a sample of trials, and so it is difficult to say on a single-trial basis whether the person was conscious of a stimulus or not. For these reasons subjective measures are often employed instead of, or in addition to, objective measures.

Subjective report. Subjective report measures allow research participants to report their mental states directly. This often takes the form of a verbal report, but can also be realised through other intentional actions such as button pressing on a computer, tracking voluntary eye movements, or using a joystick to indicate the degree of consciousness (e.g. Naber, Frassle, & Einhauser, 2011). Typically in these experiments after a stimulus is displayed the participant is asked to provide a subjective report of whether, or to what degree, they saw a visual stimulus. Subjective report is widely regarded as the most important data of interest in consciousness research (Overgaard, 2009). This is because even though there are various other measures, they all rely on subjective report to establish their status as a measure of consciousness. All "signal measures" (brain measures and objective behavioural measures) are first correlated with report and then subsequently used as measures on their own. This lends particular significance to report as the most direct access we have to consciousness at the moment. As Overgaard (2009, p. 16) argues:

> Since the conscious state cannot in itself be observed from the outside, the use of a subjective report about the relevant state seems the only possible methodology. Accordingly, no other kind of response can be a more reliable indication of a given conscious state than the subjective report itself. The objective performance correlated with the subjective report, given this correlation is perfect, is thus exactly as valid a measure of consciousness as the report itself.

Subjective reports also have the advantage of being sensitive to graded consciousness when elaborated scales are used and the data they produce can be sorted on a trial-by-trial basis into conscious, unconscious and partially conscious states (Dehaene & Changeux, 2011). Subjective reports can be realised through binary response options (yes/no), or through rating scales with three or more levels (e.g. unaware, partially aware and fully aware). These elaborated rating scales are particularly popular in studies in the debate on the form of visual consciousness. Four kinds of scale measures that are currently employed in the debate are as follows:

1. *Confidence ratings:* Participants are asked to rate their confidence in having seen something or having made a correct discrimination (Dienes, 2007).
2. *Post-decision wagering (PDW):* Participants are asked to make a discrimination and then wager an amount on its outcome (Koch & Preuschoff, 2007).
3. *Perceptual Awareness Scale (PAS):* Respondents are required to rate the quality of their subjective experience directly (as opposed to expressing their confidence in their judgements). The scale is typically anchored on four points: (1) "No experience", (2) "Brief glimpse", (3) "Almost clear experience" and (4) "Clear experience", and was designed from participants' input in a briefly displayed visual identification task (Ramsøy & Overgaard, 2004).
4. *21-point visibility scale:* Sergent and Dehaene (2004) introduced a 21-point scale that requested ratings of the subjective visibility of the target visual stimuli in three experiments. The scale is anchored "not seen" on the left and "maximal visibility" on the right.

The special status of subjective, first-person data described earlier comes with several obstacles. Chalmers (2004) describes three prominent challenges in this regard. The first issue is the inherent privacy of subjective data. Despite being better than signals and objective report measures, subjective reports still provide only indirect access to the actual experience of a subject. Problematically, some experiences, such as musical experiences, are difficult to describe and our current language might not be ideal to convey them accurately. A second challenge is the comparatively rudimentary state of first-person methods as opposed to third-person methods. Some training might improve participants' characterisations of their experience, but may also corrupt the original experience with theory. The third issue is that the formalisms available to express first-person data are limited and typically take the form of qualitative description or parameterisation of data, which enables easier analysis but might not be true to the actual experience of the observer. Chalmers (2004) argues that these are simple formalisms that might not bring systematic theories within reach. Despite these challenges, Chalmers (2004) offers a defence of the general preference for subjective reports. He argues that we can use verbal reports as a guide to conscious experience, unless there are specific reasons to doubt the validity of those reports. We can distinguish between easy and hard cases for this approach. Verbal reports of simple experiences can reasonably be expected to be more robust than those of complex experiences. The idea is thus to assess the reliability of verbal report on a case-by-case basis. Subjective data should not be uncritically accepted as a direct window onto the conscious experience of a subject, but if there is no strong reason to suspect that the report is unreliable then there is considered to be sufficient grounds for believing that the subject is having the experience they describe. The pragmatic stance in the science of consciousness is evident when Chalmers (2004, p. 51) summarises the ambitions of the movement: "For now, we are not aiming for a perfect characterization of the structure of consciousness, but simply for a better characterization".

Interim Summary: Definitions and Measures

The main ideas presented in the review of the foundational issues of definition and measurement of consciousness are summarised below. In addition, the relevance of these matters to the debate addressed in this thesis is elucidated. Firstly, with the ambiguity in the usage of the term "consciousness" it is imperative that any study of consciousness should be clear about what is meant by the term to demarcate the boundaries of the investigation. The debate about the visual contents of consciousness is the primary focus of this thesis. Further, while the phenomenological aspect of conscious contents is often cited as the most interesting feature of consciousness, current measures fail to address this hard problem of consciousness (Chalmers, 1995). This debate, like consciousness studies generally, is confined to addressing the functional, easy problems of the phenomenon. A next implication is that a universally agreed upon definition may not be necessary before we proceed with the empirical study of consciousness and its contents. The working definition of consciousness as behavioural report is currently widely employed and serves as a productive starting point for scientific investigations. The importance of subjective report was reviewed, and it was argued, in line with recent opinion in the field, that it currently presents the most judicious form of measurement. Studies in this debate have used elaborated subjective rating scales to explore the issue of the form of consciousness.

Contrastive Analysis: An Obstacle to Investigating Graded Consciousness

The studies that directly address the debate of the form of consciousness have appeared fairly recently in the new science of consciousness. Studies by Ramsøy and Overgaard (2004) and Sergent and Dehaene (2004) can be regarded as the first empirical studies involved in the recent disagreement. Before this, research on consciousness, and conscious visual perception, had proceeded without directly asking the question. As the next section will argue, a prevailing methodological approach – contrastive analysis (CA) – was an obstacle to addressing the possibility of graded consciousness.

The Method of Contrastive Analysis

Baars (1989) outlined a simple approach to exploring consciousness: Compare two identical mental events, one conscious and the other unconscious, and infer the characteristics that are unique to consciousness. This simple idea advocates treating consciousness as an experimental variable with two levels: consciousness-present and consciousness-absent. McGovern and Baars (2007) note that even if there is no completely unconscious condition a low-level conscious condition (e.g. drowsiness, stimuli presented with distraction) will suffice, as long as there are two qualitatively distinct levels. The theoretical goal of these investigations is to identify what is common across all conscious as opposed to unconscious mental events.

Common Techniques for Creating Visual Consciousness Contrasts

The CA approach has been applied to a variety of domains, including memory, imagery and attention. Given the focus of this study, its application in the area of visual perception is of particular interest. In the domain of visual perception there are now various psychophysical techniques, summarised in Kim and Blake (2005) that can create contrasts between conscious and unconscious mental events required for CA. They are summarised as follows:

- *Degraded visual stimulation:* One of the simplest ways to degrade the subjective visibility of a stimulus is to present it very briefly, in the millisecond range.
- *Visual masking:* When a target stimulus is presented briefly in close spatial and temporal proximity to a mask after (*backward mask*) or before (*forward mask*) the target, the visibility of the target is typically disrupted.
- *Visual crowding:* A visible stimulus is rendered unrecognisable when surrounded by other stimuli nearby.
- *Bistable figures:* These are ambiguous figures that can be interpreted in two ways, a familiar example being the case of the Necker cube, of which the top portion can be interpreted as the near or far surface of the transparent cube.
- *Binocular rivalry:* Two competing figures, such as a house and a face, are presented simultaneously to the two eyes of an observer. Unlike the bistable

figures, which are ambiguous and use the same stimulus to induce various interpretations, binocular rivalry involves separate images competing for consciousness.

- *Motion-induced blindness:* When a small object is embedded in a larger field of flowing objects, the target object can be rendered invisible.
- *Inattentional and change blindness:* In inattentional blindness the observer misses an obvious object in their visual field while attending to a demanding task. A popular example asks participants to look at a video of people engaged in throwing a basketball and to count the number of passes (Simons & Chabris, 1999). During the video a person wearing a gorilla costume walks into the centre of the screen for a period of time, but is missed by a large proportion of the observers. In the case of change blindness two successive pictures with a blank interval are presented to observers. When there is a small change in the two pictures, the observers take many seconds to notice it.
- *Attentional blink (AB):* When observers are asked to search for two items in a rapidly presented sequence with distractors, they typically miss the second item if it is presented in close temporal proximity to the target.
- *Troxler fading:* When an observer maintains a gaze at a central object dim targets in the periphery disappear from consciousness (Bonneh et al., 2014).
- *Continuous flash suppression:* When the first eye is presented with a static visual stimulus while the other eye is presenteuncod with a series of rapidly changing stimuli the static image presented to the first eye dissapears (Tsuchiya & Koch, 2005).

Common to all of these techniques is the ability to render typically visible stimuli invisible, although they have differing strengths and weaknesses in doing so (Kim & Blake, 2005). CA has exploited the ability of these techniques (and various others) to create minimal contrasts in order to study consciousness. For example, in a masking study, participants are shown a word displayed very briefly. When the word is displayed without the mask, participants find the target clearly visible (consciousness-present condition). However, when the mask is added to the event, participants claim to be unable to state what they saw, even though all other factors were kept constant (consciousness-absent condition). This contrast allows the researcher to uncover the unique characteristics of the conscious event of seeing the word, in terms of, for example, brain states, response times, ability to use the conscious representation in a flexible way, etc.

The CA method has uncovered many interesting characteristics of consciousness using this approach, the general findings of which are summarised by McGovern and Baars (2007). Conscious processes (1) are computationally inefficient, contain many errors and are performed at low speed; (2) they have a great range of contents and are flexible; (3) they have high internal consistency at any time; (4) the clearest contents are perceptual and semi-perceptual, and (5) they are associated with voluntary actions. Unconscious processes (1) are very efficient in routine tasks, contain few errors and proceed at a high speed; (2) they have a limited range of contents and proceed at a fixed pattern; (3) the set of routine unconscious processes are diverse and can operate concurrently; (4) they are involved in all mental tasks, including perception, memory, knowledge representation and access, skill learning, etc.; and (5) they are associated with non-voluntary actions. This list of characteristics comes from a large body of evidence across many domains of consciousness – perceptual and non-perceptual. The features revealed by this process have led to the formulation of workspace theories of consciousness, notably those by Baars (1989) and Dehaene and Naccache (2001). The logic of CA is also a key strategy in the search for the NCC, where brain states associated with conscious events are compared to brain states associated with an unconscious event.

Contrastive Analysis and the Form of Consciousness Debate

The CA method has been a productive approach for studying consciousness. It has however precluded the detection of potentially degraded consciousness by comparing only two levels of consciousness. Typically the question posed to participants in experiments in visual perception has been a simple binary choice to indicate whether they were aware or unaware of the stimulus. While it is quite possible that visual consciousness indeed contains only two levels, as some in this debate have argued (e.g. Sergent & Dehaene, 2004), it is not possible to determine empirically whether this is the case using the CA approach. The recent interest in the debate stems largely from studies that use elaborated scales containing anywhere from 3 (Christensen, Ramsøy, Lund, Madsen, & Rowe, 2006) to 21 (Sergent & Dehaene, 2004) levels. It is only with these longer scales that degraded consciousness can be detected or refuted. The CA approach outlined by Baars (1989) preceded the first series of studies involved in this debate by 15 years (Ramsøy & Overgaard, 2004; Sergent & Dehaene, 2004), during which time the dominant way to probe consciousness may have impeded even the question of whether consciousness can be degraded.

Summary

In order to situate the thesis in the broader domain and clarify some of the conceptual matters involved in the debate, a number of key points were reviewed and argued. Firstly, it was noted that the debate comes at a time when there is renewed interest in the field of consciousness studies generally. Over the last few decades researchers from multiple disciplines have been attracted to study consciousness and the numerous challenges presented by the phenomenon. Further, the difficulty in defining consciousness was reviewed, and the nebulous nature of the concept was examined. It was shown that the *content of consciousness* is a fundamental notion of consciousness, and that *visual conscious contents* are the central concern of the current debate and this thesis. Regarding measurement, *subjective behavioural report* was put forward as the key method in studying conscious contents. Finally, the late emergence of the debate was argued to be partly caused by a commitment to *contrastive analysis* that calls for the comparison of consciousness at just two levels. This practice did not allow for the detection of degraded states, and it was only when elaborated subjective scales were introduced that the debate ignited.

Chapter 2

Literature Review

The literature review surveys the dichotomous and graded views of visual consciousness that are at odds in the debate, as well as a third class of proposals that attempt to integrate these opposing stances. The review begins with a summary of each view, along with its theoretical underpinnings or corroborating arguments from other areas. The dichotomous view is presented first, and it will be shown how this view is strongly influenced by the global neuronal workspace theory (GNWT) (Dehaene & Naccache, 2001). The graded view of visual consciousness does not have a similar overarching theory underpinning its predictions; however, corroborating arguments from blindsight, the phenomenology of fringe consciousness and probabilistic models of cognition are presented. Two stimulus processing level accounts are discussed next, both suggesting that dissociable levels of consciousness are responsible for the contradictory findings, but each specifying a different manner in which this occurs. Empirical studies relevant to the debate are then reviewed, along with a critical examination of methodological and conceptual shortcomings in the extant work that provide the impetus for the research of this thesis. The chapter concludes with a summary of the rationale, and the aims and hypotheses, of the research.

Dichotomous View of Visual Consciousness

Summary of the View

The dichotomous view of visual conscious perception argues that consciousness is a matter of all-or-none: a person is either completely aware or completely unaware of an object at any given time. This view opposes the suggestion that a person can be only *somewhat* aware of a visual stimulus. While not explicitly stated, this assumption is evident in prominent methodologies, such as the CA research paradigm advocated by Baars (1989), reviewed earlier and, as the subsequent review shows, this view is strongly informed by the

GNWT (Dehaene et al., 1998; Dehaene, Sergent, & Changeux, 2003; Dehaene & Changeux, 2011; Dehaene & Naccache, 2001).

Theoretical Underpinnings

Theoretically, dichotomous awareness states are predicted by models that consider interactions between distinct (and often distant) brain areas as a prerequisite for consciousness. This class of visual perception theory argues for a sharp difference in the conscious status of various stages of visual information processing. For example, Lamme and colleagues (e.g. Lamme, 2003; Lamme & Supèr, 2000; Supèr, Spekreijse, & Lamme, 2001) propose that an initial, unconscious, feed-forward sweep of information from the early visual areas (V1) to the extrastriate areas and parietal and temporal cortex precedes a secondary, conscious stage where the early visual areas and higher areas engage in recurrent processing. According to this view, this recurrent processing between distant brain areas is the hallmark of conscious visual awareness. A similar position is expounded by Lollo and Enns (2000, p. 481), who argue for re-entrant signalling amongst processing levels as the property of conscious visual brain activity:

> … processing is accomplished through iterative exchanges of neural signals among levels. An initial wave of stimulation ascends rapidly through the system, followed by descending signals between levels. Together, the ascending and descending pathways form part of an iterative-loop system, aimed at noise reduction and hypothesis verification, thereby establishing the most plausible perceptual interpretation of the incoming stimulus.

The recurrent interaction between brain areas is also a key concept in the GNWT (Dehaene et al., 1998; Dehaene, Sergent, & Changeux, 2003; Dehaene & Changeux, 2011; Dehaene & Naccache, 2001), which is reviewed in detail here as a key theoretical model used to support a dichotomous view of conscious perception.

Global neuronal workspace theory. Three theoretical assumptions underpin the GNWT. The first is a modular view of unconscious components of brain function. The model proposes that quite complex processing (e.g. face recognition) can proceed unconsciously, but only if a specialised set of interconnected modular systems is dedicated to each operation. Multiple unconscious processes can proceed in parallel as long as they do not simultaneously interact with the same module in contradicting ways.

A second foundational concept is a non-modular global workspace that links multiple distant brain areas through long-distance connections. This workspace is the common "communication protocol" (Dehaene & Naccache, 2001, p. 13) through which specialised processors can broadcast information to enter consciousness and gain access to the contents of other connected processors. If a module is not connected to the workspace (e.g. blood pressure control in the brainstem), its contents can never become conscious, despite introspective attempts. Five main categories are predicted to be connected to the workspace: (1) Perceptual circuits that provide information from the external environment, (2) Motor circuits that allow planning and execution of actions, (3) Long-term memory circuits that recall previous workspace states, (4) Evaluation circuits that bestow a valence to states in relation to previous states, and (5) Attentional/top-down circuits that selectively orient the focus of awareness. The apparent unity of diverse conscious contents, and the flexibility to engage multiple conscious processes, is proposed to be produced by the connectedness of the systems to the workspace. In this view the reportability of conscious contents is possibly due to the linkage of motor and language systems with the workspace.

The third proposition of the GNWT concerns an attentional mechanism through which information is broadcast to the workspace and thus becomes conscious. The postulate is that of a top-down attentional process that temporarily mobilises processors connected to the workspace, making their contents available to it. This implies that a similar activity in a given processor can sometimes be conscious and sometimes not. For contents to be conscious, the activity must be amplified and maintained for a sufficient duration so that other processors can gain access to it. This *dynamic mobilisation* is the difference between conscious and unconscious information processing. A further implication is that the location of the workspace fluctuates as certain processors are temporarily mobilised and demobilised. It is the style of the activation and not its location that is a feature of conscious brain activity.

Three predictions based on this model are put forward by Dehaene and Naccache (2001). Firstly, there are structural (anatomical) constraints on information that can become conscious. This view predicts that conscious information will always be represented in an active manner in the firing of one or several neuronal assemblies, and that in order for dynamic mobilisation to occur these assemblies must have bidirectional connections with the other sets of workspace neurons. The second prediction concerns temporary constraints on information that can become conscious. This is the attempt to explain the inaccessibility of information for dynamic reasons, as witnessed in, for example, masking paradigms. When a masked stimulus is presented for a short duration, it cannot be consciously perceived despite attentional effort, whereas a longer display makes the stimulus easily visible. According to the GNWT the explanation for these phenomena is a temporal granularity imposed by the time taken for the top-down attentional system to establish a link with the active processor and for a closed loop to be established. There is thus a minimum duration of activation required to create the dynamic mobilisation. As a consequence the GNWT predicts two temporal thresholds for information processing. The first is a minimum amount of stimulus display taken to cause any activity at all. The second (conscious) threshold is the longer duration taken for the stimulus display to reach consciousness. Stimuli presented between these two durations cause neural activation, but only unconsciously. The information can still propagate through multiple circuits (subliminally) but cannot reach consciousness.

The final implication of the GNWT considers the neural correlates of consciousness (NCC). The GNWT posits multiple processors that contribute various contents to consciousness, and that all share the same mechanism. Dehaene and Naccache (2001) subsequently distinguish between two broad types of brain-imaging studies based on this view: studies of the contents of consciousness and studies of the mechanism of consciousness. The location of the contents of consciousness is described as varied and distributed due to the involvement of numerous processors in the workspace. There is evidence of tight correlations between specific conscious contents and particular brain areas such as the fusiform face area, or fusiform gyrus, that appears active whenever participants report perception of a face (Kanwisher, McDermott, & Chun, 1997). The neural substrates of the mechanism of consciousness (dynamic mobilisation) are hypothesised to be related to two areas in particular: the prefrontal cortex (PFC) and the anterior cingulate (AC). The justification for this attribution stems from imaging studies that link the PFC and AC to tasks that would seem to require consciousness (Dehaene & Naccache, 2001).

According to the GNWT there are three levels of conscious accessibility. Some information in the nervous system is permanently inaccessible to consciousness (set I1), and some information is connected to the workspace and can be conscious if attended to (set I2). Only a subset of the second set is conscious at any given time (I3). Dehaene and Naccache (2001) speculate that the access- and phenomenal consciousness distinction proposed by Block (1995) is potentially related to the large set of information that can be accessed in the form of I2, as opposed to the limited contents that are found in I3.

The GNWT has also been employed to propose a taxonomy of types of information processing relative to consciousness (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006). Three types of processing are distinguished, based on signal strength (bottom-up activation) and attention (top-down processing):

1. *Subliminal* processing occurs when the signal strength is insufficient to cause the dynamic mobilisation needed for consciousness. This type of signal does not reach the "consciousness threshold" as defined earlier. Two subtypes of subliminal processing are proposed, based on the presence or absence of top-down attention. When attention is absent there is very little brain activation, and this quickly dissipates after onset, along with little or no priming and no reportability. When attention is directed at the below-threshold signal the GNWT predicts strong feed-forward activation, short-lived priming and no reportability.
2. *Preconscious* processing is a state where the signal is sufficiently strong, but top-down activation (attention) is not directed at the stimulus and is thus not conscious. Preconscious information can become conscious if attended to. This state is proposed to be characterised by intense activation, but is confined to the sensori-motor processors, with multiple levels of priming but no signal reportability while unattended.
3. Fully *conscious* processing occurs when signal strength is sufficient (beyond the conscious threshold) and attention is oriented towards the signal. The sensori-motor activation is now amplified and spreads to the parieto-frontal network with long-distance loops and global synchrony. Accurate verbal report on the state is only possible in the fully conscious mode.

GNWT predictions for the form of consciousness debate. The GNWT predicts that the transmission of information to consciousness happens in a sudden, non-linear manner. A continuum of subliminal and preconscious states is proposed to exist, but there is a sharp transition from preconscious to conscious, predicted by the characterisation of consciousness as a self-amplified non-linear system (Dehaene et al., 2006). More specifically, the GNWT predicts that when a control parameter is decreased (e.g. duration or intensity of stimulus exposure) there is an initial gradual decrease in consciousness of a stimulus, but a threshold value occurs where there is a discontinuous jump to a lower level of activation (complete loss of conscious perception) (Sergent & Dehaene, 2004). The threshold value for this transition exhibits a range of values where high (conscious) and low (unconscious) levels of activation coexist. Figure 1 depicts this prediction and shows the s-shaped sigmoidal curve that the GNWT posits as being characteristic of conscious perception[4].

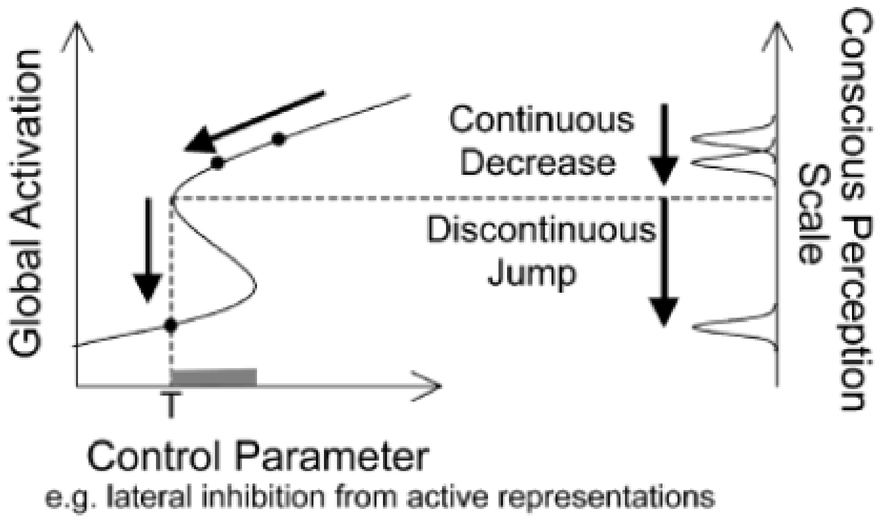

Figure 1. The GNWT prediction of a non-linear transition from unconscious to conscious processing (Sergent & Dehaene, 2004, p. 721).

Graded View of Visual Consciousness

Summary of the View

Arguments supporting a graded view of conscious perception propose that conscious perception can be present in varying degrees. Early evidence suggesting that conscious perception might not be dichotomous is reported by Sidis (1898), who presented participants with letters or digits on small cardboard cards at various distances. Research participants' reports did not conform to a dichotomy, but the participants sometimes claimed to have *some*

[4] It should be noted that while Sergent and Dehaene (2004) strongly link GWNT to a dichotomous view of consciousness, this association is not a necessary feature of this theory. It is possible to make a graded view of consciousness compatible with this theory, without detracting from its other major features.

sort of experience of the target. More recently, others have endorsed the existence of the diluted forms of consciousness observed by Sidis (1898) more than 100 years ago.

Theoretical Underpinnings

Traditionally, studies supporting a graded view of consciousness do not typically cite a substantive overarching theory that competes with the GNWT. This situation has recently changed with the development of the REF CON (reorganization of elementary functions and consciousness) by Overgaard and Mogensen (2014). This model, derived from research in blindsight and subliminal perception proposes consciousness operates as the top level of functions organised at several different levels of analysis, ranging from localised perceptual functions to higher algorithmic levels. A graded view of consciousness is an intrinsic part of this theory. Further corroborating arguments are reviewed from the phenomenology of fringe consciousness, the phenomenon of blindsight and the probabilistic models of cognition.

Fringe consciousness. In a phenomenological analysis Mangan (2001) defends the significance of “peripheral” (or “fringe”) conscious experiences. He observes that when the contents of consciousness are considered, vivid focal sensory experiences are often emphasised, such as “the blare of a trumpet, a twinge of back pain, the saturated red of a ripe tomato” (Mangan, 2001, p. 2). He contends that peripheral conscious experiences constitute a fundamental (but neglected) category of consciousness. Mangan (2001) distinguishes between two types of peripheral conscious experience: peripheral non-sensory experiences (such as the *feeling of knowing* and the *tip-of-tongue* phenomenon), and peripheral-sensory experiences. It is the existence of the latter that is of concern in the present debate. These peripheral-sensory experiences are often depicted as the context information of vivid experience, but according to Ramsøy and Overgaard (2004) they may also describe the experience of stimuli presented at the subjective awareness threshold.

Blindsight as degraded vision. Indications of degraded perceptual experience have been observed in patients with blindsight. These patients, suffering from a lesion of the V1 (primary visual cortex), report not being able to see anything in a portion of their visual field, but they can guess at above-chance levels if prompted for various stimulus attributes presented in that field (Weiskrantz, 1996). This finding has been considered an example of unconscious vision, and is one of the most famous conditions in the study of consciousness. However, the interpretation that the vision occurs without consciousness has been disputed by studies that show residual awareness in these patients. For example, Zeki and Ffytche (1998, p. 29) present a study on a blindsight patient referred to as G.Y., who, instead of being completely unaware of a visual stimulus, would report something resembling a “shadow” and a “feeling of something happening”. Zeki and Ffytche (1998) further summarise nine other studies on blindsight conducted between 1974 and 1992 that also reveal evidence of weak (but non-zero) conscious experiences. A recent review (Overgaard, 2011), and later studies by Overgaard, Fehl, Mouridsen, Bergholt, and Cleeremans (2008) and Stoerig and Barth (2001), further support the idea that blindsight is, at least in some cases, degraded conscious (and not unconscious) vision. These findings seem to suggest that conscious perception is not necessarily all-or-none. If degraded states of perception are evident in blindsight, they are at least a possible feature of normal perception.

Probabilistic models of cognition. The graded view of consciousness also bears similarities to the assumptions of recently popular probabilistic models of cognition. These models propose that mental representations are graded probabilities that can take on any value from 0 to 1 (Chater, Tenenbaum, & Yuille, 2006). This line of thinking has been applied to areas such as knowledge (Vul & Pashler, 2008), object perception (Kersten & Yuille, 2003) and attention (Vul, Hanus, & Kanwisher, 2009), and forms the basis for Lau’s (2008) theory of conscious perception. The findings generated by the probabilistic approach to cognition would seem to imply that at least in some instances cognition is graded, even though some (Vul et al., 2009) have argued that consciousness samples discrete outputs from the underlying graded representations. It should be noted that Vul et al. (2009) base their proposal of discrete consciousness on findings from a single paper in this debate (Sergent & Dehaene, 2004). The alternative view is that graded representations lead to graded conscious states, and are thus not ruled out by their proposal.

Dissociable Levels of Consciousness

This section reviews proposals suggesting that a reliance on might have unjustifiably constrained the forms of consciousness that can be observed. Instead of formulating consciousness as consisting of a single level, which may be dichotomous or degraded, several recent proposals suggest the existence of multiple dissociable levels of consciousness. In so doing these proposals try to integrate the contradictory evidence into a consistent, new framework.

In order to understand these recent hypotheses, it is worth considering the things that are typically used as targets in the experiments in the debate. The stimuli used in typical tests for dichotomous or graded visual consciousness vary from simple objects (e.g. letters and digits) to complex, multi-featured objects (e.g. words) that consist of multiple levels of detail. For example, words consist of at least the following (seemingly hierarchically organised) levels: features, letters or phonemes, and whole words (Kouider & Dupoux, 2004). In a typical experimental setup participants are asked to provide a single rating of their level of consciousness of the stimuli or object. This seems least problematic for simple stimuli such as single letters or numbers, but when participants are asked to rate their awareness of a complex stimulus such as a word (Nieuwenhuis & De Kleijn, 2011; Sergent & Dehaene, 2004), things become less clear. It would seem possible that different levels of complex stimuli could be accessed independently, so that, for example, a person is conscious of certain letters but not the whole word. More generally, Kanwisher (2001, p. 97) explains this intuition as follows:

> There are as many ways to be aware of a stimulus as there are kinds of information to register about that stimulus. Thus, perceptual awareness might involve any aspect of the stimulus, from its simple presence (as opposed to absence), to the presence or nature of one or more of its perceptual attributes, to the category of object present in the image, to a fine-grained recognition of a particular exemplar of that category, to the 'gist' of a complex scene.

The idea that consciousness is not a unitary phenomenon is captured in the micro-consciousness theory of Zeki (2003). Zeki distinguishes between three hierarchical, but dissociable, levels of consciousness in visual perception. The first level is *micro-consciousness* of primitive visual attributes (e.g. colour, position or motion) that can be accessed independently of each other. The second level is *macro-consciousness*, which is the perception of a compound stimulus or object consisting of multiple primitive attributes. Finally, these two types of consciousness lead to the *unified consciousness* of a person as perceiver that consists of multiple macro-consciousness features. The debate on the form of visual consciousness has recently seen two proposals that utilise the dissociable levels of consciousness to integrate the opposing views presented earlier. These two proposals claim that consciousness can be graded or dichotomous, depending on the level of consciousness being addressed.

Partial Awareness Hypothesis

The first formulation that allows for multiple levels of consciousness is the partial awareness hypothesis (Kouider et al., 2010). According to the developers of this account, graded reports for overall consciousness of complex stimuli could be the result of all-or-none consciousness of a limited number of lower levels of representation (Kouider et al., 2010).

For example, when viewing a coloured word being briefly flashed, the participant might claim to have a degraded conscious experience of the coloured word at an overall level. This account would explain the degraded overall state by claiming that the person was fully conscious of the colour and fully unconscious of the word (or conscious of the word, not the colour). These lower levels were thus consciously accessed in a dichotomous fashion, resulting in the degraded overall state. This model retains the all-or-none view of the GNWT at the lower level of consciousness, but allows for degradation to occur at higher levels due to incomplete access at the lower levels.

Processing Hierarchy Hypothesis

Another proposal that relies on a level of processing view is the processing hierarchy hypothesis suggested by Windey et al. (2013). This account predicts that stimuli at a lower level (e.g. colour perception) in the processing hierarchy will produce a graded experience, while those at a higher hierarchical level (e.g. words and semantic content) will exhibit a more dichotomous character. This account is different from the partial awareness hypothesis in that the lower level features are now proposed to have a graded character, while certain cases of higher level features, such as words, are proposed to elicit a dichotomous form of consciousness.

Implications of Dissociable Levels of Consciousness

A framework that allows for multiple levels of consciousness opens up interesting new possibilities in studying the form of visual consciousness. It also exposes challenges to the current methodology of using predominantly one-dimensional stimuli and probing only for overall awareness levels. Consider, for example, what a graded overall stimulus rating of a multi-featured object implies about the subjective experience of the observer. Is the whole object experienced as a degraded “gestalt” with all attributes equally faint in the subject’s awareness, or are certain features fully visible while others are wholly imperceptible? Overall stimulus ratings are not able to answer this question. In addition, the world rarely presents a visual system with one-dimensional objects, so studying multi-featured objects appears a better approximation of what occurs in natural perception.

Despite its intuitive allure this line of thinking introduces further complexity to the debate. This becomes evident when the implications of these accounts are further developed. Kouider et al. (2010) suggest that graded overall consciousness could be achieved through all-or-none access at lower levels of consciousness. So when a person reports graded access to a multi-dimensional object, such as a face, they could be accessing only some of the features of the face, in an all-or-none way. However, there are various other possible combinations of attribute level consciousness (Zeki's (2003) micro-consciousness level) and overall stimulus ratings (Zeki's (2003) macro-consciousness level). It is worth laying out some qualitatively different cases for consideration, as in Table 1.

Table 1

Different Combinations of Dichotomous and Degraded States at Feature and Overall Levels for Multi-Dimensional Stimuli

Type	Type of consciousness at feature levels	Type of consciousness at overall stimulus level
1	Dichotomous	Dichotomous
2	Degraded	Dichotomous
3	Dichotomous	Degraded
4	Degraded	Degraded

Four different awareness states are distinguished in Table 1. There are numerous possibilities concealed in these categories, because extreme degraded states can take on an infinite number of values. Further, there are numerous possible lower level features that could make up complex objects. Still, these categories are instructive as a basis for testing alternative hypotheses. *Type 1* states are all-or-none at all levels, with no intermediate awareness states. *Type 2* states can take on intermediate values only on the feature level, but the overall awareness states are all-or-none. This resembles most closely the account of Windey et al. (2013). *Type 3* states contain all-or-none feature level states, but degraded overall awareness ratings, which corresponds to the prediction by Kouider et al. (2010). *Type 4* states contain degraded consciousness at the feature and overall levels. As becomes clear from this table, the ratings found for overall stimulus awareness could result from a variety of feature-level awareness states. Research in the area has not fully addressed the possibilities implied by this elaborated view of levels of consciousness.

Empirical Results

Behavioural Findings

The preceding accounts of the nature of visual consciousness have been put to the test in various behavioural studies, summarised in Table A.1 in the Appendix.[5] All studies were conducted in the domain of visual perception, largely amongst healthy adult participants, though one study (Del Cul, Dehaene, & Leboyer, 2006) included a group of schizophrenic patients. Five of the experiments reported results that supported a dichotomous view of consciousness, nine reported graded results and four produced ambiguous results.

The studies have involved psychophysical experiments that manipulate the consciousness of participants while they view visual targets. These studies have

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[5] A note about the inclusion of a study with a problematic design (Study 2) is warranted. This study seems unable to test for graded consciousness because of the limited number of control parameter levels. In this case, the stimulus onset asynchronicity (SOA) between the two targets was varied at only two levels. This imposes a dichotomy on the subjective rating data, which may have disappeared if intermediate SOA levels were included. Even though the primary objective of this study was to examine the temporal dynamics of neural events underlying consciousness, and not to test for dichotomous or graded consciousness as such, the study is cited in later work as evidence of dichotomous consciousness (e.g. Del Cul, Deheane, & Leboyer, 2006) and is thus included in Table A.1.

predominantly used two degradation paradigms: the attentional blink (AB), and masking, a study by Naber et al., (2011) being an exception as it used perceptual rivalry. The AB is a phenomenon, first described by Broadbent and Broadbent (1987), that is observed when participants are required to search for two visual targets in a rapidly presented sequence of items. When the first and second targets are separated by 200 to 500 ms the observer is typically unable to detect the second target (Kim & Blake, 2005). For example, in Study 1 in Table A.1, Sergent and Dehaene (2004) presented participants with a series of letter strings on a computer screen, and required them to identify the two targets embedded therein. The first target was either "XOOX" or "OXXO"; the second target was one of four French number words: "DEUX", "CINQ", "SEPT" or "HUIT". After viewing the sequence, participants were asked to rate the subjective visibility of the second target (the number word) using a 21-point scale (with endpoint anchors of "not seen" and "maximal visibility"). On every trial the delay between targets (SOA, stimulus onset asynchronicity) was varied to induce the AB. When the AB effect was strongest, and visibility of the second target most markedly disrupted, the response distributions on the awareness scale showed a bimodal pattern. Instead of moving gradually from high visibility to lower levels, there was consistent use of the endpoints of the scale. This finding suggested that participants suddenly jumped from being completely unconscious to being completely conscious of the target. As such the data corroborated a dichotomous view of awareness.

Visual masking occurs when a briefly displayed visual target is preceded (forward masking) or followed (backward masking) by a second visual item (the "mask") in close spatial and temporal proximity. The result is a reduction in the visibility of the target stimulus (Enns & Lollo, 2000; Kim & Blake, 2005). For many of the masking studies an additional manipulation of stimulus visibility involves displaying the target stimulus for varying durations in the range of ~10 to 200 ms. For example, in Study 8 in Table A.1, Overgaard et al. (2006) presented participants with line drawings of different orientations as target stimuli. These targets were presented at six durations on different trials (with a range of 12 to 96 ms) before and after the target mask was displayed. The mask consisted of overlapping lines covering the area where the target was presented. First the participants were asked to identify the target, after which they made use of a 4-point scale ("no experience", "brief glimpse", "almost clear experience" and "clear experience") to indicate their subjective experience of the target. The results revealed that participants used the scale in a gradual way, with increasingly higher ratings as stimulus duration increased.

A typical experiment in the debate involves some variation of the above procedures, where participants are exposed to a target stimulus (e.g. a letter, digit, word, shape, etc.) while one or more objective parameters (e.g. duration of exposure to stimulus, masking strength, stimulus onset asynchronicity etc.) are manipulated in an attempt to induce varying degrees of consciousness. After each exposure the subject is asked to identify the target (to assess accuracy) and to rate their subjective experience (to assess consciousness) of the target.

Brain Findings and Electrophysiology

Brain imaging and electrophysiological studies relevant to the debate have delivered similarly ambiguous results. Evidence for sudden, dichotomous, all-or-none brain events associated with consciousness are reported in some studies (Bowman, Craston, Chennu, & Wyble, 2007; Del Cul, Baillet, & Dehaene, 2007; Sekar, Findley, & Llinás, 2011; Sergent et al., 2005). For example, in the masking study by Del Cul et al. (2007), high-density event-related potential (ERP) recordings revealed a P3 ERP component with a sharp non-linear increase in activation that correlated with the subjective report data. Thus, there appeared to be a threshold value where a sudden increase in conscious brain activation occurred around SOAs of 33 to 66 ms. However, other imaging studies have suggested a gradual increase in brain activity associated with increased conscious recognition of an object (Bar et al., 2001; Christensen et al., 2006; Grill-Spector, Kushnir, Hendler, & Malach, 2000; Moutoussis & Zeki, 2002). In the masking study by Bar et al. (2001), the cortical activity increased gradually as subjective awareness of the masked object increased.

Critical Analysis of Empirical Work

A critical examination of the conflicting literature in the debate reveals methodological and conceptual shortcomings in previous work that has made the findings difficult to interpret and compare. These matters are reviewed here, with the aim of informing the experimental work of this thesis.

Methodological Shortcomings and Untested Proposals

The studies summarised in Table A.1 reveal a pattern of results that appear to be method-dependent. Indeed, the studies that have supported the degraded account appear to have consistently used a set of methods that is different from those employed by the opposing dichotomous account. For that reason there have been several proposals that suggest these methodological differences have influenced results.

A first such observation is that the two dominant paradigms in these studies tend to deliver opposing results: findings from AB studies generally support a dichotomous view (Nieuwenhuis & De Kleijn, 2011; Sergent et al., 2005; Sergent & Deheane, 2004), while results from masking experiments mostly endorse a graded view of conscious perception (Overgaard et al., 2006; Ramsøy & Overgaard, 2004; Sandberg, Martin, Timmermans, Cleeremans, & Overgaard, 2011; Sandberg, Timmermans, Overgaard, & Cleeremans, 2010; Sergent & Dehaene, 2004). The method-dependent results seem to suggest that different mechanisms were at work in the two phenomena. The Dehaene et al. (2006) taxonomy of cognitive processing states reviewed earlier is based on bottom-up stimulus strength and the presence or absence of top-down attention. According to this classification the AB allows for *preconscious* processing, a state where the bottom-up stimulus signals can be sufficiently strong but where top-down activation (attention) is degraded. Masking on the other hand corresponds to *subliminal* presentation, because even if attention is fully present the bottom-up stimulus signal can be degraded below the subjective awareness threshold. Whatever the explanation for these results, the findings suggest that different forms of consciousness are elicited by these different visual phenomena.

Other methodological concerns have been expressed around the use of words as targets. Studies that use words as targets have been criticised for biasing results towards a dichotomous view, because even if the target was not completely seen our cognitive systems have been shown to exhibit “interactive activation”, where the perception of a few letters can lead to full word recognition (Nieuwenhuis & De Kleijn, 2011, p. 365). Indeed, in two identical AB experiments Nieuwenhuis and De Kleijn (2011) found dichotomous ratings for words and gradual ratings for characters.

The choice of a 21-point scale used in the studies by Dehaene and colleagues has been criticised (Nieuwenhuis & De Kleijn, 2011; Overgaard et al., 2006) in relation to the concern that people are unlikely to be able to report the fine subjective gradations presented by a 21-point scale. A corresponding concern is that only the endpoints of the scale were anchored with descriptions. Both these facts could have led to bias towards the endpoints of the scale (and thus to dichotomous ratings), because they are the only values that hold sufficient meaning for participants. Recently, some researchers have also suggested that the 4-point PAS scale might cause a bias to finding degraded conscious states because participants may feel compelled to use all four categories when these are available (Windey et al., 2014).

Just a few studies have directly investigated the propositions put forth in support of the processing levels of consciousness view described earlier. An early study by Ramsøy and Overgaard (2004) asked for different stimulus features to be reported (shape, colour and position), and found that some aspects (colour and position) were on average more easily consciously identified than others (form). This suggests the possibility that degradation could occur differentially at distinct levels. However, this was not an objective of the study and was never explicitly addressed in the paper, and so there is only tentative support for the hypothesis. Another set of studies (Windey et al., 2014) that addressed the processing hierarchy hypothesis found contradictory evidence for differences in the form of consciousness at different levels of processing. Consequently, as yet there is no conclusive evidence of whether, and through what means, consciousness may differ at various levels.

In summary the variations in extant findings have been ascribed to differences in degradation technique, stimulus type, awareness scale length and stimulus processing level. Despite the various proposals direct empirical tests of these ideas are lacking, and as such the question of whether these factors have affected results is still open to investigation.

Limitations of Stimuli Employed in Previous Studies

A next critical observation concerns the relatively small set of stimuli has been used in studies involved in the debate. Previous studies have employed words (e.g. Sergent et al., 2005), geometric shapes (e.g. Overgaard et al., 2008), alphanumeric characters (e.g. Nieuwenhuis & De Kleijn, 2011) and textured displays (e.g. Overgaard et al., 2006) as visual targets. At least one study has found that the nature of the stimulus influences the form of consciousness shown in the experiment (Nieuwenhuis & De Kleijn, 2011). It is surprising then that the set of stimuli employed in these studies has not been expanded to encompass other, real-world examples of visual objects. Human face perception is an example of a well-studied domain (e.g. Farah, Wilson, & Tanaka, 1998; Kanwisher, 2001) that could extend the representativeness of findings revealed in the debate. Notably, studies in the area of face perception unrelated to the current debate about the form of visual consciousness debate have suggested that face information (e.g. identity, gender, emotion) is perceived categorically (e.g. Beale & Keil, 1995; Campanella, Chrysochoos, & Bruyer, 2001). However, these studies have made use of different methods, including the use of binary scales, which are not optimal for studying degraded consciousness. Further, these studies have manipulated face visual detail, with limited investigations into the effect of stimulus duration, which is a more commonly manipulated parameter in the debate on consciousness. As such this area presents a productive area of study to extend the current debate. Without these kinds of experiments the debate's conclusions are limited to simple and often artificial conditions unlike those encountered by humans in natural environments.

Lack of Definition for Degraded Consciousness

The various challenges in defining consciousness have been reviewed earlier. A related obstacle to progress in the form of consciousness debate has been the lack of an explicit definition of a degraded conscious state offered by extant research. As a consequence it has been difficult to compare findings from different studies without agreement about what is being pursued. It is considered critical to this work that the definition of degraded consciousness be defensible to the same extent as conscious and unconscious states.

In this thesis a degraded conscious state will be defined in relation to the widely accepted definitions of conscious and unconscious states. Using the McGovern and Baars (2007) definition reviewed earlier as a framework, derived criteria are put forward for a degraded conscious state to guide the present research. This derived definition considers a mental state to be degraded consciousness if (a) it is claimed to be degraded awareness, (b) it can be reported, (c) its presence can be verified as distinct from both unconscious and conscious states, (d) and (a) to (c) occur under optimal reporting conditions. Typical definitions of consciousness simply employ the first criterion, arguing that conscious states are reported as such. Thus, criterion (a) and (b) do not yet improve on current implicit definitions. The third criterion states that this type of conscious state should be verified as being unique by something other than the person's report. In this way making a more specific and rigorous claim about what a degraded state is. A comparison of the three states – conscious, unconscious and degraded consciousness – is presented in Table 2.

Table 2

Criteria for Conscious, Unconscious and Degraded Consciousness States

	Conscious (McGovern & Baars, 2007)	Unconscious (McGovern & Baars, 2007)	Degraded consciousness (derived)
(a) Claim	Claimed to be conscious	Not claimed to be conscious	Claimed to be degraded consciousness
(b) Possibility of being reported	Can be reported	Cannot be voluntarily reported, operated upon or avoided	Can be reported
(c) Verification	With verifiable accuracy	Their presence can be verified	Their presence can be verified as distinct from both unconscious and conscious states
(d) Reporting conditions	Under optimal reporting conditions	Even under optimal reporting conditions	Under optimal reporting conditions

This derived set of criteria constrains the type of evidence considered necessary for degraded consciousness, and disqualifies some of the ways of detecting degraded consciousness currently in use, as illustrated in the next section.

Problematic Interpretations of Degradation

It appears that degraded consciousness is understood in two ways in the literature. In one view (Koch & Preuschoff, 2007; Sandberg et al., 2011) graded consciousness is inferred through mean ratings plotted on psychophysical curves that compare average consciousness (e.g. ratings on a subjective scale) with an objective parameter (e.g. stimulus duration). However, using across-subject mean scores does not specify the nature of the curves for an individual or a specific trial (Estes, 1956; Nieuwenhuis & De Kleijn, 2011; Vul et al., 2009), and participants could produce intermediate mean ratings by using an awareness scale in a completely binary manner, implying all-or-none consciousness on any given trial but graded consciousness across trials. This definition of degraded awareness across trials appears to be an awkward measure for the issue at hand, which is whether degraded states of perceptual awareness exist for a given individual at a single point in time. It is argued here that what is at stake is the within-trial gradation, which is the nature of the consciousness on any single trial. Referring back to the criteria for degraded states developed in the previous section it is clear that the psychophysical curve method does not fulfil the requirement for criterion (a), because averaged data does not conclusively show individual reports of degraded states. As such, in the analysis of the experiments described in this thesis the focus is on detecting the within-trial degradation. For this reason the percentage of reported degraded states is preferred rather than the mean awareness ratings as the relevant dependent measure in many of the experiments. In cases where the analyses compared mean ratings (e.g. analysis of variance techniques), the existence of degradation on a within-trial level was confirmed before applying the technique.

Existence, Degree and Generality of Degradation

Debates around discreteness and continuity[6] of mental processes have occurred elsewhere in cognitive psychology. Miller (1988) showed how narrowly defining the issue of discreteness and continuity in these debates is an oversimplification that leads to problems in resolving matters. He raises three points about previous debates that are highly applicable as criticisms in the current arguments around consciousness (Miller, 1988). Firstly, Miller (1988) observes that in cognitive psychology, unlike mathematics and statistics, it is not possible to clearly classify variables as being either fully discrete or fully continuous. Rather,

[6] Up to this point the predominant terms used have been “dichotomous” and “graded”. Miller’s (1988) terms are used here to make a point about the nature of cognitive variables. The usage of terms is fixed in the next section.

there are various intermediate possibilities, which can be classified by the "grain size" dimension, which is the minimum unit of change (Miller, 1988, p. 195). The smaller the grain size the more continuous a variable is; the larger the grain size the more discrete it is. For ordered variables at the discrete extreme, the grain size could correspond to the entire range of variation, making the variable binary. At the continuous extreme a variable could have a minimum unit of zero. A complication is that grain size might not be consistent across the range, so the same variable might be considered discrete and continuous at different stages of the range (e.g. variables with thresholds). Further, Miller (1988) argues that there are at least three different senses (representation, transformation and transmission) in which continuity and discreteness could apply to information processing. A given cognitive process could thus be made up of relatively discrete and continuous aspects at various levels. Finally, many models of cognition, and several of the proposals reviewed here, are made up of multiple stages of processing. These stages may be more or less discrete or continuous, making a simple classification of the process as one or the other very difficult. This analysis reveals the complexity of debates on discreteness and continuity in cognition, and implies that aside from extreme cases the dichotomous classification of some level of cognition as discrete or continuous is likely to be an oversimplification. A result of the preceding argument is that three separate, but related, questions appear to characterise the debate. They are whether degraded awareness states exist at all, and if so to what degree and in which instances:

- *Question of existence:* The first question is whether degraded states exist at all. As per Miller's (1988) analysis this is the narrowest framing of the debate. The relevance of questions about degree and generality are premised on a confirmatory answer to this most basic question in the argument. Finding robust evidence that a degraded state exists under any condition would suffice to answer this question. Indeed, many of the studies summarised in Table A.1 suggest that degraded states are at least possible. This basic way of framing the debate's central issue is thus closest to being settled.

- *Question of degree:* The next question is to what degree degradation is present in a given scenario. As Miller (1988) argues, it is more accurate to speak of the relative discreteness or continuity of cognitive processes. For example, we could ask about the degree of degradation of aggregated subjective awareness data. A masking procedure might produce 80% claims of degraded states from 20 people when the stimulus was presented for 53 ms, but only 20% claims of degraded states when the stimulus was presented for 200 ms. We could interpret this to be a case where 200 ms produced "dichotomous" awareness and 53 ms produced "graded" awareness, but we are left with 20% of the data that disagrees with the general conclusion in each instance. More accurately, we could state that the 200 ms display duration produced relatively fewer degraded states. Similarly, the relative degree of degradation could differ in magnitude across participants or across experimental conditions.
- *Question of generality:* The third question is how prevalent degraded awareness states are. The generality of degradation is a further component of the debate. In his analysis, Miller (1988) focuses on the generality of degradation introduced by different stages of processing, and this aligns with the speculations developed by levels of processing accounts (Kouider et al., 2010; Windey et al., 2013). We could also ask about the differential manifestations of the form of consciousness in different experimental conditions. Indeed, as this review has shown, some research techniques and stimuli appear to be more conducive than others to eliciting degraded states. The general variation in findings due to stimulus, degradation technique and awareness scale (reviewed in Table A.1 and an earlier section) casts

doubt on the view of consciousness as consistently graded or dichotomous. Aside from controlled experimental conditions it is also an open question of how prevalent degraded awareness states are in everyday situations. As Kim and Blake (2005) argue, the various techniques used in psychophysical lab experiments on visual perception do not always match what happens in natural conditions. To the best of my knowledge there has been no investigation into how visual consciousness is disrupted in natural conditions, by for example fast moving natural objects and interference of attention in everyday scenarios, and as a result of habituation in routine tasks, such as driving a car.

Current work in the area has not fully acknowledged the implications of these three distinct aspects of the debate.

Summary of Terminology Employed in this Thesis

Given the introductory review that underlined the ambiguity of the term "consciousness", and the examination of the considerations offered by Miller (1988) about the terms "discrete" and "continuous", it is clear that the choice of terminology in this thesis is not a trivial consideration. As such the preferred terms employed herein are clarified.

Consciousness

In this thesis "consciousness" refers to visual consciousness, unless otherwise denoted. Less often, the terms (or some combination of) "awareness", "subjective experience" and "visual perception" are employed to have the same meaning.[7]

[7] These additional terms cannot be completely avoided at the expense of using just "consciousness", because the measures and theories of consciousness are often referred to as *awareness* scales or as *perceptual awareness* scales, *subjective visibility* scales, *partial awareness* hypothesis, etc.

Graded and Dichotomous Consciousness

The opposing positions in the debate have been referred to by various labels. The dichotomous view has also been called all-or-none, discrete or discontinuous. The graded position is also often called continuous or degraded. In this thesis the term "dichotomous" is preferred over alternatives because it specifies the exact position more clearly than other options. The term "discrete" is problematic because discreteness could still imply that more than two levels are proposed. The term "discontinuous" applies most accurately in psychophysical experiments when data are plotted on curves, but is less versatile when used in other contexts. The term "all-or-none" is used less often as a synonym. Regarding the graded position the term "continuous" is not ideal, because the data in this debate come from subjective reports on predominantly ordinal scales, making the use of the word "continuous" suspect. The term "degraded" is employed to refer to an intermediate value of gradation.

Form of Consciousness

The central debate being investigated is often referred to as the "form of consciousness" debate instead of specifying that the debate is about whether conscious visual perception is graded or dichotomous.

Rationale and Aims

Summary and Rationale

The review of the literature reveals that the debate on the form of visual consciousness is ongoing and unresolved. Results from the various studies have not conclusively ruled out one of the opposing views. Further, the recent attempts to explain the disparity in findings through a dissociable level of consciousness view have yet to be substantiated with empirical data. The literature contains various proposals for why these findings have been so inconsistent. The two main degradation techniques – the AB and masking – have been speculated to have influenced the different results. This comes from the observation that the masking studies tend to support a graded view of consciousness, while the AB studies tend to deliver more dichotomous findings. The type of visual stimulus has also been suggested as a factor that affects the findings. Dichotomous ratings are found more frequently when using word stimuli. The length of the awareness scales is another factor that has been speculated to influence results. Specifically, the 21-point scale used by Sergent and Dehaene (2004), with only endpoints labelled, has been proposed to lead to more dichotomous ratings. Finally, developers of the dissociable levels of consciousness hypotheses (Kouider et al., 2010; Windey et al., 2013) have suggested that the level of stimulus features being probed influences the form of consciousness. These speculations have not been tested systematically in controlled studies. It is thus a major aim of this thesis to provide a systematic investigation into the factors that have been proposed to cause differences in the form of consciousness.

This empirical work is grounded on the conceptual foundations developed here. It has been argued in this chapter that in order for studies in this area to make progress, a working definition of a degraded conscious state should be attempted. As such I have provided a definition adapted from the typically employed definition of conscious and unconscious states. This derived definition identifies a state as degraded consciousness if (a) it is claimed to be degraded awareness, (b) it can be reported, (c) its presence can be verified as distinct from both unconscious and conscious states, (d) and (a) to (c) occur under optimal reporting conditions. This approach in defining consciousness reveals the problem with interpreting consciousness through psychophysical curves based on across-trial degradation because averaged data do not confirm the presence of degraded reports on individual trials. Further, it has been argued in this chapter that the orientation of the debate as determining only the existence of degraded consciousness is overly narrow, and may in fact already be answered when considering the mounting number of studies that have found evidence of degraded states in certain conditions. Instead, I have called for an extension of the debate into issues of degree and generality of degradation. Rather than asking whether consciousness can be degraded, I have proposed that we should ask to what degree consciousness is degraded in a specific circumstance. In this regard a further aim of this thesis is to extend the debate by introducing unstudied real-world stimuli. A qualification is required about pursuing the objective of addressing the generality of degraded consciousness. It would be extremely difficult to sample a representative set of conscious visual experiences. This is not an aim of this thesis; instead what is being tested is the general proposal that the relative degradation of consciousness varies as a function of viewing conditions and rating scales.

Before proceeding with the statement of the aims of the empirical chapters, the boundaries of this investigation are summarised. As reviewed in Chapter 1, the debate is not whether different forms of the background level of consciousness exist, as there is little disagreement that there are qualitatively different forms of this kind of consciousness. Instead, the debate is around the degradation of conscious contents, as defined earlier. In addition, although the arguments are often framed more generally, the empirical debate has been contested largely in the domain of visual perception. Similarly, the focus of the research in this thesis is on the issue of conscious visual experience.

An answer to the question of dichotomous or graded conscious perception has implications for several areas of research on consciousness. Firstly, if degraded perceptual awareness states do exist, the predominant binary report methodology in consciousness research will have to be amended to reflect this. Further, if consciousness is not simply present or absent the search for the neural correlates of consciousness will have to include the possibility that the neural events underlying consciousness are gradual. Theoretically, finding graded awareness states will conflict with predictions from prominent workspace theories of consciousness, necessitating a reassessment of certain assumptions of these models.

Questions and Hypotheses

In brief, the overarching aim of this study was to explore the factors that may influence the form of visual consciousness, by addressing the following questions and hypotheses:

1. **(Q1[8]) Does the type of visual degradation technique influence the form of consciousness?**

   From the review of the literature the following hypothesis is formulated:

   (H1) Hypothesis 1: The masking condition will result in more reports of degraded conscious states than the AB condition.

   The first question is addressed in the Experiment 1, reported in Chapter 3.

2. **(Q2) Does the type of visual stimulus influence the form of consciousness?**

   Based on the trend observed in the literature, it is expected that word stimuli will be more prone than simple geometric shapes to delivering more dichotomous awareness states.

   (H2) Hypothesis 2: Word stimuli will deliver significantly fewer degraded states compared to shape stimuli.

   A further assessment of impact of visual stimuli on the form of consciousness is the extension of the debate into the area of face perception. Based on previous studies in the area, it is expected that face stimuli will deliver relatively more dichotomous awareness states compared to other stimuli.

   (H3) Hypothesis 3: Face stimuli will result in more dichotomous awareness ratings compared to other (control) stimuli.

   Hypothesis 2 is tested in Experiment 1, reported in Chapter 3, and Hypothesis 3 is explored in Experiment 3, reported in Chapter 5.

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[8] Abbreviations in parentheses are introduced for the four major questions (Q1 – Q4) and the resultant five hypotheses (H1 – H5). They are employed consistently in the rest of the thesis to make it easier to identify instances where they are addressed.

3. **(Q3) Does the length of the awareness scale influence the form of visual consciousness?**

   The 21-point scale introduced by Sergent and Dehaene (2004) has been suggested to cause a bias towards dichotomous ratings (e.g. Overgaard et al., 2006).

   (H4) Hypothesis 4: The 21-point awareness scale will result in more dichotomous awareness ratings compared to the shorter 3-, 4- and 7-point scales.

   Experiment 2, reported in Chapter 4, explores the issues of awareness scale length in detail.

4. **(Q4) Do features of the same visual stimulus on different levels of processing elicit dissimilar forms of consciousness?**

   Recent proposals suggest that the processing level of stimuli influences the form of consciousness. Both recent proposals make specific but competing claims about how the difference should be realised (whether lower or higher level features should be degraded). For this reason the hypothesis being tested assesses the general claim that there is *any* difference in the form of consciousness across the different processing levels, as opposed to the more specific claim of the direction of the difference.

   (H5) Hypothesis 5: Features on distinct levels of processing will differ significantly in the level of degradation.

   This hypothesis is tested in Experiment 1 with words, shapes and colours, reported in Chapter 3, and with two stages of face processing in Experiment 3, reported in Chapter 5.

Chapter 3

Effect of Degradation Technique, Stimulus Type and Level of Stimulus Processing on the Form of Visual Consciousness

Introduction and Background

In a typical experiment in the form of consciousness debate the visibility of a target stimulus is disrupted through a combination of very brief presentation and either visual masking or AB degradation approaches. Afterwards, participants are commonly asked to rate the subjective visibility of the stimulus on an overall level. Across many of these studies it has become evident that certain visual stimuli and degradation techniques seem more prone to cause dichotomous awareness reports, while others generally elicit a graded form of consciousness. This observation has led to the proposal that degradation technique and stimulus type influence the form of visual consciousness (Nieuwenhuis & De Kleijn, 2011).

Degradation technique refers to the way in which an experimenter attempts to disrupt the visibility of a stimulus. Both the AB and masking techniques that are common to the debate were described in detail in the preceding literature review chapter, so they are only briefly reviewed here. The attentional blink (AB) is observed when participants are required to search for two visual targets in a rapidly presented sequence of items. When the first and second targets are separated by 200 to 500 ms the observer is typically unable to detect the second target (Kim & Blake, 2005). Visual masking occurs when a briefly displayed visual target is preceded (forward masking) or followed (backward masking) by a second visual item (the “mask”) in close spatial and temporal proximity. The result is a reduction in the visibility of the target stimulus (Enns & Lollo, 2000; Kim & Blake, 2005). Experimenters that employ these techniques attempt to vary the strength of the disruption of visibility by manipulating the duration between the first and second target in the AB approach. In the case where masking is employed the target display duration is varied in the millisecond range in order to achieve this aim. There has been a striking contrast in the findings delivered by the two techniques. When participants are exposed to a stimulus under AB degradation they tend to report a complete loss of visual consciousness of the stimulus instead of a mere degradation, despite experimenters varying the delay between the targets gradually (Bowman, et al., 2007; Nieuwenhuis & De Kleijn, 2011; Sergent et al., 2005; Sergent & Dehaene, 2004). However, when participants are exposed to a stimulus under masking degradation they tend to report mostly degraded awareness states at intermediate durations of target display, supporting a graded view of visual perception (Overgaard et al., 2006; Ramsøy & Overgaard, 2004; Sandberg et al., 2011; Sandberg et al., 2010; Sergent & Dehaene, 2004).

As reviewed in the preceding chapter the disparate results delivered by variations in stimulus type also warrant further exploration. Former studies have employed words, alphanumeric characters and basic geometric shapes, amongst others. In a study by Nieuwenhuis and De Kleijn (2011), in two identical AB experiments results revealed dichotomous ratings for words and gradual ratings for numeric characters. Studies that use words as targets have been criticised for biasing results towards a dichotomous view, because even if the target was not completely seen our cognitive systems have been shown to exhibit “interactive activation”, where the perception of a few letters can lead to full word recognition (Nieuwenhuis & De Kleijn, 2011, p. 365).

It is not only the type of stimulus, but also the level of stimulus processing that has been suspected to cause different findings in previous studies in this debate. There are at least two recent proposals (Kouider et al., 2010; Windey et al., 2013), reviewed earlier, that claim that the level of stimulus processing influences the graded or dichotomous nature of consciousness. Consequently, the developers of these proposals argue that more than one level of consciousness should be probed in experiments that try and resolve the debate.

To date no previous studies have systematically compared the impact of degradation, stimulus type and stimulus processing level on the form of visual consciousness within a single study. It is thus unclear how these three factors, independently and in combination, may affect the form of visual consciousness observed in previous experiments reported in the literature. The current experiment made use of four conditions, shown in Table 3, with varied stimulus and degradation conditions, and aimed to answer three of the four main questions posed in this thesis.

Q1 Does the type of visual degradation technique influence the form of consciousness?

H1: The masking condition will result in more reports of degraded conscious states than the AB condition.

Q2 Does the type of visual stimulus influence the form of consciousness?

H2: Word stimuli will deliver significantly fewer degraded states compared to shape stimuli.

Q4 Do features of the same visual stimulus on different levels of processing elicit dissimilar forms of consciousness?

H5: Features on distinct levels of stimulus processing will differ significantly in the level of degradation.

Method

Design

The experiment contained four conditions. Participants took part in one of the four conditions in a between-participants design. . A between-participants design was preferred to avoid learning effects from one task to the next and to keep sessions shorter.

Participants

Thirty-six participants recruited from the University of Cape Town's Department of Psychology undergraduate subject pool were randomly assigned to one of the four conditions of the experiment in a 2 (stimulus type) x 2 (degradation type) between-participants design. In two conditions participants viewed either coloured word or coloured shape stimuli with visibility disrupted through a backward masking procedure. In the other two conditions the visibility of the same coloured word and coloured shape stimuli were disrupted through the AB procedure. In the data screening phase, ten participants were excluded due to very low accuracy scores and evidence of misunderstanding the task. This resulted in a total of 26 participants included in the analysis across the four conditions. Participant information is summarised in Table 3.

Table 3

Four Experimental Conditions based on Stimulus Type and Degradation Technique

Stimulus type	Type of perceptual degradation	
	Masking	Attentional blink
Word stimuli	*MW: Masked word condition* 8 participants (4 female, aged 18–28, M = 21.13, SD = 3.31)	*ABW: Attentional blink word condition* 5 participants (2 female, aged 19–20, M = 19.80, SD = 0.45)
Shape stimuli	*MS: Masked shape condition* 6 participants (5 female, aged 18–24, M = 20.33, SD = 2.16)	*ABS: Attentional blink shape condition* 7 participants (3 female, aged 20–23, M = 21.00, SD = 1.00)

All participants reported normal or corrected-to-normal vision, normal colour vision and no history of a psychiatric condition or neurological damage. Participants received course credit for participation.

Procedure and Materials

The procedure for the four conditions is illustrated in Figure 2.

Masking procedure. In the masking conditions participants were asked to identify and report on the subjective visibility of two features of a briefly displayed masked target. Each trial started with a fixation cross presented for 975 ms at the centre of the computer screen, followed by the target stimulus presented for one of six randomly determined durations in multiples of 13 ms (determined by the 75 Hz refresh rate of the Phillips 107 E6 CRT monitor): 13, 27, 40, 53, 67 and 94 ms. All stimuli were presented on a black background in the centre of the computer screen at a viewing distance of ~ 60 cm, subtending a visual angle of 3.3 x 2.1°. In the MW condition the target stimuli set consisted of three English number words ("ONE", "TWO" and "SIX") displayed in size 48 point Courier font and presented in one of three randomly varied colours (red, green or blue). In the MS condition the target stimulus was one of three geometric shapes (oval, rectangle or triangle), again presented in one of the three colours, for a total of nine unique combinations. Four white squares surrounded and cued the target (matching the AB condition). In 10% of the trials no target was presented – the white squares were displayed on a blank screen. Two masks, each presented for 53 ms, followed the target stimulus. The masks in the MW condition were random three-letter consonant strings, with all three colours (red, green and blue) present in each string and the position of each colour randomly varied across the letter positions in the different strings. Masks in the MS condition consisted of coloured shapes similar to the target shapes, with the constraints being that the first mask following the target could not be the same as the target and that no similar masks were presented in the same trial. The first two questions following the stream of images asked participants to identify the colour (both conditions) and the word (MW) or shape (MS) that was presented. The final two questions asked participants to indicate how clearly they saw each feature that they had attempted to identify by using the Perceptual Awareness Scale (PAS) (Ramsøy & Overgaard, 2004). This scale was chosen because previous studies that had employed it were able to detect graded states (Overgaard et al., 2006; Ramsøy & Overgaard, 2004; Sandberg et al., 2011; Sandberg et al., 2010). The scale consisted of four points, with labels and descriptions as follows:

1. *No experience:* This means that you had no impression of the stimulus. Your answer is experienced as mere guessing.
2. *Brief glimpse:* Use this category if you have a feeling that something was present, even though the content (features) cannot be specified any further.
3. *Almost clear experience:* Feeling of having seen the stimulus feature, but being only somewhat sure about it.
4. *Clear experience:* Non-ambiguous experience of the stimulus feature.

A copy of the full scale instructions and descriptions were left with participants for reference during the trial session. It was emphasised that participants should report their experience and not their confidence in seeing, as the latter has been shown to cause different responses (Sandberg et al., 2010). In interviews conducted after the sessions, participants in all conditions indicated having no problem using or understanding the scale even though the scale had, as far as could be determined by the author, never been used on a South African sample before. After an explanation of the task participants completed a practice block of 20 trials, with stimuli presented at the longest two durations (67 and 94 ms) before proceeding to 60 formal trials.

Attentional blink procedure. In the AB condition the participants' tasks were also to identify two features of a target stimulus and to report the clarity of the experience in viewing the stimulus features. An additional task in these conditions asked participants to identify another target, presented before the second stimulus. This is a necessary task in order to induce the AB effect on the second stimulus, by diverting attention to the first stimulus. Stimuli were presented on a black background in the centre of the computer screen. Each trial started with a fixation cross presented for 975 ms, followed by six items: the first target (T1), which in both of the conditions was the uppercase letters “OXO” or “XOX” presented in white, a mask, a second fixation cross with the duration varied in six durations, the second target (T2) and two successive masks. T1, T2 and the masks were presented for 53 ms and were separated by blank screens lasting 53 ms. The stimulus onset asynchronicity (SOA) between T1 and T2 was manipulated through the varied timings of the second fixation to result in six lags between the targets of 107, 213, 320, 427, 533 and 693 ms. Increments were determined by the refresh rate of the monitor (75 Hz). T2 stimuli were matched to those used in the masking conditions: in the ABW condition, T2 was again of three English number words (“ONE”, “TWO” and “SIX”) presented in one of three randomly varied colours (red, green or blue), and in the ABS condition the target stimulus was one of three geometric shapes (oval, rectangle or triangle) in one of the three colours. Four white squares were presented as a simultaneous cue to T2, and in 10% of the trials these squares were presented alone, with no T2 present. Masks were also matched to the masking condition, and in the additional mask succeeding T1 the coloured consonant string masks from conditions MW and ABW were used.

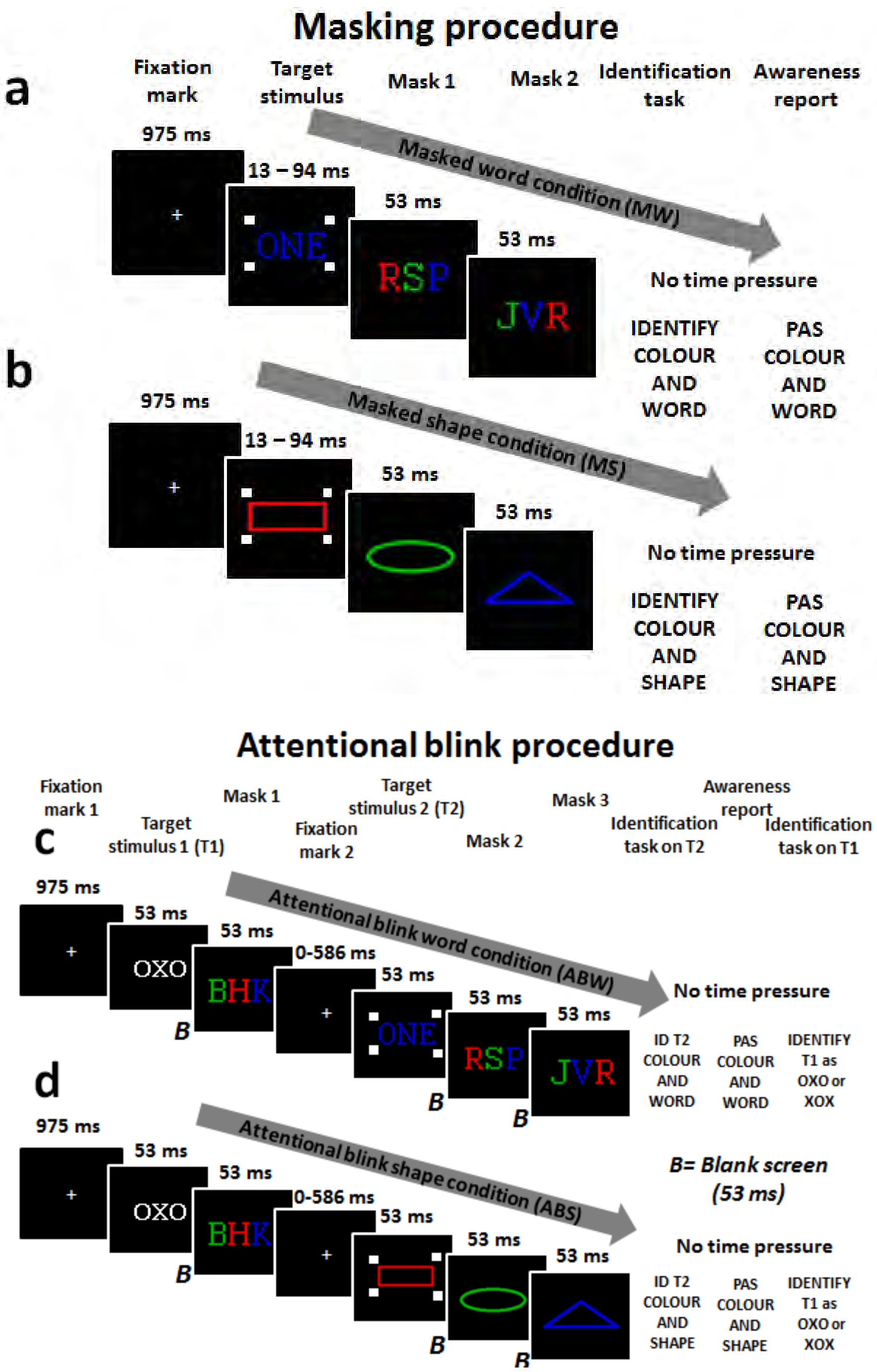

Figure 2. Experimental procedure for the four conditions: **(a)** Masked word condition (MW), **(b)** Masked shape condition (MS), **(c)** Attentional blink word condition (ABW) and **(d)** Attentional blink shape condition (ABS).

Five questions followed the series of items: first on the colour, word identity (ABW only) and shape identity (ABS only), then two questions on the PAS for each feature of the stimulus and finally a question about T1 identity[9]. A practice block with 20 trials using only the two longest SOA durations (533 and 693 ms) was followed by 60 formal trials.

All sessions were conducted in a psychology research lab, with attenuated lighting, generally free from noise and other distractions.

Results[10]

The analyses presented here were aimed at answering the central questions of this experiment about the effect of degradation technique, stimulus type and stimulus processing level on the form of visual consciousness. Before addressing these aspects directly, preliminary analyses are presented on the accuracy and awareness data in order to provide the necessary context for the primary analyses. For all analyses involving multiple comparisons a Bonferroni correction was applied to keep the type I error rate below an alpha level of 0.05.

Preliminary Analyses

Accuracy data. The accuracy data was analysed with the goal of identifying whether accuracy differed between the conditions and whether there was a meaningful difference in the ability to identify any specific stimulus feature over another in any of the conditions. In the AB condition trials with an incorrect response to T1 were discarded because a successful AB procedure relies on attention being verifiably focused on T1. This resulted in 58 trials being discarded in the ABW condition (242 trials were retained) and 17 trials in the ABS condition (403 trials were retained).

Figure 3 displays the feature identification accuracy by condition on an overall level and as a function of the timing levels (stimulus duration and SOA). In general, the ability to correctly identify the stimulus features was high across all tasks (accuracy > 60%). When comparing conditions, the MS condition appears to have been the most difficult for

[9] Ideally in this experiment less than five questions would have been asked to avoid later judgements being based on decayed experiences after a passage of time. Unfortunately due to the nature of the study this was unavoidable. Interview after the sessions did reveal a preference for the present order in which the identification is made first and the awareness rating after that.

[10] Raw data files are available as Appendix B.

participants. As statistical confirmation of this observation a chi-square analysis limited to the masking conditions comparing accuracy in identifying the colour, χ^2 (1, *N* = 840 from 14 participants) = 45.68, $p < .0001$, *phi* = -.233, and shape versus word, χ^2 (1, *N* = 840 from 14 participants) = 96.54, $p < .001$, *phi* = -.339, revealed significantly lower accuracy for both MS features (colour = 65%, shape = 61%) compared to the MW features (colour = 85%, word = 89%). Accuracy was also significantly lower in the MS condition than it was in the ABS condition (colour = 78%, shape = 78%) when comparing the same stimulus features: colour, χ2 (1, *N* = 780) = 15.24, $p < .001$, *phi* = .140, and shape, χ2 (1, *N* = 780 from 13 participants) = 25.94, $p < .001$, *phi* = .180[11].

There appear to be no major visible dissociations between the average across-trial ability to identify one feature over the other for any condition at a given timing level. This conclusion is corroborated by multiple paired sample T-tests comparing the mean accuracy proportion for feature reports at each timing level (stimulus duration or SOA) within conditions. None of the comparisons yielded significant differences ($p > .05$) between the mean feature identification accuracies.

In summary, the accuracy data shows one condition (MS) that had very low accuracy scores compared to the other three conditions. The possibility that task difficulty infleunces ratings can thus not be excluded. No significant difference is evident for the ability to identify one feature over another within any of the conditions.

[11] Chi square analyses were preferred here due to the dichotomous nature of the accuracy data.

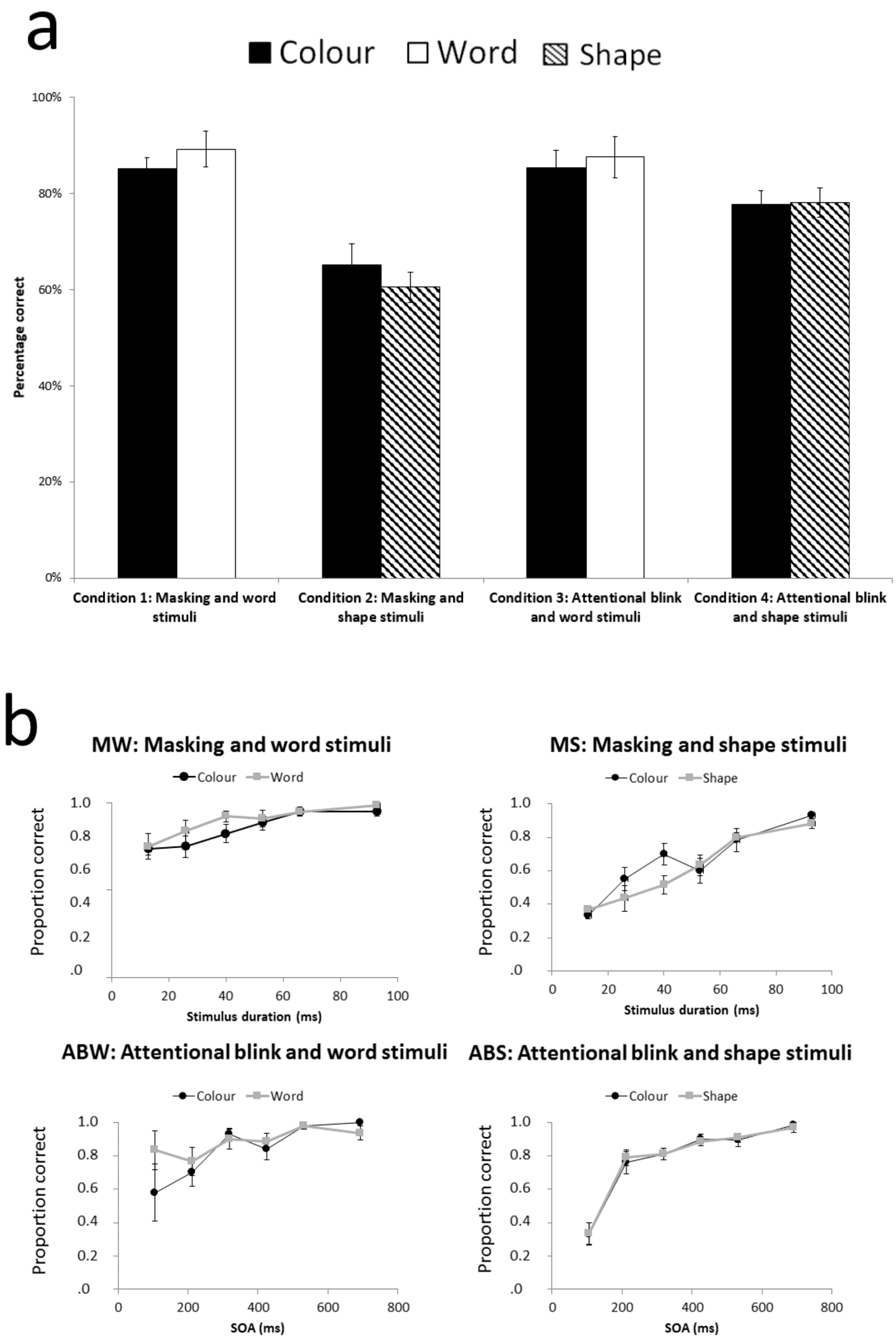

Figure 3. Accuracy data: **(a)** The overall proportion of target features correctly identified by the condition. **(b)** The proportion of targets accurately identified as a function of stimulus duration (MW and MS) and SOA between T1 and T2 (ABW and ABS). Error bars represent the standard error.

Awareness data. For the analyses of the awareness data only target-present trials were included, and in the AB condition only trials where T1 was correctly identified were considered. The awareness data is examined in this section with the aim of determining whether the four criteria for degraded states, developed in Chapter 2, are met in this experiment. These criteria consider degraded awareness to be present if (a) there are claims of degraded awareness, (b) these claims can be reported, (c) the degraded states' presence can be verified as distinct from both unconscious and conscious states, and that (d) requirements (a) to (c) occur under optimal reporting conditions. The final requirement (d) was met in this experiment, as trial sessions were free from distraction and reports occurred with minimal delay after the mental event that had to be reported (the viewing of the stimulus). The other three criteria are considered below.

Criteria (a) and (b): Reports of degraded states. Figure 4 shows the response distributions of the PAS ratings in target present trials as a function of stimulus duration and SOA between T1 and T2.

In the MW condition there was clearly a gradual displacement towards higher visibility ratings as stimulus duration increased. For colour awareness ratings in this condition at the shortest duration reports of a *brief glimpse* (PAS level 2) were most common (47%), and this then gradually shifted towards reports of a *clear experience* (PAS level 4) at the longest stimulus duration (63%). Significant in relation to the leading research question is the observation that at some intermediate durations the degraded state reports of a *brief glimpse* and an *almost clear experience* were collectively used more than any other category. In the MW condition there was thus no evidence of a bimodal rating pattern, but rather a graded displacement towards higher degrees of visibility. The same pattern held for the awareness ratings of word identity in this condition. The similarity between awareness ratings for the two features within a condition means that only colour features are discussed in this section, while the conclusions hold for both features.

The MS condition showed an interesting pattern of awareness responses. Reports of a *brief glimpse* were very prominent (51% overall) for the colour awareness ratings and even at the highest duration only 15% of the trials yielded reports of a *clear experience*. The awareness ratings for the MS condition appeared to reflect a more difficult task, consistent with the accuracy data. While not traversing the full spectrum of experience reports evident in the MW condition, the prevalence of degraded state ratings was also suggestive of a graded form of conscious perception.

Colour awareness reports for the ABW condition revealed a different pattern of responses from those observed in the masking conditions. At the shortest SOA two report types were equally prominent: a *brief glimpse* (35%) and a *clear experience* (34%); however, all longer SOAs showed a clear peak (range: 49–79%) at the dichotomous, top end (*clear experience*) of the scale. There was less evidence of the gradual displacement observed in the MW condition, and it appears that the AB in this condition induced a relatively more dichotomous transition that could be consistent with the dichotomous awareness states observed in some previous studies.

In contrast to this, in the ABS condition the response distribution of colour awareness ratings again appeared to be gradual, similar to the MW condition. At the intermediate SOAs experience reports of degraded awareness states were most common and there was a gradual increase in awareness ratings towards the longer SOAs.

In summary, despite differences in the magnitude of degraded state reports, all conditions delivered claims of degraded consciousness.

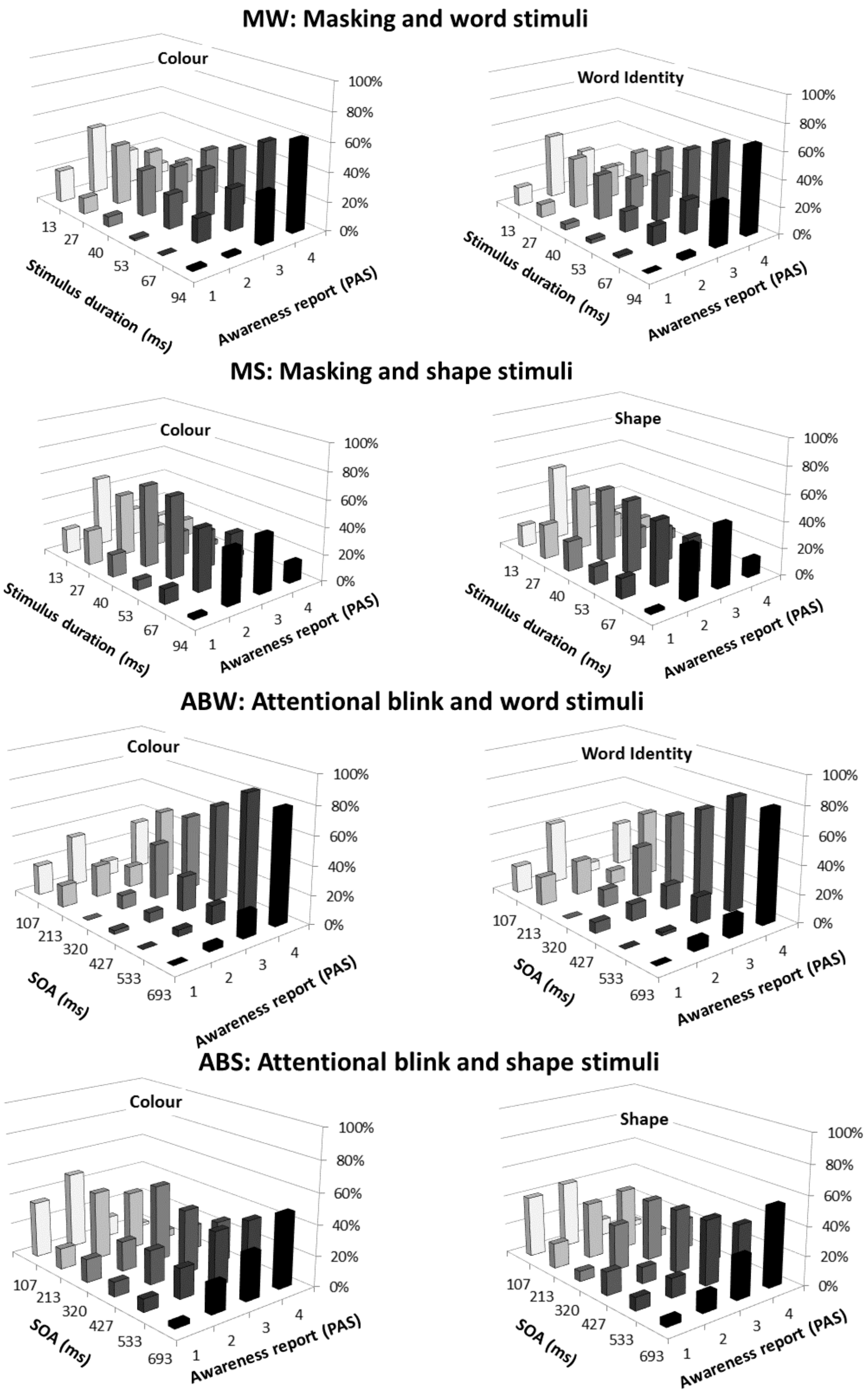

Figure 4. Response distribution of PAS ratings in target present trials as a function of stimulus duration (MW and MS) and SOA between T1 and T2 (ABW and ABS). The PAS awareness reports

are represented by numerals 1 to 4: 1="no experience", 2="brief glimpse", 3="almost clear experience", 4="clear experience".

Criterion (c): Verifying degraded states as distinct from conscious and unconscious states. Even though a substantial number of degraded states were reported, the meaningfulness of these reports needs to be established. Associations with other factors are useful in verifying the validity of these reports and in addressing the possibility that participants were using the scale categories in a haphazard way (Overgaard et al., 2006). One objectively manipulated factor was the timing level (stimulus duration or SOA). The relation between the timing factors and mean PAS rating is shown in Figure 5, where it is evident that the mean awareness ratings increased steadily across the timing levels for all conditions.

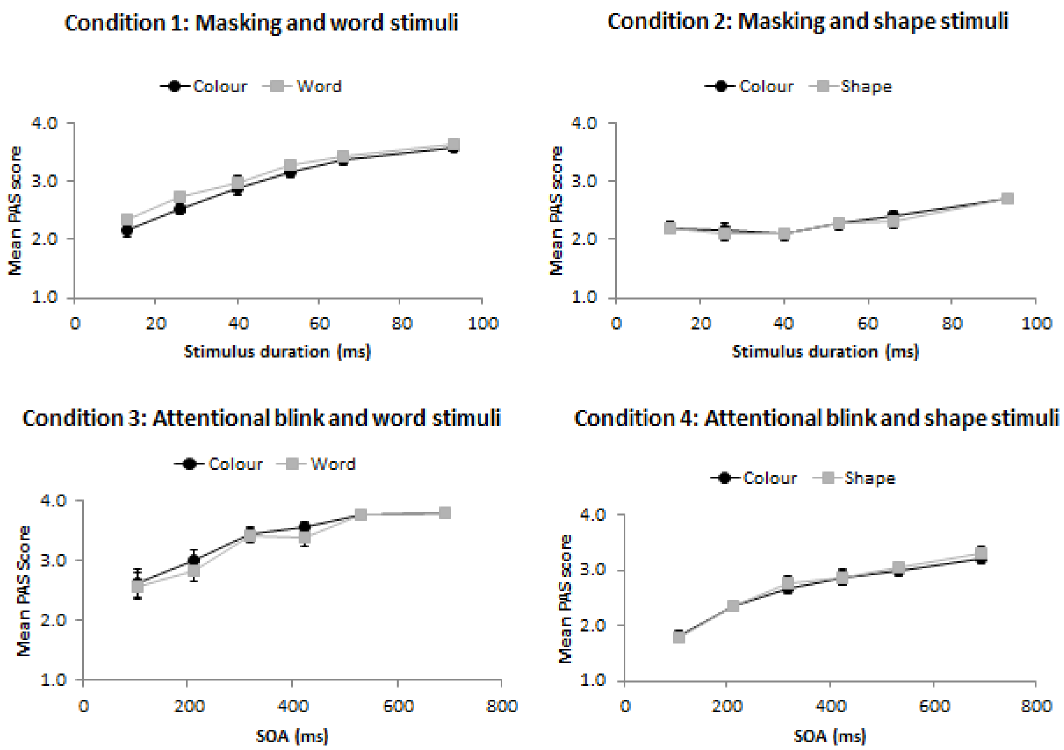

Figure 5. The mean PAS score as a function of timing level. Error bars represent the standard error of the mean.

Analyses of variance (ANOVAs) were performed with PAS rating as the dependent variable and stimulus timing level as the independent variable. This analysis was performed for all eight feature conditions. Results are summarised in Table 4. In all instances the ANOVA revealed a significant effect of timing level on PAS ratings.

The criteria for degraded states require, more specifically that degraded states should be verified as distinct from conscious and unconscious states. Not only should the awareness reports associate statistically with timing factors on an overall level, but the degraded states themselves should be associated with distinctive intermediate levels of these other variables. Post hoc Tukey HSD tests were employed in order to conduct these comparisons. In order to conduct the analyses for each of the conditions, two timing conditions were selected as comparison conditions. These were the shortest (most likely to be reported as *no experience*) and longest durations (most likely to be reported as a *clear experience*) of timing levels for each experiment. For masking the shortest duration was 13 ms, and the longest 93 ms. For the AB conditions the shortest SOA was 106 ms and the longest 692 ms. It should be noted that these conditions serve only as proxies for completely unconscious and completely conscious conditions. This is because these timing levels are not perfect substitutes for these states since the data show that even at the lowest timing levels *no experience reports* are not the primary types of reports, and in fact in many conditions reports of a *brief glimpse* are most common at the most brief timing levels. A similar point applies to the longest timing levels, where *clear experience* reports do not always represent the majority of the reports. Despite this limitation these durations present the best available comparison conditions for these analyses. With the comparison conditions selected the Tukey HSD post hoc test results were investigated in order to find intermediate timing levels that were significantly different ($p < .05$) from *both* the longest and shortest comparison conditions. This would imply that these display levels delivered ratings that were distinct from both the least and most clear contrast conditions. These unique ranges are identified by asterisks in Table 4. It appears that two of the conditions contained distinct mean ratings, these were the MW and ABS conditions, while the MS and ABW conditions did not reveal similarly unique mean ratings. Whether this is due to a genuine lack of distinct associations affected by the conditions or whether it is due to the limitations of the contrast conditions reviewed above is unclear. Nevertheless, the general finding suggests that degraded consciousness can be verified as distinct from high and low states of visibility in at least some masking and AB conditions.

Table 4

Mean PAS Ratings by Timing Levels

PAS rating by timing	Display time								
	13	26	40	53	66	93	*F*	*p*	*Eta squared*
MW colour	2.15	2.53	2.88*	3.15*	3.38	3.58	30.42	< .001	.211
	(0.85)	(0.90)	(0.96)	(0.83)	(0.76)	(0.60)			
MW word	2.35	2.72	2.97*	3.26	3.43	3.63	23.28	< .001	.160
	(0.84)	(1.00)	(0.95)	(0.82)	(0.78)	(0.54)			
MS colour	2.20	2.15	2.09	2.28	2.39	2.7	4.26	< .01	.053
	(0.86)	(0.96)	(0.71)	(0.66)	(0.79)	(0.74)			
MS shape	2.20	2.11	2.09	2.28	2.31	2.7	4.01	< .01	.059
	(0.83)	(0.90)	(0.83)	(0.79)	(0.84)	(0.72)			
	SOA								
	106	212	319	425	532	692			
ABW colour	2.63	3.00	3.45	3.55	3.76	3.81	10.22	< .001	.191
	(1.27)	(1.13)	(0.69)	(0.74)	(0.54)	(0.46)			
ABW word	2.57	2.84	3.42	3.38	3.76	3.78	10.4	< .001	.194
	(1.22)	(1.21)	(0.72)	(0.96)	(0.49)	(0.53)			
ABS colour	1.8	2.34*	2.68*	2.86	3.00	3.22	21.4	< .001	.228
	(0.73)	(0.77)	(0.92)	(0.93)	(0.95)	(0.87)			
ABS shape	1.77	2.34*	2.77*	2.87	3.03	3.32	24	< .001	.248
	(0.78)	(0.81)	(0.86)	(1.02)	(0.91)	(0.88)			

Note. Standard deviations appear in parentheses below means.

*Indicates mean ratings at intermediate timing levels that differ from ratings at both the longest and shortest timing levels at p < .05, Tukey HSD post hoc tests.

A further test of the meaningfulness of the reported experience categories was the association with accuracy scores. Figure 6 shows the monotonic increase in the proportion of targets correctly identified as a function of the PAS report. For example, in the ABW condition, when the lowest PAS rating (*no experience)* was provided for colour, only 21% of the colour feature trials were correctly identified, whereas a PAS level 4 rating (*clear experience*) was associated with almost perfect accuracy (96% accuracy). Importantly, when participants claimed to have a degraded experience (*brief glimpse* or *almost clear experience*) the accuracy percentage was intermediate, falling between the associated accuracy level for *clear* and *no experience* reports.

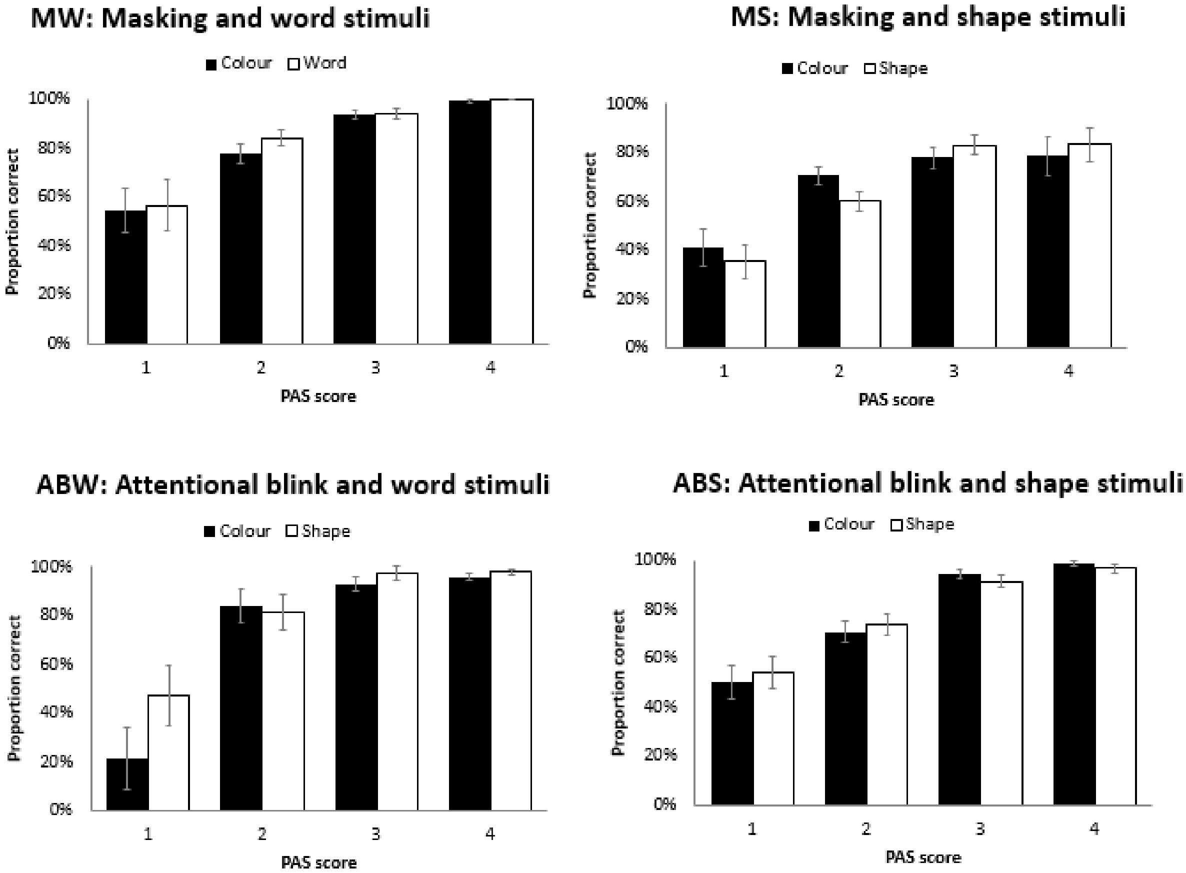

Figure 6. Proportion of features correctly identified as a function of the PAS score. Error bars represent the standard error.

To estimate the association between PAS score and accuracy, Kendall's tau b correlations were employed, as shown in Table 5. For all eight feature scenarios a higher PAS feature rating was associated with a significant increase (all p values < .0002) in correct identification of the feature, with *tau* coefficients > .310 for seven of the eight conditions, and *tau* = .199 for the colour accuracy and PAS rating association in the MS condition. This provides further substantiation of the awareness ratings' association with other objective measures.

Table 5

Kendall's Tau B Correlations between Accuracy and PAS Ratings

	Tau coefficient for PAS rating	N	*p*
MW colour accuracy	.34	432 (8 participants)	< .001
MW word accuracy	.31	432 (8 participants)	< .001
MS colour accuracy	.19	324 (6 participants)	< .001
MS shape accuracy	.31	324 (6 participants)	< .001
ABW colour accuracy	.35	222 (5 participants)	< .001
ABW word accuracy	.36	222 (5 participants)	< .001
ABS colour accuracy	.39	369 (7 participants)	< .001
ABS shape accuracy	.34	369 (7 participants)	< .001

In summary, the four criteria for degraded conscious states are largely met in this experiment. The large number of reports of degraded experiences was corroborated through the association of the awareness reports with timing and accuracy levels for two of the conditions. The data from these analyses suggest that degraded awareness states in these conditions are associated with intermediate values of these other factors, as required for the verification of claims of degraded awareness.

Primary Analyses

Having established that degraded conscious states are present in the data, the primary analyses seeks to establish the effect of degradation technique, stimulus type and stimulus processing level on the degree of degradation reported in these experiments. From the response distributions reviewed earlier it was clear that the ABW condition contained far fewer degraded states across the timing levels compared to other conditions, and it appears that the combination of word stimuli and the attentional blink produced more dichotomous awareness states than the other conditions. In order to statistically compare the number of degraded states across conditions chi-square tests were performed. Degraded (PAS levels 2 and 3) experience reports were grouped together to facilitate comparison. The proportion of degraded states in each condition is illustrated in Figure 7.

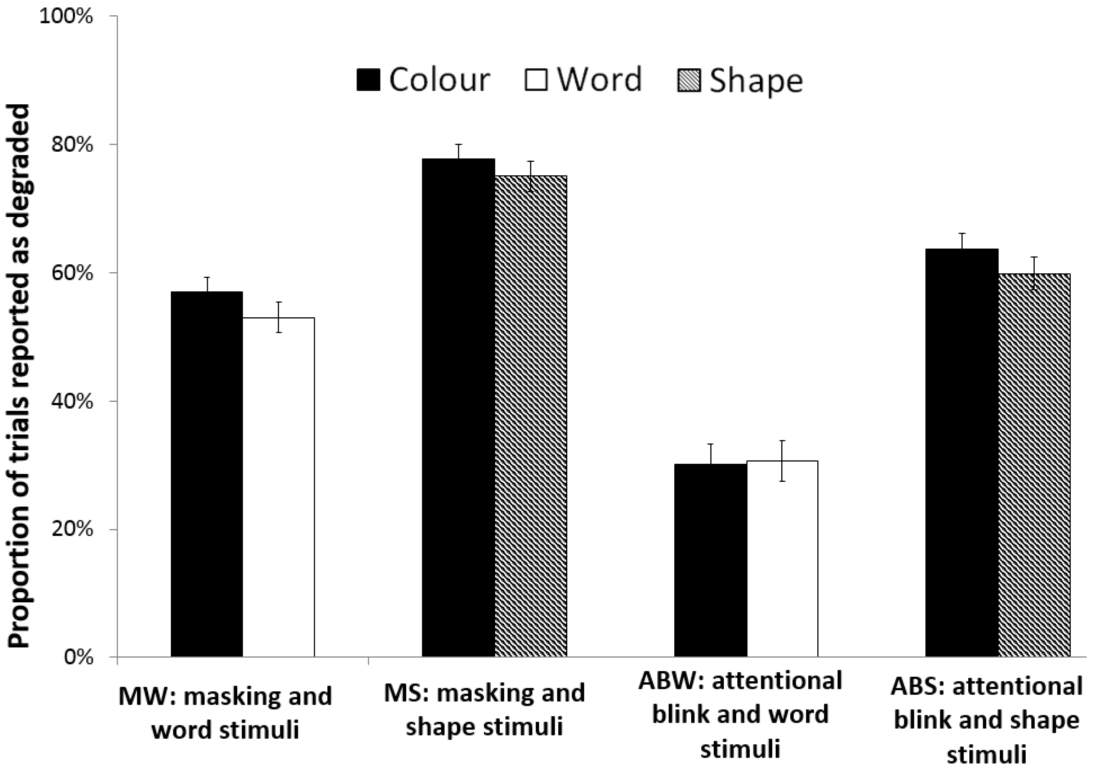

Figure 7. Proportion of degraded states (PAS level 2 or 3) reported in the four conditions. Error bars represent the standard error of the proportion.

Q1 Does the type of visual degradation technique influence the form of consciousness? In order to make the masking data directly comparable to the data from the AB condition only trials with the same target display time (53 ms duration) from the masking conditions were compared to the AB trial data. Furthermore, comparisons were limited to conditions with the same stimulus sets. The ABW condition delivered fewer degraded reports for both word, χ^2 (2, N = 294 from 13 participants) = 8.92, p = .003, *phi* = -.174, and colour features, χ^2 (2, N = 294 from 13 participants) = 16.76, p < .001, *phi* = -.239, than the MW condition at the same stimulus duration of 53 ms. Similarly, at this duration the ABS condition resulted in fewer degraded state reports than the MS condition for colour, χ^2 (2, N

= 423 from 13 participants) = 13.51, $p = .002$, *phi* = -.179 and shape, χ^2 (2, N = 423 from 13 participants) = 7.82, $p = .005$, *phi* = -.136[12].

Consequently the first major hypothesis of this thesis (H1) is supported by this data. Both masking conditions delivered a greater frequency of degraded conscious state reports compared to the AB conditions. motion

Q2 Does the type of visual stimulus influence the form of consciousness? The MS condition delivered significantly more degraded PAS reports for colour compared to the MW colour reports, χ^2 (1, N = 756) = 35.75, $p < .001$, *phi* = .271, and more degraded states for shape compared to the MW word reports, χ^2 (1, N = 756) = 38.17, $p < .001$, *phi* = .225. For comparison of the AB condition the procedure in the ABW condition resulted in significantly fewer degraded PAS colour reports compared to the ABS colour reports, χ^2 (1, N = 591) = 62.27, $p < .001$, *phi* = .325, and significantly fewer degraded word reports compared to shape reports in the ABS condition, χ^2 (1, N = 591) = 47.49, $p < .001$, *phi* = .283. Thus, the two shape stimuli conditions were significantly more likely to result in degraded awareness reports than the word stimuli conditions.

Accordingly, the second major hypothesis of this thesis (H2) is also supported in this experiment. The word stimuli resulted in significantly fewer degraded state reports compared to the shape stimuli.

The type of stimuli and nature of the degradation procedure thus both showed meaningful effects on the number of degraded states that were reported, with masking and shape stimuli most likely to have resulted in reports of degraded states.

Q4 Do features of the same visual stimulus on different levels of processing elicit dissimilar forms of consciousness? A dissociable levels of consciousness view would predict that at some timing levels one feature is more visible than the other. However, the

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[12] Chi square analyses were performed here instead of ANOVA because degraded states were binned making the data dichotomous and ANOVA analyses less optimal.

PAS response distributions (Figure 4) and mean PAS scores (Figure 5) by timing level for each feature within a condition appear very comparable and suggest an association between the two feature awareness states on a given trial. In addition, Kendall's tau b correlations revealed a significant association between feature awareness reports within conditions (MW *tau* = 0.824, $p < .001$; MS *tau* = 0.560, $p < .001$; ABW *tau* = 0.831, $p < .001$; ABS *tau* = 0.769, $p < .001$). Furthermore, multiple paired samples t-tests revealed no difference ($p > .05$) in the mean awareness ratings at any of the timing levels aside from the 13 ms duration in the MW condition.

In order to investigate how participants responded to each feature on individual trials a conditional analysis of the awareness data was conducted. This was done in order to examine whether the PAS ratings for the two features on the same trial are comparable. As shown by Figure 8, the second feature PAS rating (word or shape) is most likely to have come from the same PAS level chosen for colour on a particular trial. This holds true across conditions and suggests that participants' subjective experience of both features was the same on the majority of trials. In the MS condition there was some evidence of less symmetrical ratings per trial, with for example clear experience ratings for colour followed by an almost equal number of clear experience (43%) and almost clear experience ratings (39%) for shapes. This asymmetry in these ratings warrants further investigation into the possibility of dissociated experiences for colour and shape in some conditions. However, in general, there appeared to be no clear dissociation between experience reports on a given trial so that the same level of subjective visibility was evident for both features in most trials. As a result there is only limited evidence for a dissociation between the forms of consciousness of different levels of stimulus processing in this data.

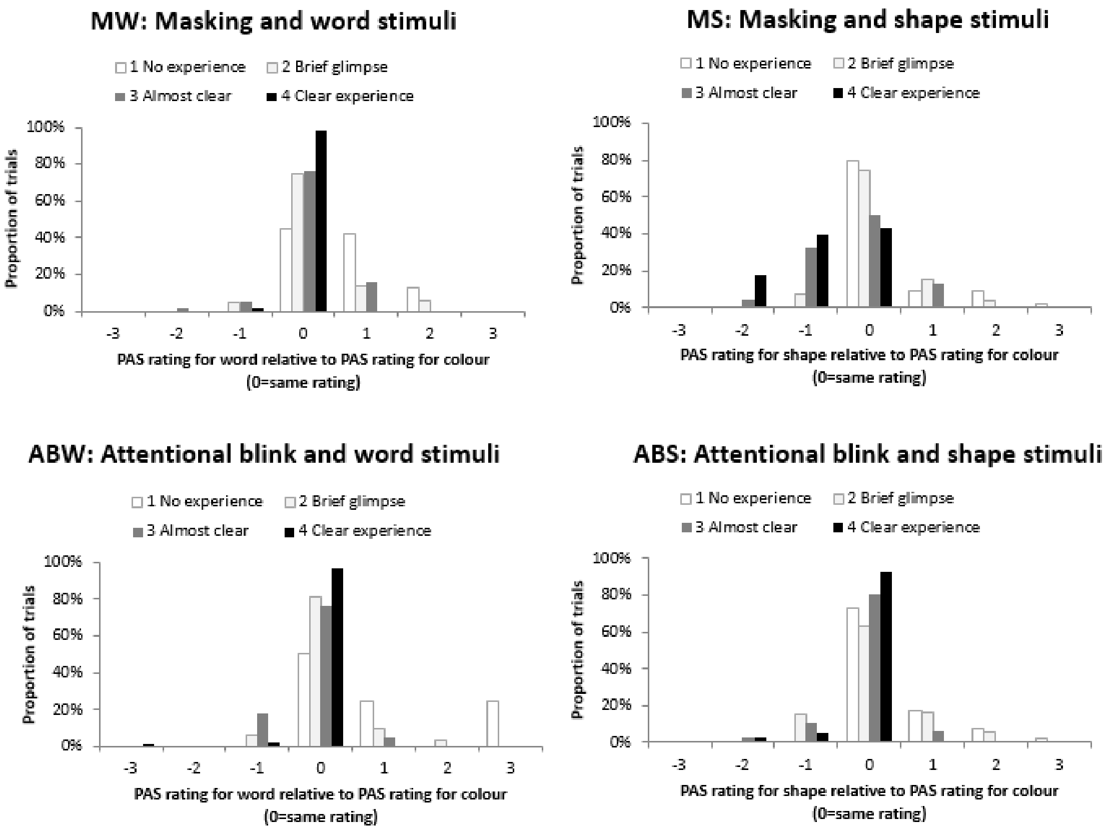

Figure 8. Conditional analysis of PAS ratings per trial: The horizontal axis represents the serial position of the second PAS rating relative to the colour PAS rating for that trial. “0” indicates a PAS rating from the same position as the colour rating on that trial, “-1” means a rating one level lower than the colour rating, “1” means a rating one level higher than the colour rating and so on.

The implication for the fifth major hypothesis of this thesis (H5) is that the difference in only the MS condition ratings provides only partial support for a difference in the degree of degradation on different levels of stimulus processing.

Discussion

The results reported here contribute to the debate on the form of conscious perception in several ways. On the general issue of whether degraded awareness states exist, the participants in this study certainly reported their experience as degraded on many trials (ranging from 30 to 78% per condition). Further, the association of the awareness reports with other measures (timing level and accuracy) suggests that these states represent meaningful experiences that can be verified through means other than relying solely on participants' reports. This finding strongly questions the view that conscious visual perception is generally a dichotomous phenomenon.

However, the results also warn against a rigid interpretation of these states as evidence of a consistently graded form of visual consciousness. The difference in degree of degradation reported here calls into question the general framing of the form of visual consciousness debate as having to determine whether conscious visual perception *is* dichotomous or graded. Regarding stimulus type, the shape conditions delivered more degraded awareness reports than the word stimulus conditions. Comparing degradation type it is evident that the AB procedure was less likely than the masking procedures to result in degraded awareness reports. The combination of the AB and word stimuli conditions delivered significantly fewer degraded awareness reports (only around 30% for both features) than other conditions. Indeed, this is the same combination (AB degradation with word stimuli) that delivered the mostly dichotomous ratings discussed in the controversial article by Sergent and Dehaene (2004). The comparison with results in this study appears to agree with the speculation presented by Nieuwenhuis and De Kleijn (2011) that this particular combination of methods biases results towards a dichotomous form of visual consciousness.

The experiment also examined the idea that a dissociation in the awareness states from two different features of the same stimulus is possible. The findings showed no clear dissociation in the participants' ratings of colour and word or colour and shape on the same trial. Further investigation into this proposition, using other stimuli and features could assist in addressing the possibility that the set of methods employed in this study was unable to detect a dissociation. In summary, the variation of findings with the systematic comparisons employed here warns against a rigid "either-or" framing of the current debate. According to these findings the form of conscious perception observed in a particular experimental setup depends at least on the type of stimulus and degradation technique employed.

Chapter 4

Effect of Awareness Scale Length on the Form of Consciousness

Introduction and Background

Data in the debate about the graded or dichotomous nature of conscious visual perception are delivered predominantly by subjective awareness ratings. A challenge is that there has been no agreement on which of these measures is the optimal index of conscious experience. This methodological issue is itself a matter of ongoing debate and study (Dienes & Seth, 2010; Koch & Preuschoff, 2007; Seth et al., 2008; Timmermans, Sandberg, Cleeremans, & Overgaard, 2010).

One aspect of awareness scale variation that is unresolved is the matter of optimal number of response categories. Previous studies have employed anywhere from 3 to 21 response alternatives, as shown in Table 6, and the use of a particular scale length is not always defended in these studies. A challenge for researchers interested in the debate is that these studies have delivered such different conclusions that some investigators (Nieuwenhuis & De Kleijn, 2011; Overgaard et al., 2006) have suggested that the conclusion that visual consciousness is graded or not depends on scale choice.

In an early study that stimulated interest in the graded or dichotomous form of visual consciousness, Sergent and Dehaene (2004) employed a "continuous" scale with 21 categories where only the endpoints were labelled ("not seen" at the minimum end on the left, and "maximal visibility" at the maximum end on the right of the scale). This specific scale was developed to be "… sensitive to continuous changes in perception" (Sergent & Dehaene, 2004, p. 723). In the AB experiment participants' awareness ratings revealed an all-or-none pattern, suggesting a dichotomous form of consciousness. However, Overgaard et al. (2006) argue that the 19 unlabelled intermediate categories are difficult for participants to interpret and this causes a bias towards the extreme categories. Furthermore, 21 categories also appears excessively fine-grained for someone to use in expressing their subjective experience, making the findings difficult to interpret (Nieuwenhuis & De Kleijn, 2011; Overgaard et al., 2006). The use of a 21-point scale is contentious and may be part of the reason why a dichotomous form of consciousness was observed in studies that employed the scale. Despite these concerns subsequent studies have continued to employ this scale (Del Cul et al., 2007; Del Cul et al., 2006; Sergent et al., 2005).

Ramsøy and Overgaard (2004) reported the development of a scale based on a generalisation of participants' open-ended responses in a masking experiment. The PAS uses four categories and has been employed in a number of subsequent masking experiments (Overgaard et al., 2006; Ramsøy & Overgaard, 2004; Sandberg et al., 2010). The scale points are typically labelled as follows from minimum to maximum levels: "no experience", "brief glimpse", "almost clear experience" and "clear experience". In general these studies suggest that a 4-point scale is used in a graded fashion, with responses distributed across all four points. Recently, this scale length has been challenged, with Windey et al. (2014) suggesting that the 4-point PAS scale might cause a bias to finding degraded conscious states because participants may feel compelled to use all four categories when these are available. The idea that four points is optimal is also questioned in an fMRI study (Christensen et al., 2006) because participants found it difficult to distinguish between the two intermediate categories of the scale. For this reason a 3-point alternative was employed to better corroborate participants' subjective experiences. The options were, in this instance, from minimum to maximum levels: "no perceptual experience of the stimulus", "vague or glimpse-like perceptual experience of the stimulus" and "clear perceptual experience of the stimulus" (Christensen et al., 2006, p. 1712). Moreover, another recent study found better performance for a 3-step version of the PAS than the typical 4-point scale when comparing information from curve estimations (Sandberg et al., 2011). The studies that employed three categories have supported the idea that visual consciousness is graded, with participants using the middle category and not only the endpoints of the scale.

Another variation of awareness scale length was introduced by Nieuwenhuis and De Kleijn (2011), who employed 7-point scales in four experiments. The scale descriptions were based on the 21-point scale by Sergent and Dehaene (2004) and had only endpoints labelled "not seen" at the minimum end and "maximal visibility" at the maximum end of the scale. While 7-point Likert-type rating scales are commonly employed in psychology, the authors recognise that the use of this scale length in consciousness research is not without uncertainties when they remark that "… 7 is still a rather arbitrary choice of scale points" (Nieuwenhuis & De Kleijn, 2011, p. 367). The findings from the experiments suggest that the scale can be used gradually, at least in some circumstances.

In summary, the question of whether the findings from the various studies have been influenced by scale length is a pertinent and unresolved question. Indeed, Table 6 reveals an interesting pattern where longer scales (7- and 21-point) were generally more likely to find dichotomous forms of consciousness while the shorter 3- and 4-step versions generally revealed a graded pattern of responses. However, these experiments also differed in other respects, such as use of AB or masking as the degradation technique, and variations in stimulus types, so it is not clear that scale length was instrumental in showing these conclusions. No previous studies have compared the findings from different scale lengths in the same experimental set-up with randomised assignment to different scale length groups. Consequently, while the issue of optimal rating scale has been studied comprehensively in other fields (e.g. Cox, 1980; Krosnick & Fabrigar, 1997), the unique nature of the research in this area makes a direct investigation into the issue a vital requirement for progress in resolving the debate about the form of conscious visual perception. Such an experiment is reported in this chapter. The central aim of the experiment was to compare the results of four variations of subjective awareness scales in a backward masking paradigm. This experiment addresses the third key question of the thesis, which is whether the length of the awareness scale influences the form of visual consciousness.

Q3 Does the length of the awareness scale influence the form of visual consciousness?

H4: The 21-point awareness scale will result in more dichotomous awareness ratings compared to the shorter 3-, 4- and 7-point scales.

Aside from this main question and hypothesis, a further exploratory question was considered: Which of the four scale lengths tested in this set is the optimal measure of perceptual awareness? Specifically it is asked which of the scales deliver the most clear, unambiguous task to participants and researchers.

Table 6

Subjective Measures of Consciousness and Number of Response Options

Study/Experiment	Type of measure	Hypothesis supported by findings
3 response categories		
Christensen et al. (2006)	PAS	Graded
Sandberg et al. (2011)	PAS	Graded
4 response categories		
Ramsøy and Overgaard (2004)	PAS	Graded
Overgaard et al. (2006)	PAS	Graded
Sandberg et al. (2010)	PAS, confidence ratings and PDW*	Graded
7 response categories		
Nieuwenhuis and De Kleijn (2011) *Experiment 1*	Visibility scale	Dichotomous
Nieuwenhuis and De Kleijn (2011) *Experiment 2*	PDW	Inconclusive
Nieuwenhuis and De Kleijn (2011) *Experiment 3*	Visibility scale	Graded
Nieuwenhuis and De Kleijn (2011) *Experiment 4*	PDW	Inconclusive
21 response categories		
Sergent and Dehaene (2004) *Experiment 1*	Visibility scale	Dichotomous
Sergent and Dehaene (2004) *Experiment 2*	Visibility scale	Graded
Sergent and Dehaene (2004) *Experiment 3*	Visibility scale	Mixed
Sergent et al. (2005)	Visibility scale	Dichotomous
Del Cul et al. (2006)	Visibility scale	Dichotomous
Del Cul et al. (2007)	Visibility scale	Dichotomous

** PDW: Post-decision wagering*

Method

Design

The experiment contained four conditions. Participants took part in one of the four conditions in a between-participants design. It was decided to expose participants only to one version of the scale to avoid potential contamination effects from one condition to another. In particular the concern was that the usage of one scale type would bias the participant to use a simialr rating system with subsequent scales.

Participants

For the main experiment a total of 40 participants were randomly assigned to one of the four conditions of the experiment in the between-participants design. A total of ten participants took part in identical tasks, each with a different scale length. In the data screening phase eight participants (two per condition) were removed due to anomalous awareness rating data. These participants used one category of the scale almost exclusively, neglecting other scale points. This resulted in eight participants per condition included in the final analyses, as displayed in Table 7. All participants reported normal or corrected-to-normal vision, normal colour vision and no history of a psychiatric condition or neurological damage.

The main experiment was conducted in Johannesburg in a quiet room with attenuated lighting, free from noise and other distractions.

Table 7

Four Experimental Conditions Based On Scale Length, and Age and Sex of Participants (N = 32; Eight Participants per Condition)

Condition	Age	Sex
3-point scale	M = 30.12, SD = 5.51	5 female
4-point scale	M = 34.12, SD = 7.32	7 female
7-point scale	M = 30.00, SD = 7.72	4 female
21-point scale	M = 29.75, SD = 6.04	3 female

Procedure and Materials

Masking procedure. Participants took part in a masked visual identification task adapted from a previous study (Sandberg et al., 2010). A masking task is preferred because masking studies have generally been able to detect degraded states of awareness. AB studies have been shown to result in a higher likelihood of binary responses. It is important for the present study that any effect of scale on form of consciousness is maximally detectable. As illustrated in Figure 9, each trial started with a fixation cross presented on a computer screen for one of four durations (500, 1 000, 1 500 or 2 000 ms). The fixation cross was replaced by one of four geometric shapes (circle, square, diamond or triangle) presented for one of 12 durations (ranging from 13 to 200 ms, determined by the 75 Hz refresh rate of the CRT monitor). The target stimulus was presented on a grey background in the centre of the computer screen at a viewing distance of ~ 60 cm, subtending a visual angle of 3.3 x 2.1°. A mask, consisting of all four of the shapes overlaid on each other, followed the target and covered up the entire area where the shape was presented. The mask was displayed for 3 000 ms. Participants were first asked to identify the shape that was presented by pressing keys on the keyboard (“c”, “s”, “t” or “d”), and were then prompted to provide an awareness rating using one of the four scales. The awareness rating was made by using the mouse cursor to select from the available options, displayed as contiguous blocks per response option.

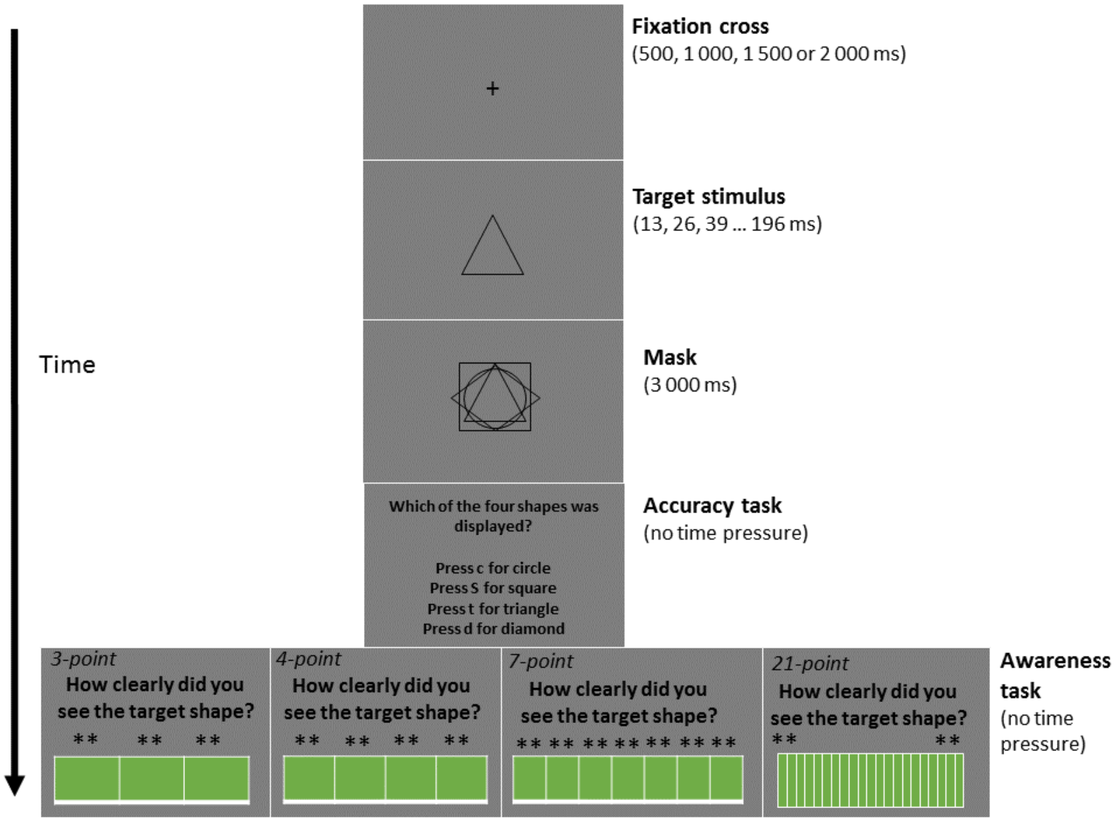

Figure 9. Experimental procedure for the four conditions. ** Actual labels provided as follows: **3-point**: 1 – "No experience of stimulus", 2 – "Brief glimpse or vague experience" and 3 – "Clear experience". **4-point:** 1 – "No experience of stimulus", 2 – "Brief glimpse", 3 – "Almost clear experience" and 4 – "Clear experience". **7-point:** 1 – "No experience", 2 – "Almost no experience", 3 – "Slight or brief experience", 4 – "Moderately clear experience", 5 – "Somewhat clear experience", 6 – "Almost clear experience" and 7 – "Clear experience". **21-point:** Only endpoints labelled: 1 – "No experience of stimulus" and 21 – "Clear experience".

Each session began with a practice block of 48 trials with only the longest stimulus durations. The formal trials consisted of 384 trials divided into two blocks of 192 trials. Participants could take a brief break between the two blocks if they preferred.

Subjective measures of consciousness. After each shape-identification attempt participants were asked to rate their level of awareness of the target stimulus using one of the four subjective measures of consciousness. Scale labels were adapted from the PAS (Ramsøy & Overgaard, 2004), which has been shown to be an effective measure of graded consciousness (Sandberg et al., 2010). Similar labels were used for the minimum and maximum levels for all scales. The set of scale lengths has been chosen to be consistent with the variations employed in previous studies. Only the longest, 21-step scale version was not fuully labelled with verbal descriptors due to the difficulty in labelling this extended scale. The set employed here was formatted as follows:

- *3-point scale:* At least two studies have employed a 3-point awareness scale (Christensen et al., 2006; Sandberg et al., 2011). In this study the 3-point scale was formatted as follows: 1 – "No experience of stimulus", 2 – "Brief glimpse or vague experience" and 3 – "Clear experience".
- *4-point scale:* Studies that used the PAS (Overgaard et al., 2006; Ramsøy & Overgaard, 2004; Sandberg et al., 2010) typically employed four response options. In this condition the standard PAS descriptions were used: 1 – "No experience of stimulus", 2 – "Brief glimpse", 3 – "Almost clear experience" and 4 – "Clear experience".
- *7-point scale:* The study by Nieuwenhuis and De Kleijn (2011) employed a 7-point confidence rating and PDW scale. Only the PDW scale was fully labelled, with the amount of money that is wagered indicated at each level. To make this scale maximally comparable to the 3- and 4-point versions it appeared appropriate to fully label this scale: 1 – "No experience", 2 – "Almost no experience", 3 – "Slight or brief experience", 4 – "Moderately clear experience", 5 – "Somewhat clear experience", 6 – "Almost clear experience" and 7 – "Clear experience".
- *21-point scale:* Studies that employed this scale length (Del Cul et al., 2007; Del Cul et al., 2006; Sergent et al., 2005; Sergent & Dehaene, 2004) did not label every step of the scale due to its elaborate nature. This scale was the only scale-length version tested here that had just the endpoints labelled: "No experience" and "Clear

experience". Although this introduces a variation for this scale only, this is consistent with the way in which the scale has been employed previously, and participants were thoroughly briefed that all points on the scale should be used to match their experience as closely as possible.

A hard copy of the scale label descriptions was left with participants for reference during the sessions.

Results[13]

Preliminary Analyses

Accuracy data. Before proceeding with the analyses of the awareness data it is important to rule out the possibility that accuracy differed across experimental groups. The percentage of shapes accurately identified across the conditions was highly similar, as shown in Table 8, ranging from 85.3 to 88.5%.

Table 8

Percentage of Targets Correctly Identified By Scale Condition (Total for All Participants)

	3-point	4-point	7-point	21-point
Accuracy	86.3%	85.3%	88.5%	88.5%

If differences are observed in awareness ratings they are thus unlikely to have been caused by differences in accuracy.

Awareness data. In order to conclude that the form of consciousness observed in a given experiment is degraded four criteria need to be met, as argued in the literature review chapter. Briefly, this definition considers a mental state to be degraded consciousness if (a) it is claimed to be degraded awareness, (b) it can be reported, (c) its presence can be verified as distinct from both unconscious and conscious states, (d) and (a) to (c) occur under optimal

[13] Raw data files are available as Appendix B.

reporting conditions. The conditions of the experimental sessions mean that criterion (d) is met. The performance of the four scales on criteria (a) to (c) are considered.

Criteria (a) and (b): Reports of degraded states. The response distributions of awareness ratings delivered by the different scales are displayed in Figure 10. All of the scales show a pattern of increasing awareness as stimulus duration increases. In addition, all of the scale conditions contain a significant number of degraded awareness reports, especially at intermediate durations. Intermediate ratings are most common at around 65 ms. The first criterion for degraded awareness states is met for all scales, with substantial numbers of degraded awareness reports. Consequently it needs to be determined, as per the second criterion, whether these degraded reports can be verified through the association with other measures.

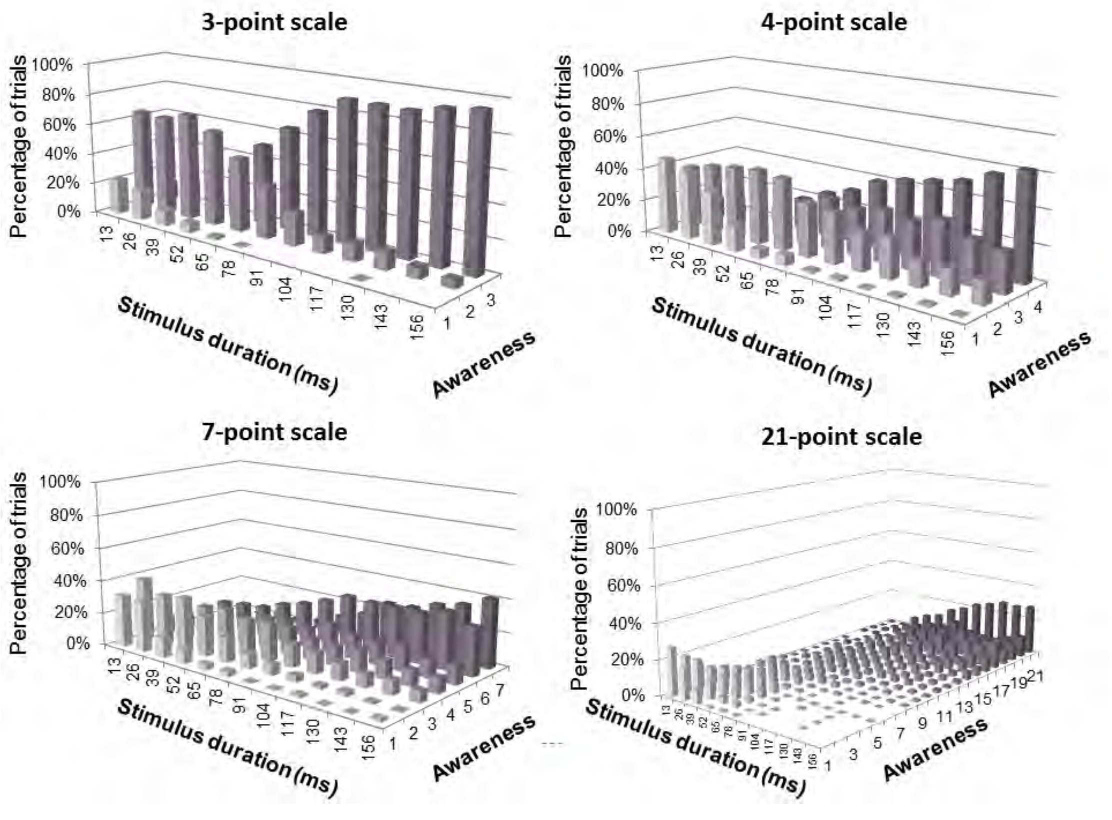

Figure 10. Awareness ratings as a function of stimulus duration in the four conditions.

Criterion (c): Verifying degraded states as distinct from conscious and unconscious states. The association between the stimulus duration and awareness data is displayed in

Figure 11, which reveals that longer stimulus durations are more likely to lead to higher mean awareness ratings.

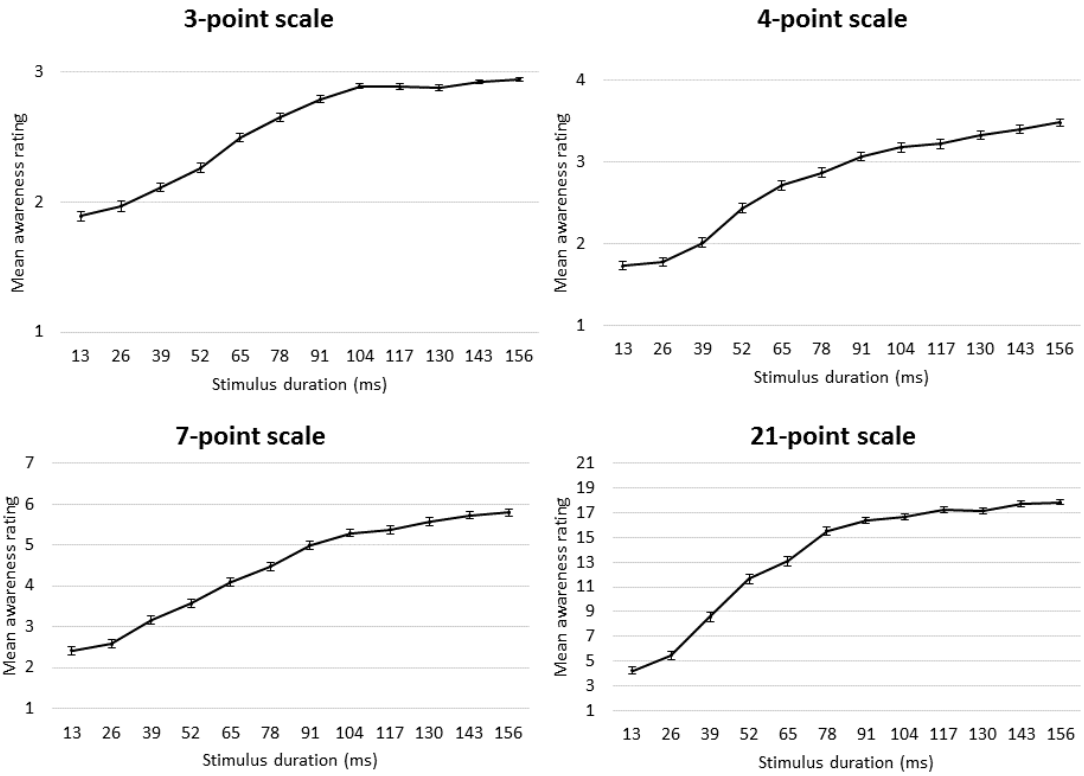

Figure 11. Mean awareness ratings as a function of stimulus duration. Error bars represent the standard error of the mean.

In order to test whether this association is statistically significant, and whether the intermediate reports of the four scales are unique, ANOVAs were performed with the awareness ratings as the dependent variable and stimulus duration as the independent variable. The results are summarised in Table 9. In all four conditions the effect of stimulus duration on awareness rating was significant.

Table 9

ANOVA Results of Effect of Stimulus Duration on Awareness Rating for Four Scale Conditions

		Stimulus duration (ms)							*F*	*p*	*Eta Squared*
		39	52	65	78	91	104	117			
3-point	M	2.11*	2.26*	2.50*	2.65*	2.79*	2.89	2.89	196.83	< .001	.42
	SE	0.03	0.04	0.03	0.03	0.03	0.02	0.02			
4-point	M	2.01*	2.43*	2.72*	2.87*	3.06*	3.18*	3.22*	140.71	< .001	.34
	SE	0.06	0.06	0.06	0.06	0.06	0.05	0.05			
7-point	M	3.16*	3.56*	4.09*	4.48*	5.00*	5.30*	5.37	158.64	< .001	.36
	SE	0.11	0.11	0.1	0.11	0.1	0.1	0.09			
21-point	M	8.57*	11.65*	13.09*	15.52*	16.39*	16.63	17.22	273.57	< .001	.49
	SE	0.4	0.39	0.38	0.3	0.27	0.25	0.23			

* Awareness ratings that are significantly different ($p < .05$) from both 13 and 156 ms, based on Tukey HSD post hoc comparisons. Only significant differences are shown.

Bonferroni adjustment was applied to the post hoc test alpha values to keep alpha levels below $p < .05$, the resulting alpha value per test (for 66 comparisons) was $p = .0007$. Post hoc comparisons were employed to assess which intermediate ratings resulted in significantly different ratings compared to the 13 ms (least visible) and 156 ms (most visible) conditions. The rationale for this approach was detailed in the previous experiment. These comparisons revealed that there are intermediate ranges of stimulus durations where all four of the scales show averaged ratings that are different from both the 13 and 156 ms conditions. For all scales this range starts from 39 ms, and extends to 91 ms for the 3-point and 21-point scale, to 104 ms for the 7-point scale and to 117 ms for the 4-point scale. The response distributions shown in Figure 10 rule out the possibility that the averaged data resulted from combining purely dichotomous (aware and unaware) ratings at the intermediate ranges. The data shows a high prevalence of degraded awareness reports at these durations.

The potential association between the awareness ratings and accuracy was tested through non-parametric ROC curves, illustrated in Figure 12.

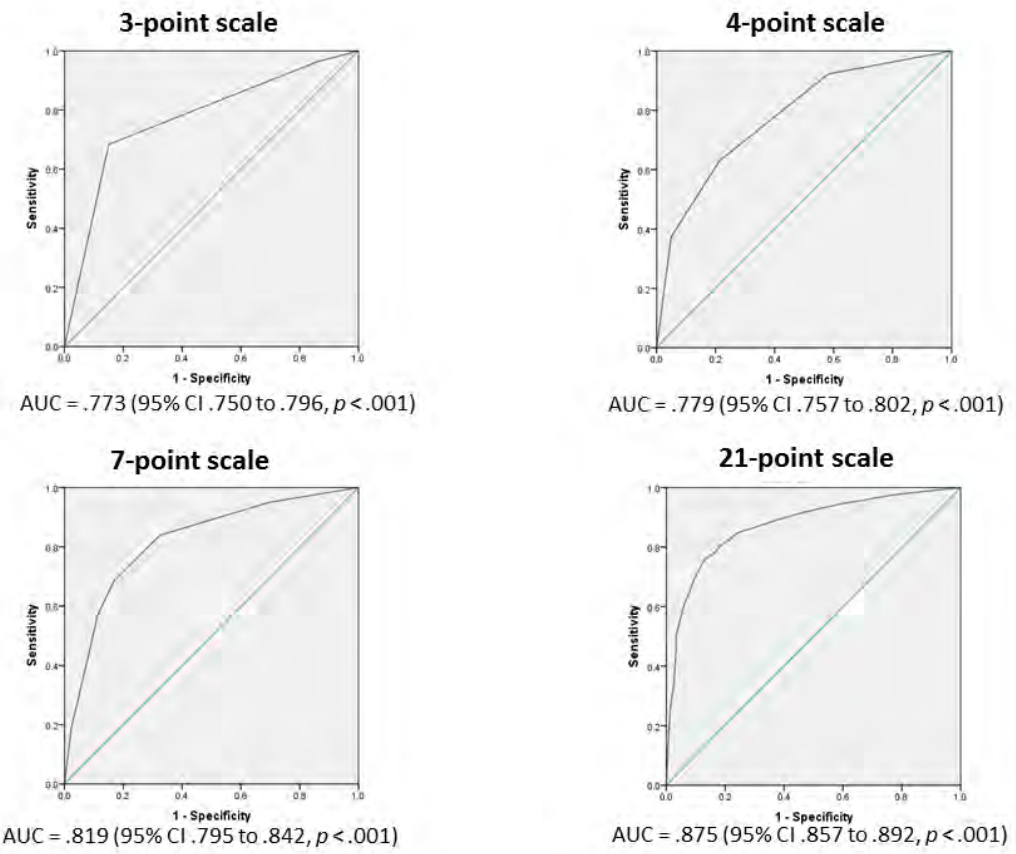

Figure 12. ROC curves for both conditions. The green line represents chance accuracy, at 25%. The blue line is the ROC curve based on the experimental data. Area under the curve (AUC) values, with upper and lower bound estimates at 95% confidence interval, are shown below the ROC curves.

For all scales the ROC analysis suggests an association between the awareness and the accuracy data. Scale length appears to influence the strength of the relationship, with longer scales having larger AUC values.

In summary, this analysis supports the idea that all four scales deliver degraded awareness data that can be verified through the association with other measures.

Primary analyses

Q3 Does the length of the awareness scale influence the form of visual consciousness? While verified degraded awareness reports are evident in each condition, the response distribution data also suggests that the proportion of reported awareness states may differ between conditions. Even though this appears evident from Figure 10, the differing scale lengths make direct visual and statistical comparisons difficult. In order to facilitate comparisons between scales a transformation of the scales was required. Different transformation strategies were considered in order to achieve comparability, as summarised below.

Simple mathematical solutions. Two simple mathematical solutions to the problem of comparing different scale lengths are: applying a simple proportional transformation, and normalising scores (Colman, Norris, & Preston, 1997). For the simple proportional transformation the 4-point scale scores would be multiplied by a factor to achieve scores comparable to the 3-point scale. A similar strategy is to convert scores from the different scales into standardised scores (e.g. Z-scores) with fixed means and standard deviations. The problem with both of these solutions is that they assume that a mathematical relationship underlies the scale use, while the differences are more likely to be psychological (Colman et al., 1997). Furthermore, even though the range of all scales will be comparable, a further transformation is required to convert all scales to three levels in order for them to be comparable.

Simple binning solution. Binning data from contiguous scale positions into the same category is a second option. The most straightforward strategy is binning all intermediate categories into a “degraded states” category to be comparable to the 3-point scale. Initially this may seem justified based on the fact that for all scales the endpoints had the same descriptions (“no experience” and “clear experience”). The resulting data is shown in Figure 13.

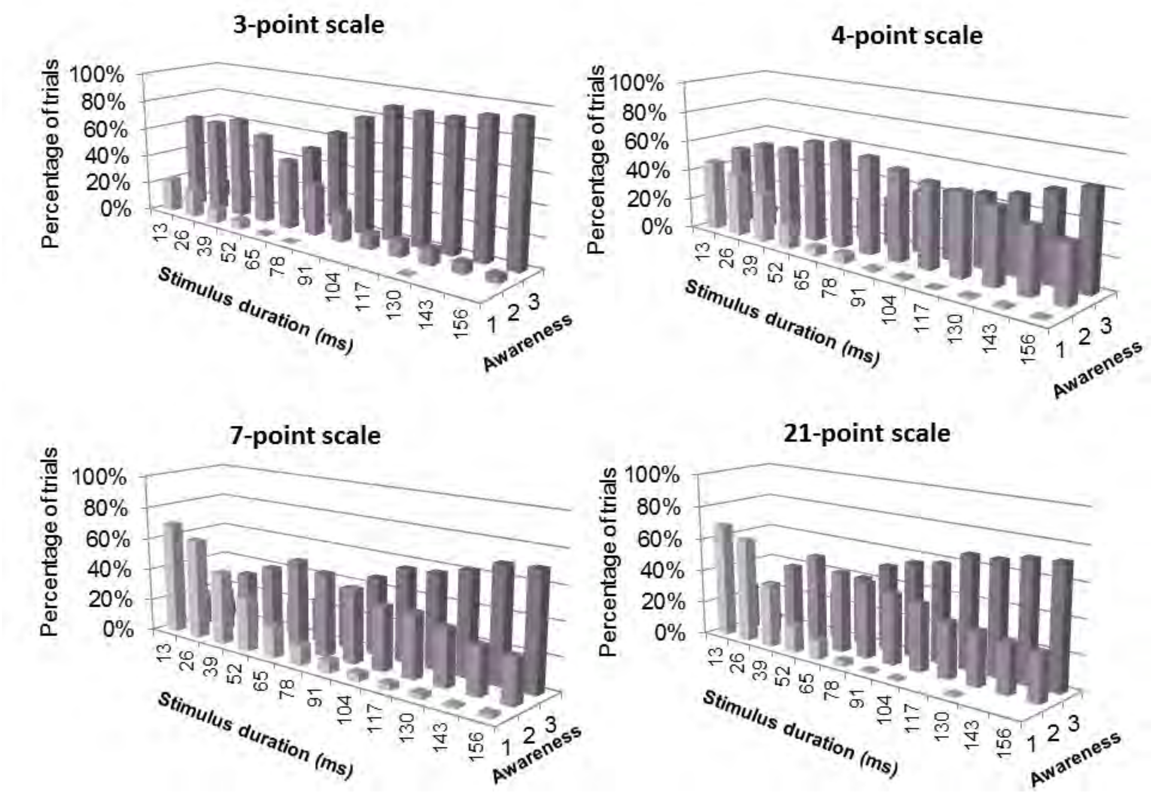

Figure 13. Awareness ratings transformed by binning all intermediate categories as a function of stimulus duration in the four conditions.

Binning all intermediate categories suggests a marked increase in degraded states as the scale length increases. However, the binning method may not be ideal for longer (7P and 21P) scales, and might have confounded “clear experience” and “no experience” with degraded steps. It is possible for example that a rating of “2” on the 21-point scale is perceptually similar to a rating of “1” on the same scale, and that the binning of all intermediate steps has missed this response error.

Other transformations. At least two other binning solutions have been employed in the debate. The first is found in a study by Sergent et al. (2005). The researchers used individual-level median responses as cut-off points to define “seen” and “not seen” states. However, amongst other problems, with this binary transformation it is impossible to detect degraded states. Another study (Nieuwenhuis & De Kleijn, 2011) that attempted to convert data from a

21-point scale to compare to a 7-point scale simply binned all three contiguous categories in series to get to the 7-point version. However, the authors admit that it is questionable whether the data would have looked the same had the original data been collected with a 7-step scale.

Criteria-based binning. A data-driven method of binning is introduced here that employs criteria based on the relationship of the stimulus duration to awareness. Firstly, it is required (and confirmed by the data) that there is a relationship between stimulus duration and awareness. Secondly, a number of criteria can be set that would characterise the three awareness states that need to be derived from the data:

1. An "unaware" state should be characterised by the following:
   a. High prevalence of reports at the shortest stimulus duration.
   b. Very low prevalence at the longest stimulus duration.
2. An "aware" state should have the following features:
   a. High prevalence of reports at the longest stimulus duration.
   b. Very low prevalence at the longest stimulus duration.
3. A "degraded" state should be identified by the following:
   a. Highest prevalence of reports at intermediate durations.
4. Binned states should be at contiguous positions on the awareness scales.
5. At the specified display duration the binned states should contain more reports than the two other possible states. For example, the percentage of "degraded" states at the intermediate durations should be higher than the percentage of "unaware" and "aware" reports.

In order to apply these rules 65 ms was identified as a unique intermediate timing category for comparison with the 13 and 156 ms conditions. This display duration was identified as unique for all scale versions tested through analysis of variance, as shown in Table 9. The post hoc Tukey tests identified the 65 ms duration as delivering unique mean ratings, significantly higher than at 13 ms, but significantly lower than ratings at 156 ms for all four scales. Based on these criteria, scale points were combined in order to achieve comparability, as displayed in Table 10.

Table 10

Scale Points Combined based on Binning Rules

	3-point	4-point	7-point	21-point
Unaware (1)	1	1	1–2	1–4
Degraded (2)	2	2–3	3–5	5–16
Aware (3)	3	4	6–7	17–21

Visual inspection of the resultant response distributions, illustrated in Figure 14, suggests data that appear more comparable across the varying scale lengths than the previous untransformed and simple binning data. The criteria-based binned data was compared in order to determine whether there are significant differences in the number of degraded states reported for each of the scales.

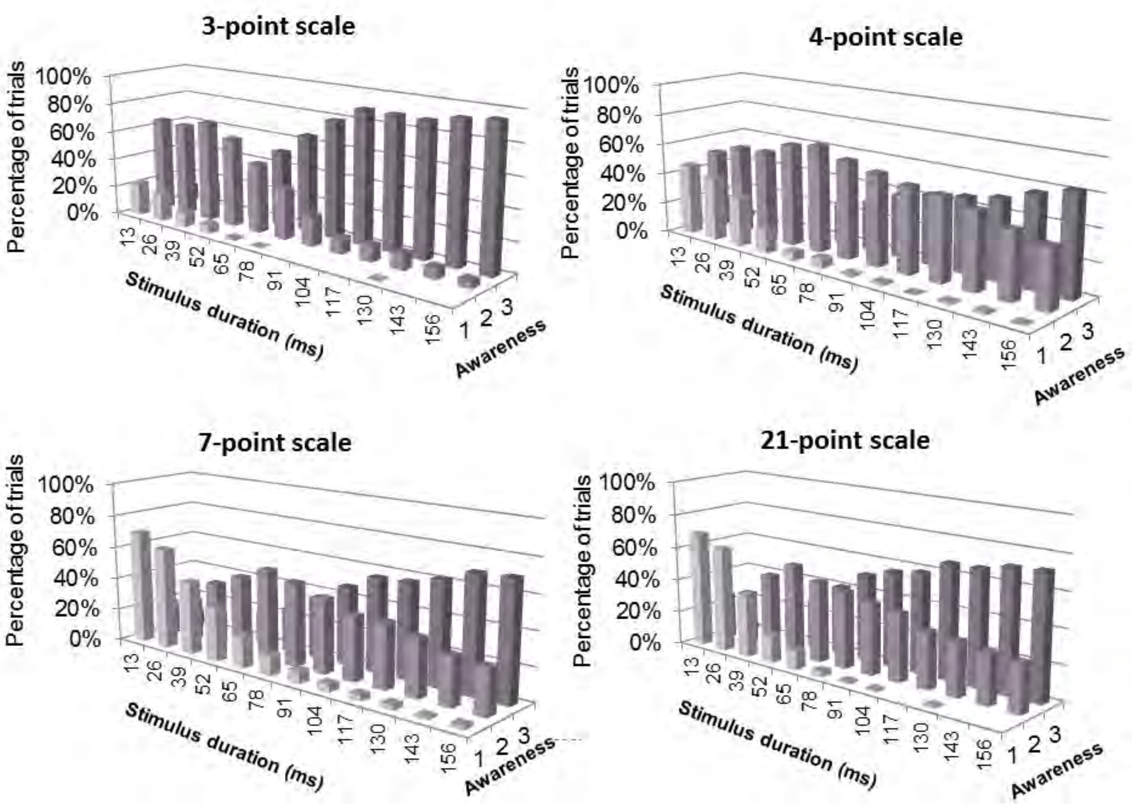

Figure 14. Awareness ratings transformed by criteria-based binning as a function of stimulus duration in the four conditions. Numbers represent awareness reports as follows: 1 = “Unaware”, 2 = “Degraded”, 3 = “Aware”.

Comparison of degraded states by scale. The percentage of total trials that delivered degraded reports of awareness is displayed in Figure 15. The use of the 4-point scale resulted in more degraded states than any of the other scales (53.7%). The 7-point (37.5%) and 21-point (37.9%) scales resulted in very similar proportions of degraded states. The lowest incidence of degraded states was reported with the 3-point version, with only 33.0% of all trials resulting in degraded reports.

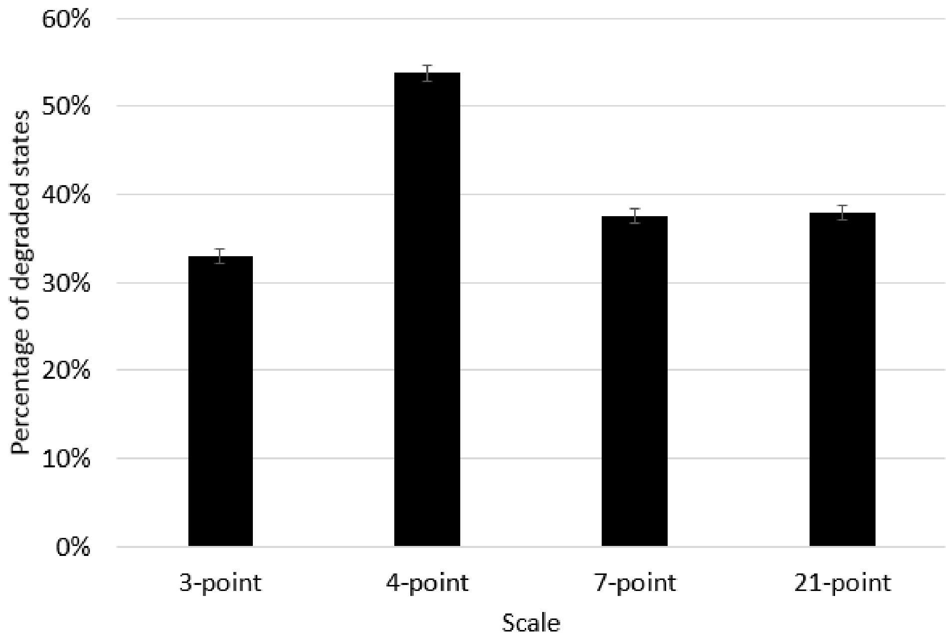

Figure 15. Percentage of total trials that delivered degraded reports by scale length. Data is based on rule-based binning. Error bars represent the standard error of the proportion.

Even though all the scales resulted in the same general conclusion about consciousness in this experiment, the magnitude of degradation suggested by the scales is significantly different. The chi-square test revealed that the effect of scale length on proportion of degraded states reported is significant, χ^2 (3, N = 12 288 from 32 participants) = 314.97, $p < .001$, *phi* = .160. Post hoc comparisons ($p > .05$) suggest the 7-point and 21-point scale do not differ significantly from each other. The 3-point scale delivered significantly lower degraded reports, and the 4-point significantly higher degraded reports than all other scales.

Regarding the central question and hypothesis that this data aimed to answer it is clear that (H4) is rejected: The 21-point awareness did not result in more dichotomous awareness ratings compared to the shorter 3-, 4- and 7-point scales.

Optimal scale length for perceptual awareness measurement. Despite differences in scale length, all four measures lead to the same conclusion about the form of consciousness – that consciousness can be degraded - but to differing degrees.

The next question is which of the scale lengths performs best as a measure of awareness. Ostensibly, longer scales have the ability to be more sensitive to small changes due to finer granularity. However, the risk is that the scale categories become ambiguous and trivial to respondents. The data from this experiment does show that longer scales tend to have more distributed responses, even under similar display conditions. Table 11 shows the individual responses in each scale condition at 156 ms, the longest display duration. Each participant was exposed to 32 trials at this duration. The data reveal a trend towards more distributed responses for longer scale lengths. This contrast is clear when comparing the shortest and longest scale versions. For the 3-point scale all participants used the third step (*clear experience*) more often than any others, an expected result. In addition the second most prevalent category (2) contained far fewer responses and was used by fewer respondents. However, for the 21-point scale there were four modal responses, all of which were not contiguous. Furthermore, the range of responses for the longest scale was 5 to 21, a large dispersion of scores. The variability under similar viewing conditions within and across participants was greatest for this scale. These effects on longer scales were evident for the intermediate 4- and 7-point scale lengths, but to a lesser extent.

What this means is that aggregating data from longer scales across participants, as would typically be done in these studies, is problematic. Some of these same issues have been discussed in the review of data transformation strategies. It is argued here that a key consideration for scale quality in the studies involved in the form of consciousness debate is lack of ambiguity for respondents and researchers. For participants this means that the scale categories should be clear and well defined. For researchers this means the way in which someone responds on the scale should be apparent and should not leave any guesswork on how to interpret the data. In this regard the shorter 3- and 4-point versions performed best, despite being less sensitive to small changes to perception.

Table 11

Individual Response Distributions (in Percentages) by Scale at 156 ms Display Duration

3-point	1	2	3
S1	0	0	100
S2	0	0	100
S3	0	0	100
S4	0	3.1	96.9
S5	0	3.1	96.9
S6	0	3.3	96.7
S7	0	13.3	86.7
S8	0	20	80

4-point	1	2	3	4
S9	0	0	0	100
S10	0	0	3.2	96.8
S11	0	3.1	9.4	87.5
S12	0	0	28.1	71.9
S13	0	16.1	25.8	58.1
S14	0	15.6	37.5	46.9
S15	0	29	51.6	19.4
S16	3.1	43.8	34.4	18.8

7-point	1	2	3	4	5	6	7
S17						12.5	87.5
S18				3.1	3.1	15.6	78.1
S19						53.3	46.7
S20	3.2	6.5	19.4	9.7	6.5	29	25.8
S21					15.6	59.4	25
S22	9.4		9.4	9.4	21.9	28.1	21.9
S23			25.8	35.5	12.9	22.6	3.2
S24				16.1	32.3	12.9	38.7

21-point	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
S25															3.1	9.4	87.5
S26					3.1					3.1				3.1	12.5	18.8	59.4
S27					3.1					9.4		9.4	6.3	6.3	18.8	18.8	28.1
S28					3.1				3.1			9.4	9.4	18.8	12.5	28.1	15.6
S29							3.1	3.1	3.1	0	6.3	9.4	12.5	21.9	9.4	15.6	15.6
S30								3.1	6.3	12.5	12.5	18.8	31.3	9.4	3.1	3.1	
S31							3.1		3.1	3.1	9.4	18.8	28.1	6.3	6.3	3.1	18.8
S32	3.1			6.3		9.4	9.4	6.3	3.1	12.5	12.5	3.1	28.1	3.1	3.1		

Note. Modal responses for every participant is indicated by the grey shading. Scale points 1 to 4 not shown for the 21-point scale as these points were not used at this stimulus duration.

Discussion

The study aimed to compare findings from four different scale versions in order to address two questions. Firstly, does the length of the awareness scale influence the form of visual consciousness? Secondly, what is the best measure of awareness in this set? The results revealed that findings from all scales suggest that a graded form of consciousness is observed in this experiment. Therefore this study does not support the notion that the 21-point scale should necessarily lead to dichotomous awareness ratings, as has been proposed (Nieuwenhuis & De Kleijn, 2011; Overgaard et al., 2006). The findings did show that the magnitude of the degradation estimated by the scales differs significantly. In this regard the 4-point version delivered the highest levels of intermediate awareness states. When comparing the quality of the scales it has been argued here that despite an increase in sensitivity for the longer 7- and 21-point scales there is also an increase in ambiguity for researchers and participants. The longer scales tend to require more judgements from researchers in order to analyse and interpret the data because of inconsistent participant-level responses. The shorter 3- and 4-point scales, while less sensitive, provide a simpler and clearer alternative.

Chapter 5

Form of Consciousness when Viewing Human Faces

Introduction and Background

Experimental work in the debate about the graded or dichotomous nature of conscious visual perception has relied on a limited set of simple stimuli to make progress. Objects such as words (e.g. Sergent et al., 2005), geometric shapes (e.g. Overgaard et al., 2008), alphanumeric characters (e.g. Del Cul et al., 2006) and textured displays (e.g. Overgaard et al., 2006) have been employed as the targets for identification in previous studies. Because the findings are contradictory on whether visual consciousness is a dichotomous or a graded phenomenon, some researchers have begun to ask whether different stimuli elicit qualitatively different forms of visual consciousness. For example, in two identical AB experiments Nieuwenhuis and De Kleijn (2011) found dichotomous awareness ratings for words and gradual ratings for numeric characters. A similar observation was made in the first experiment of this thesis, where shape stimuli were more likely to result in graded awareness states compared to words.

Consequently, what is required is to shift the focus of investigations in the area to the stimulus as an experimental variable (Garner, 1970). In doing so the generality of degraded or dichotomous awareness states will be addressed. This research agenda should extend to a greater diversity of stimuli, including those that are multidimensional, that are more likely to be encountered by humans in natural environments and that may be unique from the viewpoint of a conscious perceiver. Without these type of stimuli conclusions drawn will be limited to easily manipulated experimental stimuli.

Human faces (and face images) appear to fulfil these requirements. Evidence from a number of research areas suggests that face perception is a specialised form of object perception. In behavioural studies face perception has been shown to be more markedly disrupted by inversion than other objects (Yin, 1969). The use of functional magnetic resonance imaging (fMRI) has led to the identification of an area in the fusiform gyrus (the fusiform face area) that is selectively involved in the perception of faces (Kanwisher, McDermott, & Chun, 1997). Electrophysiologically, M170 in MEG (Tanskanen, Näsänen, Ojanpää, & Hari, 2007) and N170 in EEG (Moulson, Balas, Nelson, & Sinha, 2011) have also been identified as face-selective responses. Neuropsychological investigations, such as that by Farah, Klein, and Levinson (1995), have demonstrated that face recognition can be selectively impaired, while leaving other object recognition unaltered, a condition known as prosopagnosia. Collectively, the findings suggest that face perception is specialised and domain-specific (Farah, Wilson, & Tanaka, 1998; Kanwisher, 2000).

An alternative view should be noted to the specialised module hypothesis of Kanwisher and colleagues. Others have suggested a distributed network model (Haxby, Hoffman & Gobbini, 2002; Haxby & Gobbini, 2011). This view does retain an emphasis on a *core system* involved in the visual analysis of faces, but it elaborates with an extended system that extracts additional information from faces.

The conclusion that face processing is specialised, along with the multidimensional visual nature of faces, the social importance of face perception, the commonness of faces as stimuli in natural environments, and the dissimilarity of faces to previously employed visual targets, presents a promising extension to research on the potentially graded nature of visual consciousness[14]. While the debate has used simple stimuli to date, faces offer an omnipresent and real-world stimulus set. With findings from previous studies, such as those by Nieuwenhuis and De Kleijn (2011) and the third chapter of this thesis, having already shown a difference in the form of visual consciousness depending on the type of stimuli being

[14] It is worth noting that the unique nature of face perception may cause findings that are not representative of other natural objects and scenes. Despite this the value of employing face stimuli remains defensible based on the reasons provided here.

observed, this is a significant opportunity to broaden the understanding of the nature of visual consciousness under different perception conditions.

Evidence for Categorical Face Perception

Prior research unrelated to the present debate has suggested that face information (e.g. identity, gender, emotion) is perceived categorically. Beale and Keil (1995) found that the identification of famous faces happens in a categorical fashion despite participants being presented with linearly varied morphed face images. Regarding face gender, Campanella, Chrysochoos, and Bruyer (2001), as well as Freeman, Rule, Adams, and Ambady (2010), found that when a facial image is manipulated to change gradually across unfamiliar male and female faces, gender is perceived categorically as opposed to continuously. The recognition of emotional facial expressions, when varied across a continuum (happiness–sadness, sadness–anger or anger–fear), has also been found to happen dichotomously with a sudden shift from one emotion to the other (Calder, Young, Perrett, & Etcoff, 1996).

Despite the seemingly unequivocal findings supporting dichotomous face perception, the prior research suffers from at least two drawbacks that make the findings less applicable to the debate on the form of visual consciousness. Firstly, these studies employed a binary detection task (male vs female, happy vs sad, face a vs face b) in most cases, which is not an optimal approach when trying to detect gradual shifts in awareness (Overgaard et al., 2006). A study (Freeman et al., 2010) that employed an elaborated scale requested ratings of perceived masculinity or femininity, and not the awareness state of participants. The data from this study does thus not directly address the form of visual consciousness. Secondly, the objective parameter that has been continuously varied in these studies has been limited to face visual detail (degree of masculinity or femininity, level of emotion, etc.) with limited investigations into the effect of stimulus duration, which is a more commonly manipulated parameter in the debate on visual consciousness. At least one study in face recognition has used a backward masking paradigm with varying stimulus durations, but still employed a dichotomous recognition task (Tanskanen et al., 2007). Due to the methodological constraints in the extant research on the matter, the question of whether the conscious recognition of faces is a dichotomous or a gradual phenomenon is still unresolved.

Stages of Processing and Face Perception

Addressing the conscious status of face recognition requires a clearly delineated notion of what face recognition entails. Indeed, face recognition appears to be multifarious rather than a unitary concept or process. For example, a popular model of face perception (Bruce & Young, 1986) argues that face perception proceeds through stages, ranging from extracting detail about the face (e.g. age and gender) to linking the visual input with stored memories about the person being viewed. Accounting for the different stages of face perception is important, and it dovetails with a recent proposal in the form of visual consciousness debate. The processing hierarchies hypothesis, reviewed in Chapter 2, has been proposed as a means to reconcile the inconsistent findings in the area (Windey et al., 2013). The researchers propose that the differences in findings observed in studies arguing for a graded or binary view of visual consciousness can be explained, at least in part, by the level of processing at which the study directed the awareness task. Their study supported this idea and found that high-level processing (e.g. judging whether a numeral is smaller or larger than “5”) occurs less gradually than lower-level tasks (such as identifying the colour of the same briefly flashed numeral). While these initial results seem promising, further research is required to test the usefulness of their proposition. The experiment reported in Chapter 3 of this thesis found limited differences in awareness for different features of the same stimulus in most conditions. Probing the subjective state of participants when distinguishing the basic and subordinate level of face processing as proposed here adds an important further test of this hypothesis.

In the face perception literature evidence from MEG (Liu, Harris, & Kanwisher, 2002) and from the gated detection hypothesis (Tsao & Livingstone, 2008) points to at least two stages of face perception. An early *categorisation stage*, which distinguishes between faces and other objects, is followed by an *identification*, where individual faces are recognised.[15] It appears possible that information could be present at one level but not the other. A question for the present research is whether the early categorisation stage will result in a more graded form of visual consciousness compared to the secondary identification phase, as would be predicted by the levels of processing view.

In order to accurately characterise the nature of the subjective awareness degradation this study employed faces and non-face objects and required participants to proceed through a categorisation of the object as a face or non-face, and secondly to identify the specific face that was presented.

In summary, it is still unclear whether the conscious recognition of faces involves a gradual or a dichotomous shift in awareness with brief and varying exposure durations. A direct investigation into this question contributes to answering two of the primary questions of this thesis with information on the generality of degraded conscious states by employing a set of stimuli unstudied in the extant literature on the degradation of visual awareness.

Q2 Does the type of visual stimulus influence the form of consciousness?

H3: Face stimuli will result in more dichotomous awareness ratings compared to other (control) stimuli.

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[15] While the typical trajectory of object perception involves a temporal sequence from basic (object domain, such as recognising a face as opposed to a house) to subordinate (e.g. John's face), it is worth noting that Tanaka (2001) found evidence that adults' "expertise" in recognising familiar faces promotes a downward shift in recognition performance. Thus, as soon as the basic level is recognised (a face as opposed to another object), the person is able to accurately name the identity of the face at the same time. This ability appears unique to familiar faces. It is expected that the use of unfamiliar faces in this study will avoid this potentially confounding factor.

Q4 Do features of the same visual stimulus on different levels of processing elicit dissimilar forms of consciousness?

H5: Features on distinct levels of processing will differ significantly in the level of degradation.

Method

Design

The experiment contained two conditions. Participants took part in both conditions in a within-participants design. In the *categorisation* condition the participants' task was to name a briefly flashed object as a face or non-face object. In the *identification* condition they were asked to identify which exact face was presented in the trial.

Participants

A total of 12 participants took part in the experiment. After data screening a participant who reported the same PAS response on all trials in the identification condition was excluded. Results are reported for the remaining 11 participants (nine females, ages 24–40, M = 31.1, SD = 4.74). All participants reported normal or corrected-to-normal vision, normal colour vision and no history of a psychiatric condition or neurological damage.

Procedure and Materials

Masking procedure. Participants took part in a backward-masked visual identification task similar to the one employed in the second experiment of this thesis, and adapted from a previous study (Sandberg et al., 2010). The important difference was the use of face images and other objects rather than geometric shapes as recognition targets.

Categorisation condition. Each trial started with a fixation cross presented on a computer screen for one of two durations (493 or 1 972 ms). The fixation cross was replaced by one of 30 faces or 30 other objects, or a blank screen. The target stimuli were presented for one of ten durations (13, 26, 39, 52, 65, 78, 91, 104, 156 or 195 ms, determined by the 75 Hz refresh rate of the CRT monitor). A backward mask, consisting of scrambled greyscale squares, followed the target image and was displayed for 3 000 ms. Participants were first prompted to identify whether a face was presented or not by pressing buttons on a keyboard ("z = a face", "m = not a face"). This was followed by the 4-step PAS (Ramsøy & Overgaard, 2004) displayed on the screen with the question "How clearly did you see the image?" and options "1 = no experience", "2 = brief glimpse", "3 = almost clear" and "4 = clear experience". Participants used the numbers 1 to 4 to indicate their experience according to this scale.

The 4-point scale was chosen because the previous experiment, reported in Chapter 4, had shown that this scale length delivered the highest incidence of degraded conscious state reports. For the purposes of this experiment it was important that degraded consciousness was maximally detectable.

Participants received feedback after each trial on whether they were accurate and what the total percentage correct was thus far.

Identification condition. This condition also started with a fixation cross presented on a computer screen for one of two durations (493 or 1 972 ms). The target stimuli in this condition consisted of 30 faces only (the same 30 faces used in the categorisation task) and 20 blank trials. Stimuli were also presented for one of ten durations, followed by the same noise mask. Participants were then simultaneously presented with images of two faces, one that was actually displayed in the trial and one incorrect foil. Participants used the same buttons as in the categorisation task to indicate their responses ("z = left", "m = right"). The presentation position (left or right) of correct faces was randomised across trials. The next screen asked for a PAS rating in the same way as the categorisation condition, and was followed by the feedback display. Figure 16 summarises the trial procedure.

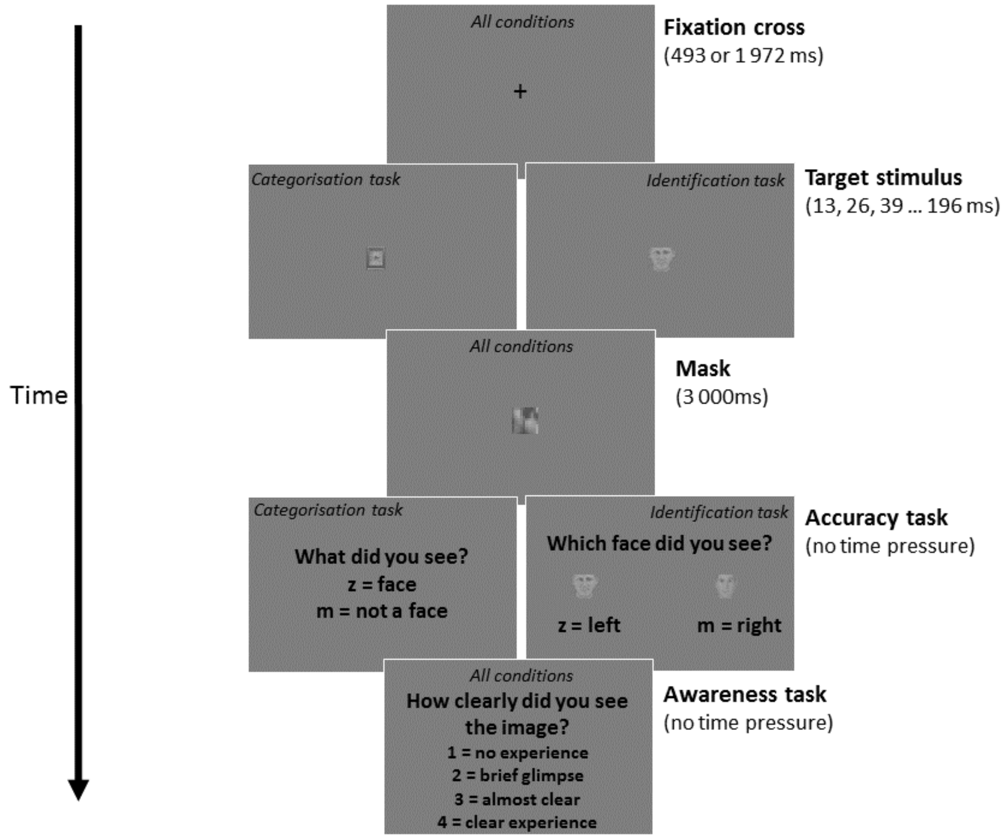


Figure 16. Trial procedure during the third experiment.

Session procedure. The order of conditions was counterbalanced across participants. After informed consent was obtained and the procedure was explained, the participants took part in a brief training session containing 20 trials at the longest display durations. Training was repeated before the second condition was introduced. In each condition participants took part in 140 trials, in which the order was randomised, for a total of 280 trials. In the categorisation condition 30 faces and 30 objects were displayed twice at each timing level, along with 20 blank trials displayed at 13 ms. In the identification task 30 faces were each displayed four times at each duration, with 20 blank trials displayed for 13 ms. Participants were not informed that there were to be trials where no stimulus was presented, and were still prompted for their responses in these trials. This was done in order to create a condition where no experience of an image was possible as a control for other durations. Participants took a brief break between sessions, and the total sessions lasted about 60 minutes. All trials were completed in a quiet room with attenuated lighting, free from distractions and noise.

Images. The 30 face images used in both conditions were selected from a collection maintained at the University of Cape Town by CG Tredoux. All face images were of White males, with the choice being based on similar frontal face orientation, neutral facial expression, devoid of beard, moustache, glasses and similar prominent characteristics. Images were cropped to contain only faces, with hair removed. The 30 other objects used in the categorisation condition were chosen from the Amsterdam Library of Object Images (Geusebroek, Burghouts, & Smeulders, 2005). Images were of everyday objects such as shoes, clock faces and small toys. In order to avoid salient lighting and colour features all images were converted to greyscale, with similar illumination colour, and all trial screens had a grey background. All stimuli were presented in the centre of the computer screen at a viewing distance of ~ 60 cm subtending a visual angle of 3.3 x 2.1°. Final images used in the study were prepared after a pilot study conducted with eight individuals found a ceiling effect in the accuracy data in the categorisation condition. Based on this finding images were degraded further in order to make the task more difficult by making all images smaller, pixelating the images and cropping faces to remove hair.

Results[16]

Accuracy Data

For the accuracy data all stimulus absent trials were excluded, because there was no correct response to these trials. Figure 17 shows the percentage of targets correctly identified as a function of stimulus duration in the two conditions. The chance performance level is 50%. For the categorisation condition, the chi-square test revealed no difference in the accuracy across the two types of stimulus employed (88.0% for faces and 89.2% for the other

[16] Raw data files are available as Appendix B.

objects), χ^2 (1, N = 1 320 from 11 participants) = .481, $p > .05$, phi = .019. For this reason the data from both face and other object trials are analysed collectively here.

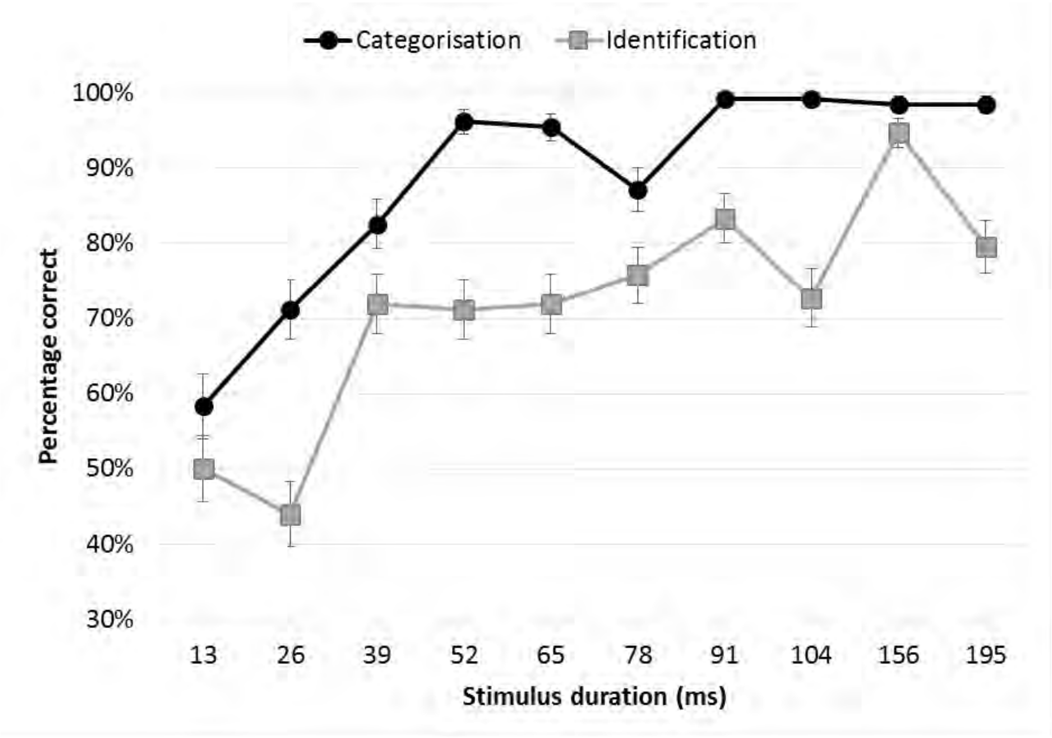


Figure 17. Accuracy data: the proportion of targets accurately identified as a function of stimulus duration. Error bars represent the standard error of the proportion.

Comparing the difficulty of the categorisation and identification tasks it is evident that the identification task was more difficult. The identification task (M = .72, SD = .09) showed a significantly lower average proportion correctly reported compared to the categorisation condition (M = .89, SD = .04), in the dependent samples t test, $t(10) = 7.88$, $p < .001$, Cohen's d = 2.44. The difference in task difficulty is evident across the range of stimulus durations, with the categorisation task exceeding 90% accuracy at 52 ms, while the identification task exceeded 90% only at 156 ms.

Q3 Does the Type of Visual Stimulus Influence the Form of Consciousness?

The third major hypothesis (H3) of this thesis proposes that face stimuli will be perceived in a more dichotomous fashion compared to other objects. Table 12 displays the relevant data that compares the prevalence of reports of each kind of state in the categorisation condition. The proportion of PAS awareness ratings does not differ significantly based on the type of shape displayed in the categorisation task (face vs other objects), $\chi 2$ (1, N = 1 320 from 11 participants) = 3.27, $p > .05$, *phi* = .05. When comparing the distribution of responses at each timing interval the same conclusion is achieved, with no differences at any of the display durations ($p > .05$).

Faces appear just as likely as other objects to result in graded awareness states, and as such (H3) is rejected. Because there is no difference in the ratings between faces and other objects for the rest of the analysis the categorisation condition data is considered collectively.

Table 12

Percentage Reports of Awareness States for Faces and Other Objects in the Categorisation Condition (1320 trials from 11 individuals)

	Shape type		
	Face (n = 660 trials)	Other (n = 660 trials)	Total (n = 1320 trials)
No experience	16.2%	18.6%	17.4%
Brief glimpse	43.8%	39.2%	41.5%
Almost clear	15.6%	15.8%	15.7%
Clear experience	24.4%	26.4%	25.4%

Evidence for Degraded States

In this thesis a degraded state has been considered present in an experiment if (a) it is claimed to be degraded awareness, (b) it can be reported, (c) its presence can be verified as distinct from both unconscious and conscious states, (d) and (a) to (c) occur under optimal reporting conditions. Similar to previous experiments in this thesis criterion (d) is met and so the other three criteria are considered.

Criteria (a) and (b): Reports of degraded states. Was there evidence of degraded awareness states when faces were perceived? Figure 18 displays the mean and percentages of

PAS ratings by stimulus duration. Both tasks resulted in a high frequency of reported degraded awareness states – as high as 70% at 52 and 65 ms for the categorisation task, and 80% in the identification task at 91 ms.

The more difficult identification task (M = 43.64, SD = 19.10) produced a significantly higher frequency of *no experience* reports compared to the categorisation task (M = 20.91, SD = 10.89), $t(10) = -3.87$, $p = .003$, Cohen's d = 1.46. Further evidence of the difference in difficulty level is the fact that the identification task (M = 6.81, SD = 8.89) also produced a significantly lower frequency of *clear experience* reports compared to the categorisation task (M = 30.45, SD = 30.1), $t(10) = 3.11$, $p = .011$, Cohen's d = 1.06. Multiple paired t-test comparisons revealed that the averaged data across the two conditions supports this finding and reveals lower PAS ratings for the identification condition on the majority of durations (p < .05), except 39, 156 and 195 ms.

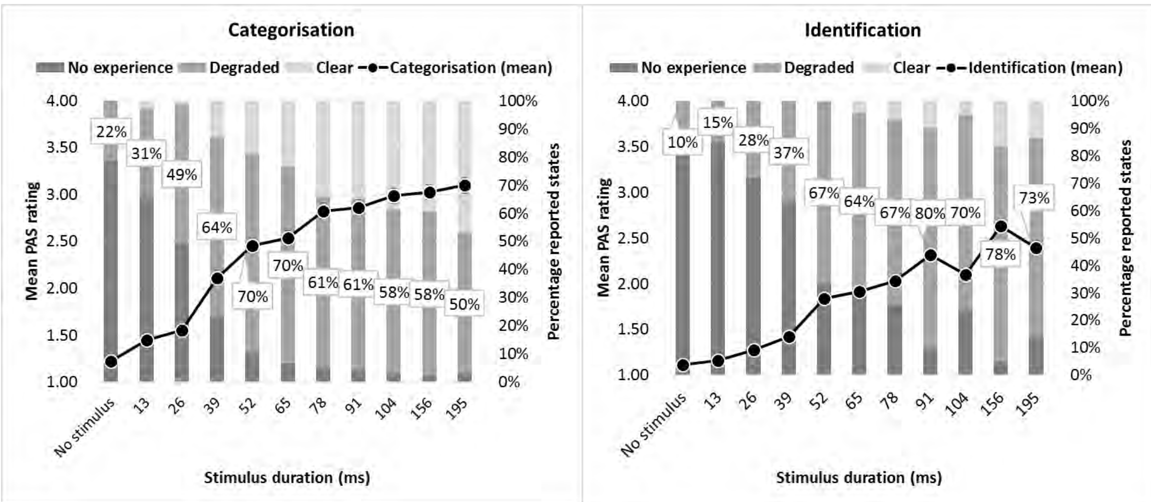


Figure 18. Awareness (PAS) data as a function of stimulus duration. Stack bar charts show the percentage of awareness states reported at each duration and the no stimulus trials. Data call-out percentages show the percentage of degraded states. The line graph depicts the mean PAS rating at each timing level. Error bars represent the standard error of the mean.

Criterion (c): Verifying degraded states as distinct from conscious and unconscious states. If degraded awareness states are robust and meaningful categories of experience, there should be an association between these reports and other measures. Two associations are tested here: the relationship with stimulus duration and accuracy. The mean data in Figure 18 appear to show the gradual building of awareness across the stimulus durations, with average ratings in both conditions at intermediate durations being distinct from “no experience” and “clear experience” reports. In order to statistically test for the uniqueness of the intermediate states of awareness, ANOVAs were performed with PAS rating as the dependent variable and stimulus duration as the independent variable. Both analyses showed that the effect of stimulus duration on PAS rating is significant, for the categorisation task $F(10,1639) = 127.45$, $p < .001$, *Eta squared* = .437, as well as the identification task $F(10,1639) = 101.17$, $p < .001$ *Eta squared* = .382.

The post hoc Tukey HSD comparisons for the categorisation condition reveal that the range of durations from 26 to 65 ms each resulted in ratings significantly different from the no stimulus trials (which had the highest “no experience” reports), and also significantly different from the 195 ms trials (which had the highest percentage of “clear experience” reports), with all comparisons $p < .001$. Similar to previous experiments Bonferroni adjustment was applied to the post hoc test alpha values to maintain alpha $p < .05$, resulting in an effective alpha value per test (45 comparisons) of $p = .001$. In the identification condition each timing level in the range from 26 to 78 ms resulted in ratings significantly different from the no stimulus and 156 ms (highest rating) conditions, with all comparisons $p < .05$. It is thus possible to isolate unique intermediate states that are different from completely aware and unaware states. While mean data could be misleading, because they could result from averaged jumps between unaware and aware states, it is apparent that this is not the case with a substantial number of degraded states evident in the data, especially at intermediate ranges.

In order to test for the association between PAS rating and accuracy non-parametric ROC curves were employed in both conditions, as presented in Figure 19. The area under the

ROC curve for the categorisation condition was .854 (95% CI .835 to .874, $p < .001$), and was .708 (95% CI .682 to .733, $p < .001$) for the identification condition. In both conditions the PAS measure shows sensitivity to and association with the accuracy data.

The findings suggest that there are substantial reports of degraded awareness states in both conditions that can be verified through the association with other measures.

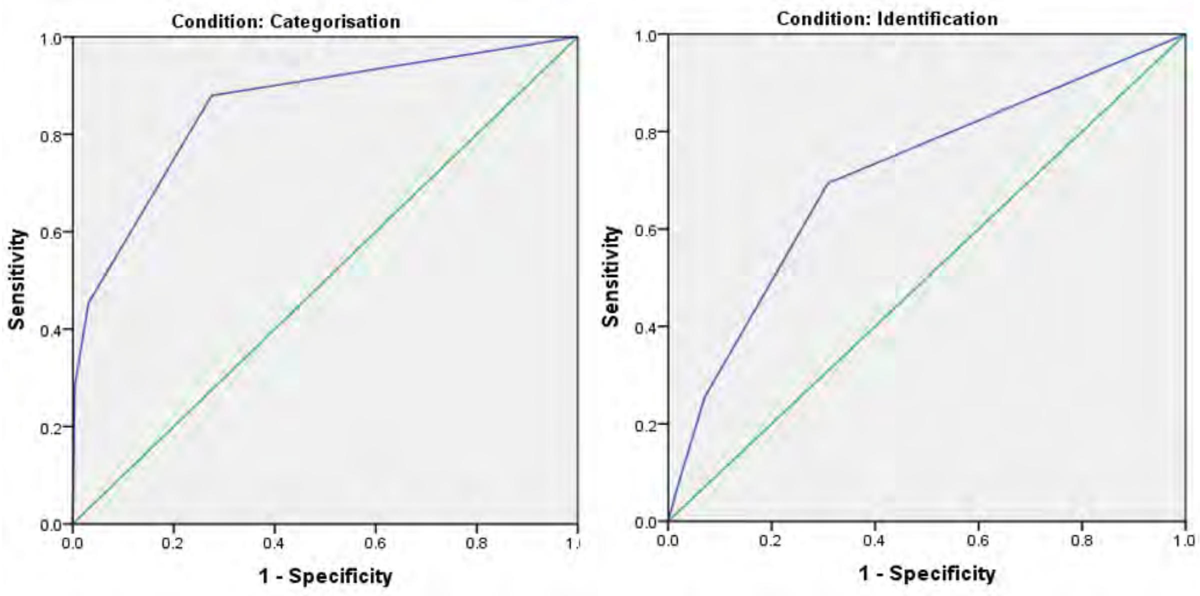


Figure 19. ROC curves for both conditions. The green line represents chance accuracy, at 50%, with an equal number of hits and misses. The blue line is the ROC curve based on the experimental data.

Q4 Do Features of the Same Visual Stimulus on Different Levels of Processing Elicit Dissimilar Forms of Consciousness?

The following analysis attempts to answer the question of whether the gradual or dichotomous nature of visual awareness differs depending on the level of processing, as suggested by a recent study (Windey et al., 2013). Two perspectives on this question are investigated: firstly, whether the frequency of the overall number of degraded states differs between conditions, and secondly whether the proportion of degraded states reported at each timing level differs significantly. Figure 20 displays the data relevant to both questions.

Regarding overall degraded states, the conditions do not differ, with both delivering ~ 50% reports of degraded awareness states. The mean number of degraded reports for the categorisation condition (M = 68.63, SD = 30.84) was very similar to the identification condition (M = 69.54, SD = 18.62), t(10) = -.104, *p* > .05, Cohen's *d* = .03.

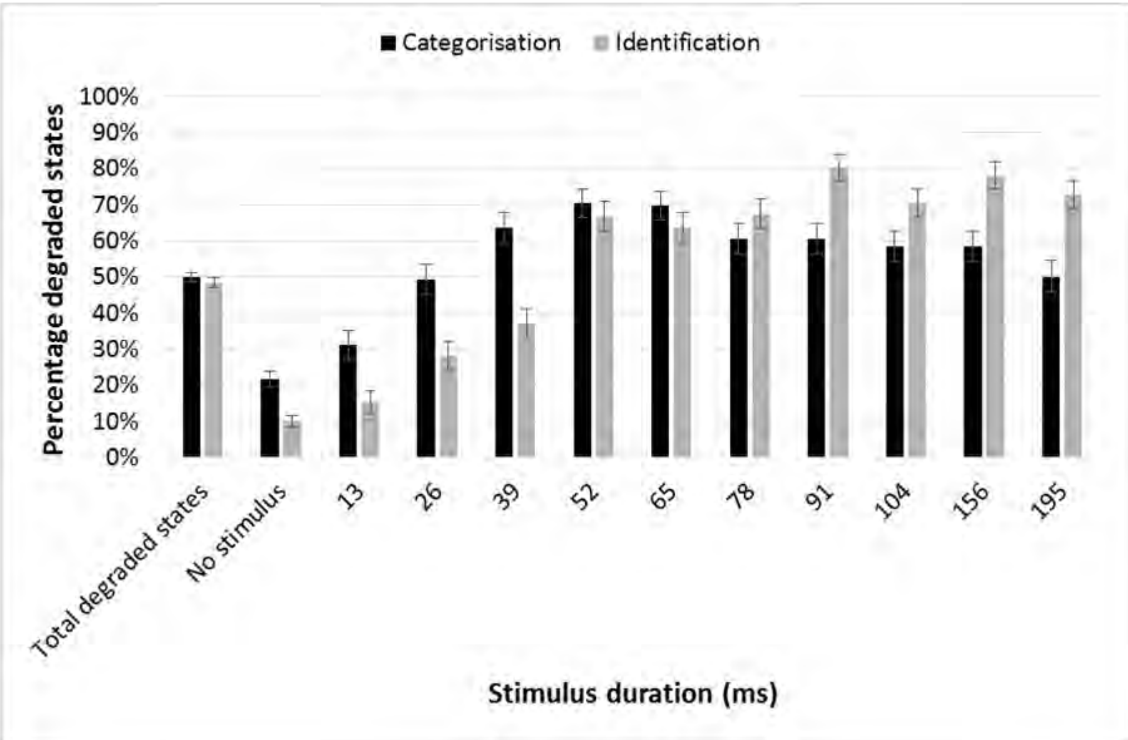


Figure 20. Degraded awareness states on a total level and as a function of stimulus duration. Error bars represent the standard error of the proportion.

The data viewed across stimulus duration reveals a different pattern. The most difficult trials from 13 to 39 ms resulted in significantly more degraded states for the easier categorisation condition, while the longer duration trials (91 ms and longer) resulted in more degraded states for the identification condition. All differences are significant (dependent samples *t* tests, *p* < .05). The conditions do not differ significantly in the intermediate 52 to 78 ms range (dependent samples *t* tests, *p* > .05). Task difficulty meant that the identification condition, even at longer durations, was more likely to be reported as not completely clear.

The increase in degraded states at longer durations for the identification condition is due to the shift from “no experience” to “degraded experience” reports, as is evident in Figure 18.

This leads to the conclusion that (H5) is rejected in general terms, because both levels of processing contained verified degraded awareness states. At the same time there is a dissociation in the awareness ratings across the timing levels, which warrants further examination of the concept of dissociable levels of processing.

Discussion

The study aimed to understand whether the conscious perception of faces is more or less graded than other objects, and whether this differs according to the stage of face perception. The findings showed many reports of degraded states in both the identification and categorisation stages. Importantly, these reports are corroborated through their association with accuracy and display duration. These results suggest that face perception can be degraded to verifiable non-zero levels without being completely eliminated. The general conclusion that visual awareness can be degraded is thus supported by these findings. This research adds to previous studies, such as Nieuwenhuis and De Kleijn (2011) and the experiment reported in chapter 3 that have found that certain manipulations of visual awareness at the level of stimulus quality can result in degraded states of awareness.

The findings comparing the nature of visual consciousness across the categorisation and identification conditions showed that while both conditions resulted in the same number of degraded states on a total level, the nature of degradation across the display range differed significantly. This finding offers two implications. Firstly, degradation, and not elimination, of consciousness occurs in both stages of processing. In each condition a specific range of durations resulted in predominantly degraded states. Accordingly, with the methods employed here, this study does thus not support the levels of processing hypothesis as set out by Windey et al. (2013). As noted by these authors the method employed in that study used averaged data, which does not make for ideal comparisons of degraded states, because degraded averaged states could result from completely dichotomous trial-level data. The methods employed here avoid this challenge. Secondly, it is becoming increasingly clear that degradation can be more or less present, depending on the interaction between level of processing and stimulus duration. It appears sensible to consider the relative level of degradation and not to classify findings as simply “dichotomous” or “graded”.

Chapter 6

General Discussion

Is Visual Consciousness Graded or Dichotomous?

In this thesis the debate of whether visual consciousness is graded or dichotomous was investigated. Arp (2007) introduced a useful metaphor for the two accounts of consciousness as being either an on-off switch or a switched-on rheostat[17]. The dichotomous view, that proposes that consciousness is always in either an *on* or *off* position, is offered by researchers who rely on GNWT as a theoretical framework (e.g. Sergent & Dehaene, 2004). The conflicting graded view states that consciousness permits degrees from *dim* to *bright* once it has been switched on (e.g. Overgaard et al., 2006). The literature review chapter demonstrated that empirical investigations have not resolved the matter conclusively, because both positions have been able to provide data that are consistent with their main ideas.

It was the aim of this thesis to clarify the factors that may modulate the graded or dichotomous nature of consciousness. To this end, the three experiments reported in this thesis explored the effects of the visual degradation technique, stimulus type, awareness scale length and stimulus processing level on the conclusion about the form of visual consciousness. The findings suggest that conscious visual perception can be degraded, but that the magnitude of degradation is dependent on the viewing conditions and rating scale employed.

These empirical findings reinforce the conceptual arguments put forward in Chapter 2 that the idea of pursuing a general solution to the form of consciousness question may not be particularly useful or capable of yielding a precise understanding. I argued that the question of whether visual consciousness *is* graded or dichotomous is a restrictive way of framing the debate. There is now a great deal of evidence reported in the literature to support the claim

[17] It should be noted that Arp (2007) introduced this comparison in the context of the level of consciousness, not the content of consciousness. Still, the metaphor is equally appropriate in this instance.

that some states of visual consciousness are degraded. Still, this is only one component of the debate. A full understanding of the phenomenon extends to issues around the *degree* of degradation of consciousness and in *which circumstances* degraded consciousness is exhibited. It is these issues that were the main themes of this thesis. In this chapter the key ideas that have emerged are reviewed with reference to the experimental findings presented in this work. This chapter will end with the limitations of the present research and will provide suggestions for further investigation.

Visual Consciousness Can be Degraded

On the whole, the findings of this thesis are consistent with the view that visual consciousness can be degraded, aligned with several studies reviewed in Chapter 2 (e.g. Overgaard et al., 2006; Ramsøy & Overgaard, 2004; Sandberg, et al., 2011; Sandberg et al., 2010). Further, as was demonstrated in the empirical chapters, the veracity of these reports can be assessed with reference to a defensible definition of degradation offered in Chapter 2. In this literature review chapter a working definition of a *degraded* conscious state was developed, by adapting the criteria for *conscious* and *unconscious* states commonly employed by McGovern and Baars (2007). It was argued that a degraded conscious state should have the following features: (a) is claimed to be degraded awareness, (b) can be reported, and (c) its presence can be verified as distinct from both unconscious and conscious states (d) under optimal reporting conditions.

Criteria (a) and (b): Reports of Degraded States.

Criteria (a) and (b) require that degraded states should be reported as such. These criteria were met in the research described in this thesis: The data from all the experiments contained degraded state reports. The incidence of degraded consciousness reports in the series of studies ranged from 30.2% in the AB word condition colour reports of Experiment 1 to 77.8% for the masked shape condition colour reports in the same experiment. All other studies contained claims of degraded states in excess of 32%. Further, by focusing on specific conditions within the experiments (e.g. intermediate stimulus display durations), it was possible to identify conditions with a disproportionately high percentage of degraded states. For example, in Experiment 2 the 3-step awareness scale produced 33.8% claims of degraded states across all trials, whereas the intermediate stimulus display duration of 39 ms evoked 68.8% claims of degraded states. The evidence presented in these experiments thus meets the two initial requirements for degraded states with substantial reports of these kinds of experiences.

Criterion (c): Verifying Degraded States as Distinct from Conscious and Unconscious States

Criterion (c) requires that the presence of degraded awareness states should be verified as distinct from conscious and unconscious states. One strategy for verifying these reported states was introduced by Overgaard et al. (2006), who tested the association between the awareness reports and two other objective variables: accuracy and stimulus duration. The experiments reported in this thesis followed a similar strategy and emphasised a more specific way of testing this criterion. Not only should the awareness reports associate statistically with these measures on an overall level, but the degraded states themselves should be associated with distinctive intermediate levels of these other variables. For example, when someone reports their consciousness as degraded, it should happen at a unique timing level from both clear experiences and no experiences. Further, these reports should predict a unique, intermediate level of accuracy in identifying the target stimuli of these experiments.

Analyses to identify unique intermediate timing levels associated with degraded state reports. Table 13 summarises the unique timing levels found in the experiments from this thesis.[18] The detailed analyses of this type is presented in each of the experimental chapters separately.

The results are derived from post hoc Tukey HSD tests from several ANOVA tests with awareness rating as the dependent variable and timing level as the independent variable. In order to conduct the analyses for each of the experiments, two timing conditions were selected as comparison conditions. These were the shortest (least visible) and longest durations (most visible) of timing levels for each experiment. Experiment 3 was an exception, as it contained a *no stimulus* condition that was used instead of the shortest duration. Because of the differences in number of timing levels, range of durations and other variations in the features of experiments, some variation in findings was expected and observed. As such, the primary aim was to assess whether a unique intermediate timing range could be identified; comparing the exact ranges was a secondary goal.

Once these contrast timing ranges had been selected the Tukey HSD post hoc test results were investigated in order to find intermediate timing levels that were significantly different ($p < .05$) from *both* these comparison conditions, suggesting that these display levels delivered ratings that were different from the *least conscious* and *most conscious* contrast conditions. These unique ranges are displayed in Table 13. The percentages below the ranges show the incidence of degraded reports at each end of the identified unique intermediate range, and confirm that the mean ratings do not result from an averaging of dichotomous ratings.

[18] The presentation of new analyses in a general discussion of a thesis is uncommon. It is argued that this is justified in this case for two reasons. Firstly, the secondary analyses is based on data integrated from all three experiments, and as such cannot be placed in any specific empirical chapter alone. Secondly, the combined view of the data presented here is crucial to the argument being conveyed.

Table 13

Unique Timing Levels that are Associated with Degraded Reports of Consciousness

Experiment	Timing range uniquely associated with degraded awareness reports	*F*	*p*	*Eta squared*
Experiment 1: Masking, word stimuli, 4-point scale, *colour reports*	Stimulus duration: 40–53 ms (59.7%) (56.9%)	30.42	< .001	.21
Experiment 1: Masking, word stimuli, 4-point scale*, word reports*	Stimulus duration: 40 ms (56.9%)	23.28	< .001	.16
Experiment 1: AB, shape stimuli, 4-point scale, *colour reports*	SOA: 212–319 ms (82.0%) (69.4%)	21.4	< .001	.23
Experiment 1: AB, shape stimuli, 4-point scale, *shape reports*	SOA: 212–319 ms (78.7%) (72.6%)	24.0	< .001	.25
Experiment 2: Masking, shape stimuli, 3-point scale, untransformed ratings	Stimulus duration: 39–91 ms (68.8%) (20.9%)	196.83	< .001	.42
Experiment 2: 4-point scale, shape stimuli, untransformed ratings	Stimulus duration: 39–117 ms (57.8%) (52.8%)	140.71	< .001	.34
Experiment 2: 7-point scale, shape stimuli, untransformed ratings	Stimulus duration: 39–104 ms (39.8%) (39.0%)	158.64	< .001	.36
Experiment 2: 21-point scale, shape stimuli, untransformed ratings	Stimulus duration: 39–91 ms (45.5%) (42.2%)	273.57	< .001	.49
Experiment 3: Face stimuli, 4-point scale, categorisation condition	Stimulus duration: 26–65ms (49.2%) (69.7%)	127.45	< .001	.44
Experiment 3: Face stimuli, 4-point scale, identification condition	Stimulus duration: 26–78 ms (28.0%) (67.4%)	101.17	< .001	.38

Note. The proportion of degraded states at each duration is shown in parenthesis below the timing range. Percentages are based on collapsing intermediate reports (ratings 2 and 3 of the 4-step PAS). Percentage at the lowest timing level appears first. For Experiment 2 data post hoc tests were performed on untransformed ratings, as reported in Chapter 4, but percentages were based on degraded states after rule-based binning, as described in that chapter, to three categories. Post hoc Tukey HSD comparisons were performed with alpha criterion < .05. Only experiments where post hoc tests identified unique intermediate timing levels are shown.

For the masking experiments the stimulus display time of 26 ms appeared to be the low end of the optimal range for degraded conscious experiences. This range stretched as far as 117 ms in one of the experiments, but was closer to 53–91 ms in most cases. There is a striking similarity between these findings and those of other researchers who have argued for the importance of this general stimulus display time. For example, Sergent and Dehaene (2004) suggest that a non-linear threshold effect is evident in the timing range of 29 to 43 ms. Similarly, Del Cul et al (2007) point to a ~ 50 ms display duration as initiating a major transition in processing, one that affects various cognitive functions. The studies reported in this thesis are consistent with the proposition that something unique is happening at this timing range. But instead of finding that consciousness disappears (e.g. Sergent & Dehaene, 2004), what the data suggests is that this duration causes a degradation of consciousness above the zero level. This idea is explored further below, under "Updating the GNWT view of conscious perception", where the visual account of this phenomenon derived from predictions of the GNWT is updated. For the AB experiments, the SOA range of 212 to 319 ms appears to be most conducive for this purpose, although only one of these experiments made use of the AB procedure, thereby limiting the representativeness of these findings.

Analyses to identify unique intermediate accuracy levels associated with degraded state reports. Regarding accuracy, the experiments reported in this thesis have also shown that a unique level of accuracy is predicted by a degraded awareness report. Figure 21 summarises all the conditions of the experiments in this thesis and the resulting accuracy level associated with reports of unawareness, full awareness and degraded awareness. The findings show that accuracy levels rise as a monotonic increase across the awareness levels, as would be predicted by a graded view of consciousness. Importantly, the degraded awareness states predict a level of accuracy between those associated with fully conscious and unconscious reports. This level varies across experiments from 67.9% in the masked shape condition of Experiment 1 for shape reports to 92.7% for the masked shape task with the 7-point scale in Experiment 2. This general finding is consistent with other results reported in the literature (e.g. Overgaard et al., 2006).

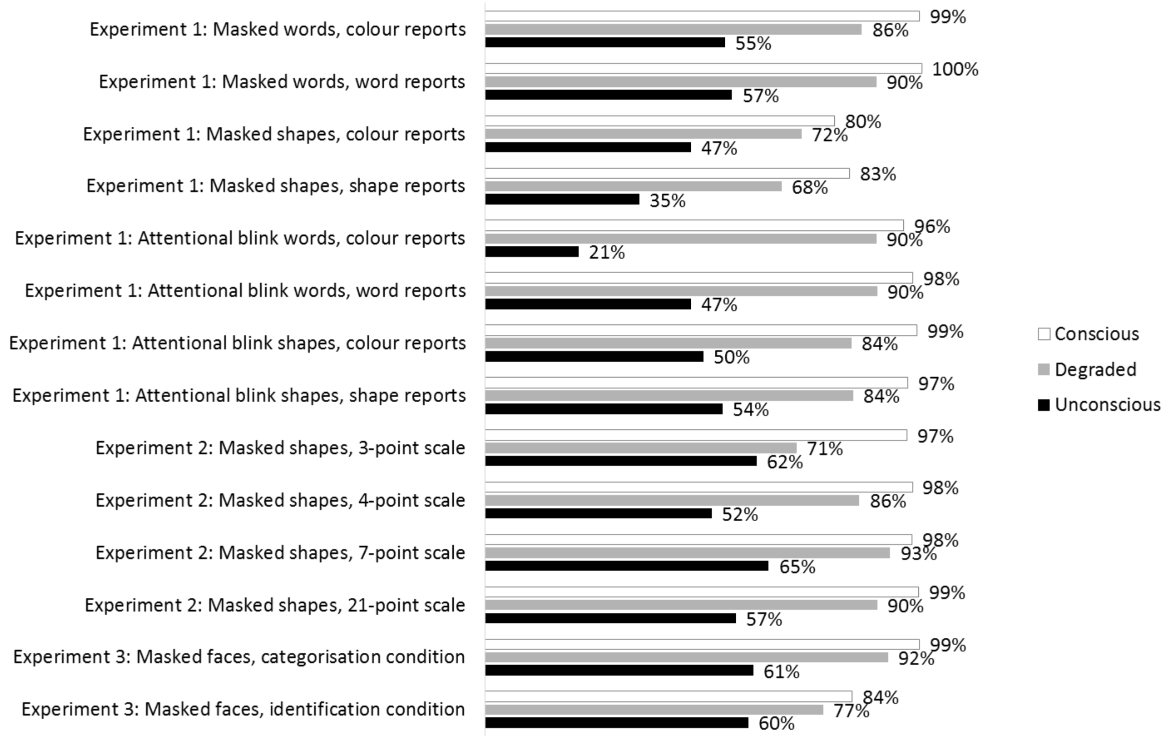


Figure 21. Average accuracy level predicted by awareness reports. Scales were binned to 3-point versions by collapsing the intermediate levels of 4-point scales into a “degraded” category. For scales in Experiment 2 rule-based binning was employed, as described in Chapter 4. Chance performance levels differed across experiments.

Criterion (d): Optimal Reporting Conditions

Finally, as per the original conception of McGovern and Baars (2007), criterion (d) states that the elicitation of the particular state of consciousness should happen in conditions with minimal delay after the event, and with no distractions. The experimental conditions employed in the experiments of this thesis were consistent with this requirement.

In summary, evidence for the existence of degraded states was found across all of the experiments reported in this thesis, and is consistent with various studies summarised in the literature review (e.g. Overgaard et al., 2006; Sandberg et al., 2011). Notably, the interpretation of the data in the studies conducted in this thesis was constrained by the same standard of proof as that typically required for conscious and unconscious states (McGovern & Baars, 2007).

Updating the GNWT Account of Conscious Perception

The conclusion that consciousness can be degraded is at odds with theories, such as GNWT, that predict that consciousness is an all-or-none phenomenon. For example, Sergent and Dehaene (2004, p. 721) made a specific prediction about the form of consciousness, and the caption of the accompanying illustration (reproduced in Figure 22) stated the following:

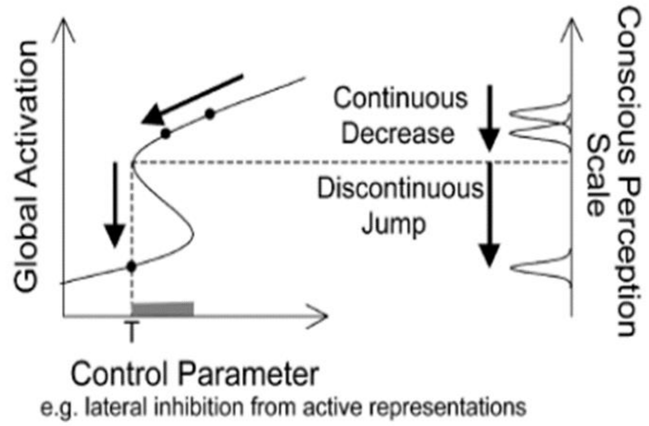
> The generic curve on the left describes activation in a nonlinear self-amplifying system (y-axis) as a function of a control parameter (x-axis) that represents the combined influences of intensity and duration of the current stimulus, as well as inhibitory influences from other concurrently processed stimuli. On the right, predicted response distributions on a subjective visibility scale are shown. Progressively decreasing the control parameter from an above-threshold value (T=threshold) initially leads to a gradual decrease in global activation and thus in subjective visibility. At threshold, however, there is a discontinuous jump to a lower level of activation, corresponding to lack of sustained activation and therefore, according to the global neuronal workspace model, an absence of conscious perception. There is a range of control-parameter values (thick gray segment) within which both high and low states of activation coexist.

In order to compare the prediction of Sergent and Dehaene (2004) to the findings from this thesis, the data from Experiment 2 were analysed. Two perspectives on the same data are shown based on mean data and frequency of response distributions. The mean data is based on normalised data (through a Z-score transformation) to ensure a comparable magnitude of scores given the different scale lengths. This data shows a gradual building of awareness as stimulus duration increases. The mean data can be compared to the response distribution data at the top to confirm that averaged ratings are due to degraded reports and not to smearing of dichotomous scores.

The present findings diverge from the GNWT account on important aspects of their predictions. While Sergent and Dehaene (2004) predict that at threshold low and high values of awareness should coexist, the data from this study do not support this idea. The grey threshold area identified as optimal for degraded consciousness (26–78 ms) contains predominantly degraded reports, which translate to a gradual reduction in the mean subjective visibility. The response distributions confirm that instead of extreme ratings the intermediate range contained mostly degraded awareness ratings as a function of stimulus display duration.

Notably, the findings from this thesis were based on a masking experiment with stimuli conducive to graded, and not dichotomous, consciousness. The Sergent and Dehaene (2004) study based its conclusions on the results of an AB experiment. It could be argued that the results are thus hardly comparable, given these differences and the strong argument for relative degradation put forward in this thesis. However, the point of this comparison is to argue that a general theory of consciousness such as GNWT should account for these disparate findings.

(a)



(b)

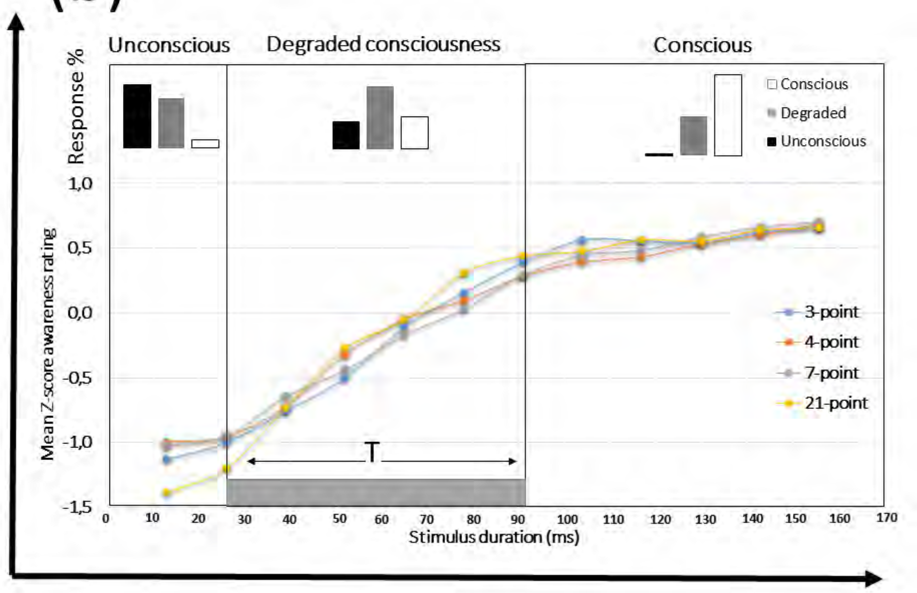


Figure 22. (a) The GNWT prediction of a non-linear transition from unconscious to conscious processing (Sergent & Dehaene, 2004, p. 721). (b) An updated illustration based on data from Experiment 2 of this thesis. The bar charts at the top show the distribution of reported states combined for all scales, based on rule-based binning data, at three timing intervals: 13 ms, 26–78 ms and 91–156 ms. The line graph shows mean normalised Z-scores of four scales in original, unbinned format The hypothetical threshold (T) is shown for comparability with (a).

Degradation of Consciousness is a Matter of Degree

While the data reported in this thesis supported a view that visual consciousness can be degraded it also revealed that there were large differences in the magnitude of degradation. Miller's (1988) first observation was that in cognitive psychology processes are best referred to as relatively – and not absolutely – graded or dichotomous. The preceding data and arguments strongly support this view. Degradation is present in all of the studies reviewed in Chapter 2 (no studies presented 100% binary reports) and in all the studies conducted for this thesis. The decision of whether the consciousness observed in a given study is dichotomous or graded thus comes down to interpretation of the relative degree of degradation. Thus, when researchers find 20% degraded states in a study, they could interpret this as being a mostly dichotomous cognitive process. Similarly, strong non-linearity observed in the averaged data across a timing parameter could be interpreted as being suggestive of a dichotomous form of consciousness. However, if there are degraded states evident in the response distributions at all, and if there is an intermediate mean value despite a sharply rising psychophysical curve, it seems more accurate to comment on the relative degradation of the data.

Viewing Conditions Modulate the Form of Consciousness

The finding that factors in the viewing conditions modulate the form of the conscious experience offer an explanation of the contradictory findings summarised in the literature review. Indeed, the experiments of this thesis suggest a number of factors that influence the way visual events are presented to our consciousness.

Stimulus Timing Level

Firstly, the timing levels employed in the experiments yielded variations in degradation. For the masking experiments the stimulus display range ~ 26 to ~ 78 ms, as summarised in Table 13, delivered more degraded reports than shorter or longer durations. This range in the masking experiments is consistent with other findings of degradation in the literature

(Overgaard et al., 2006; Ramsøy & Overgaard, 2004; Sandberg et al., 2011; Sandberg et al., 2010). Regarding the AB paradigm, the SOA between 212 and 319 ms resulted in more degraded reports than other timing levels. This range is similar to the range observed in the third experiment reported by Nieuwenhuis and De Kleijn (2011). It is thus possible to identify timing conditions that are conducive to degraded consciousness.

Degradation Technique

The direct comparison of the degradation techniques in Experiment 1 showed higher degradation of consciousness for the backward masking paradigm, compared to the AB conditions. This was true even when the stimulus display durations were matched at 53 ms. When comparing the findings in this thesis to previous studies reported in the literature, the asymmetry in results from AB and masking studies is supported. In Experiment 1 a more dichotomous version of consciousness was observed in the AB degradation condition compared to the masking approach, consistent with previous findings (Bowman et al., 2007; Nieuwenhuis & De Kleijn, 2011; Sergent et al., 2005; Sergent & Dehaene, 2004), while the masking conditions led to a more graded view, aligning with other studies (Overgaard et al., 2006; Ramsøy & Overgaard, 2004; Sandberg et al., 2011; Sandberg et al., 2010; Sergent & Dehaene, 2004). As suggested in Chapter 2 these various findings have been explained with reference to a classification of conscious states by Dehaene et al. (2006). According to their framework the AB paradigm leads to a state where top-down processing is interrupted even when stimulus strength is sufficiently strong (Dehaene et al., 2006). The researchers label this type of state "*preconscious*" (Dehaene et al., 2006). Masking on this account relates to degradation at the level of stimulus strength, and even if attention is present the bottom-up stimulus signal is not strong enough to manifest as full consciousness. The Dehaene et al. (2006) framework labels these states "*subliminal*". However, this account does not explain the non-zero awareness degradation observed in masking studies. Participants are not claiming to be fully unaware and then responding with above-chance level accuracy, as would be expected in proper subliminal processing. Instead, they are claiming to be in a degraded awareness state with a level of intermediate accuracy. Furthermore, while resulting in less degradation than masking, the AB method cannot be said to show purely dichotomous awareness states. It is interesting to observe that there is evidence of degradation in the AB experiments reported in this thesis and in a previous study (Nieuwenhuis & De Kleijn 2011). An update of the framework offered by Dehaene et al. (2006) is required to account for the degraded reports in some AB studies.

Stimulus Type

Stimulus type was also found to affect the form of consciousness in the work reported in this thesis. In Experiment 1 coloured shapes were most likely to deliver degraded reports, compared to coloured words. One explanation for the predominantly dichotomous ratings found in the case of words is offered by the “interactive activation” account suggested by Nieuwenhuis and De Kleijn (2011, p. 365). The current findings are consistent with the idea that the recognition of single letters is likely to lead to full word recognition. Interestingly, the face stimuli of Experiment 3 did not lead to the same effect, even though faces are also multidimensional visual objects with salient features that could plausibly lead to the same outcome. It is unclear whether this was because of a larger set size with less repetition of stimuli (30 faces instead of 3 words), or a more degraded stimulus due to the removal of prominent features (e.g. hair), or some other factor. In general the results show asymmetry in the awareness ratings, indicating that word stimuli are particularly likely to show dichotomous conscious states.

Stage of Processing

Various recent proposals have suggested that there are multiple stages or levels of consciousness (Zeki, 2003), and that the form of consciousness debate should be addressed with reference to these levels (Kouider et al., 2010; Windey et al., 2013). Two of the experiments in this thesis investigated this hypothesis. Experiment 1 asked for ratings of two features of the same stimuli on each trial. Participants were asked to rate the subjective visibility of the colour and either the word identity or shape that was displayed. For three of the four conditions, there was no clear evidence of dissociation in the awareness ratings, but there was some evidence of different awareness ratings in the masked shape condition. Experiment 3 probed the form of consciousness under two stages of face perception. The results suggest that while overall degradation proportions were comparable, the degradation across the display range was markedly different for the categorisation and identification conditions. In summary, the findings reported in this thesis do not suggest that some features are perceived dichotomously and some features gradually. There is evidence of degradation in all instances. At the same time, the degradation in the masked shape condition of Experiment 1, and the results of Experiment 3, suggest that there may be dissociation in consciousness on different levels of processing of the same stimulus that leads to higher or lower relative degradation. An interesting recent proposal (Windey et al., 2013) suggests that low-level non-semantic features are perceived in a graded manner, while high-level semantic content is perceived in a more dichotomous way. Further research is needed to fully investigate the value of this hypothesis.

Scale Length Influences Degree, But Not the Presence, of Degradation

Experiment 2 aimed to evaluate experimentally the importance of scale length on the form of consciousness, and found that all scales contained degraded consciousness reports. A hypothesis laid out by Overgaard et al. (2006) suggested that a 21-point scale, with only endpoints labelled, contributed to the binary ratings observed in studies by Dehaene and colleagues (e.g. Sergent & Dehaene, 2004). However, the findings from Experiment 2 did not show this to be the case. The 21-point scale contained substantial evidence of degraded state reports. Instead, it was argued that a longer (7- and 21-point) scales make the task for participants and researchers more ambiguous, and requires assumptions to be made in order to meaningfully interpret the data. The shorter 3- and 4-point scales minimise this challenge. One strong finding was that the magnitude of degradation exposed by the scales differed. In this regard the 4-point scale resulted in the most degraded awareness reports. This is not surprising given the fact that the scale was developed to be sensitive to degraded awareness states (Ramsøy & Overgaard, 2004). However, the possibility that the scale contains bias towards a degraded view, as has been recently proposed (Windey et al., 2014), is also consistent with this result. What is clear is that consciousness can be shown as graded with various scale lengths, albeit to different degrees.

Alternative Accounts

The general conclusion that visual consciousness can be degraded, and that the magnitude of degradation is modulated by viewing conditions, is strongly supported by the experiments reported in this thesis. Even so, the findings do not conclusively rule out all alternative accounts. One alternative hypothesis is presented by Sergent and Dehaene (2004)**.** In order to explain the graded ratings found in their masking experiment, they suggest that the finding may be due to increasingly richer information of varying levels of visual perception reaching consciousness (Sergent & Dehaene, 2004). Similar to the argument in the *partial awareness hypothesis* (Kouider et al., 2010), Sergent and Dehaene (2004) suggest that the degraded overall ratings may have resulted from all-or-none consciousness on lower level features. While the findings from the current research cannot rule out this possibility, the data in this experiment that probed more than one feature of a stimulus found that the ratings for these features were graded and complied with the requirements for degraded states developed in this work. Further, even if it was found that some lower levels features exhibit dichotomous consciousness that result in graded higher level consciousness that would only demonstrate that *some* levels of consciousness are dichotomous. In this way the general conclusion of this thesis is still supported: The form of consciousness would then be shown to be modulated by level of stimulus processing, but would still be graded on some of these levels. Studies with more varied and granular interpretations of level of consciousness, are required to make progress on this possibility.

A next possible challenge to the conclusion of this thesis is that it is only the report of the conscious experience, and not the experience itself that has been shown to be degraded. A basic assumption of cognitive models in psychology is that cognition proceeds through stages. The representation, the transformation, the transmission, the phenomenological experience and the report are distinct aspects of the process. As such, Miller (1988) notes that cognitive processes can be relatively dichotomous or graded at different levels of cognition. In the studies presented and reviewed here the underlying conscious representations and their phenomenological experience are only accessed indirectly via behavioural report. It is important to bear in mind that the dichotomous or graded nature of the report could be different from the underlying representation or experience. This situation is not unique to the debate, and limitations of verbal report are well recognised in the area of consciousness studies (e.g. Chalmers, 2004). It is, with current methods, not possible to rule out the possibility that the underlying conscious representation is wholly dichotomous and that the verbal report simple provides a graded output.

Limitations and Future Research Directions

While the findings presented in this thesis have contributed new insights to the debate, there are several limitations and opportunities for further work that should be noted.

Examining Further Effects of Viewing Conditions

Sampling a representative set of different conscious experiences was never feasible or necessary to answer the questions posed at the beginning of this research. Even so, a deeper understanding of the differences in the form of consciousness elicited by various viewing conditions should be an important focus for future research. This research agenda should extend to a greater diversity of stimuli and a greater variety of degradation techniques (beyond AB and masking). There are currently various psychophysical techniques that can cause disruptions in consciousness that facilitate the study of the nature and mechanisms of conscious processing (e.g. Kim and Blake, 2005). Aside from AB and masking, there is an opportunity to use techniques such as crowding, bistable figures, binocular rivalry, motion-induced blindness and change blindness to study the form of consciousness. At least one study (Naber et al., 2011) has used rivalry in this context, finding that rivalry results in graded consciousness. Questions around the form of consciousness in the other paradigms remain unaddressed. These kinds of investigations will inform not only the present debate, but also provide suggestions for how consciousness should be probed when different experimental paradigms are employed.

Extending Findings beyond Visual Consciousness

A prominent restriction in the generality of the findings is the fact that the experiments in this thesis were carried out only in the domain of visual perception, where most of the debate has been contested. The conclusions contained in this thesis are thus limited to the domain of conscious visual perception. It is unclear how the findings might translate into other perceptual and non-perceptual conscious states. Recently, at least one study has extended this debate into another area of consciousness, with interesting findings and implications (Wierzchoń, Asanowicz, Paulewicz, & Cleeremans, 2012). In their study the researchers employed an artificial grammar learning task and by probing the rule awareness of participants, found that consciousness of artificial grammar rules is a graded phenomenon (Wierzchoń et al., 2012). Other areas of consciousness present promising extensions to the findings of the debate.

The Form of Consciousness in Natural Environments

This research has kept the debate confined to the traditional psychophysical laboratory experiment. The strengths of this approach in controlling the slight manipulations of stimulus display required in this type of research justify this decision. However, it also constrains the applicability of the findings to real-world situations. Whether consciousness is graded only in strictly controlled laboratory situations is an unanswered question. The validity of these findings should be tested in natural conditions. Studies in natural environments, while more difficult, are necessary for an understanding of how and to what degree degradation manifests in everyday conscious experiences.

Further Questions on the Measurement of Consciousness

While Experiment 2 addressed one matter around the measurement of consciousness in the debate, there are still several important matters that are not yet resolved. The first comes from an observation that the awareness scale reports in this study have shown much variation in how participants used the scales. Some participants used all the scale points, while some used only a few. This was as true for the short 3-point scale as it was for the 21-point scale tested in Experiment 2. This is problematic for a number of reasons. Firstly, the analysis of data in these experiments requires aggregation either across- or within participants with multiple trials. This aggregation could result in a form of consciousness on a combined level that is not present for any given individual or any single trial. Further, if we transform data, we are making assumptions about the conscious experience of the person. If they use only two categories, how could we argue that that is not what they experience? Similarly, if a person used all 21 points on a scale, how do we know their perception is not really as fine-grained as their responses suggest? Issues like these continue to hinder a conclusive resolution to the debate.

A further significant opportunity in this regard is for integration of various types of measures. This opportunity comes from the observation that measures of consciousness often conflict in their findings on the same phenomena (Atkinson et al., 2000; Seth et al., 2008). This incongruence can be explained as each measure indexing a different aspect of consciousness (Atkinson et al., 2000). An implication of this is that often the best strategy is to use multiple measures in the same study, because conflicts will reveal new distinctions (Seth et al., 2008). Indeed, the integration of various measures is important for consciousness studies in general, and that is no different for this debate. In this regard the debate has relied heavily on awareness scales and first-person reports. Neuro-imaging studies can make important contributions to the debate by corroborating the first-person subjective data of behavioural experiments with objective measures of brain activation. This is important for clarifying the neural correlates of degraded conscious experiences. In addition, other subjective report measures have been suggested as alternatives to rating scales such as the PAS, confidence ratings and PDW. One study used the continuous movement of a joystick for participants to indicate their enhanced level of consciousness in a rivalry paradigm (Naber et al., 2011). These extensions to traditional subjective report measures are promising, but not fully utilised, techniques for studying the nature of consciousness.

Exploring the Phenomenology of Degraded Consciousness

What does it mean from a subjective standpoint for a conscious state to be degarded? A characterisation of the phenomenology of the content and nature of degraded consciousness is another question that has yet to be addressed. When a person claims to be somewhat aware of a visual object, what defines their visual experience of the object? Perhaps the whole object is experienced as a holistically degraded gestalt. Some ideas examined in the literature review suggest that primitive visual features may be accessed independently before the whole object is recognised (e.g. Zeki, 2003), so that the person becomes aware of, for example, colour but not the identity of the object. While psychophysical experiments have addressed the matter with manipulation of features and inferences from rating scales, little attention has been paid to the phenomenological experience of the perceiver in these situations. There are now several methods of phenomenology that are compatible with psychophysical experimental paradigms (Gallagher & Brøsted Sørensen, 2006), which presents an opportunity for exploring the matter with empirical data.

Conclusion

This thesis set out to explain why visual consciousness, from introspective and experimental perspectives, appears to be both dichotomous and degraded. I have concluded that the reason for this apparent contradiction is that viewing conditions modulate the form of our conscious experience. While consciousness can be degraded, what we look at and the nature of the disruption imposed on our perception will strongly influence our dichotomous or graded conscious experience. The general finding that consciousness can be degraded has implications for several areas of consciousness studies, particularly regarding its methods and theories. Concerning methods, these findings challenge approaches that rely on the dichotomising of awareness states, such as contrastive analysis. Kanwisher (2001, p. 103) explains the problem with this approach is that we force participants to deliver a binary answer to an experience that is graded: “Indeed, anyone who has been a subject in a psychophysical experiment will be familiar with the uncomfortable feeling of having to force an unclear and inchoate perceptual experience into one of a small number of discrete response categories.” The conclusion of this thesis is favourable to the idea that if consciousness permits degrees then so should our measures of the phenomenon. Theories of consciousness are tested against current empirical data about conscious and unconscious states to assess their robustness (McGovern & Baars, 2007). What the research in this thesis, and the growing body of literature in the debate suggests, is that it is necessary to add a third kind of conscious state to the list of research priorities. Clarifying the unique features of degraded conscious states will provide data that can further constrain theories of consciousness and their predictions. An example of this kind of insight has already been discussed here. The proposal of the GNWT – that the transition of content into consciousness is necessarily an all-or-none phenomenon – is at odds with the data presented and reviewed here. A comprehensive theory of consciousness will have to account for both the existence of, and the variation in, the degradation of visual consciousness.

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Appendix A: Table A.1

Table A.1

Behavioural studies on dichotomous and degraded conscious visual perception

Number	Study/Experiment	Participants	Paradigm	Type of target stimulus	Measure of consciousness	Findings
1	Sergent and Dehaene (2004) *Experiment 1*	10 normal adult participants	AB	Words	21-point scale anchored "not seen" at the left and "maximal visibility" at the right	Dichotomous consciousness
2	Sergent et al. (2005)	16 normal adult participants	AB	Words	21-point scale anchored "nothing" at left and "maximal visibility" at right	Dichotomous consciousness
3	Del Cul, Dehaene, and Leboyer (2006)	28 patients with schizophrenia and 28 healthy controls	Masking	Single numbers	21-point scale anchored "not seen" at left and "maximal visibility" at right	Dichotomous consciousness
4	Del Cul et al. (2007)	12 normal adult participants	Masking	Single numbers	21-point scale anchored "not seen" at left and "maximal visibility" at right	Dichotomous consciousness
5	Nieuwenhuis and De Kleijn (2011) *Experiment 1*	12 normal adult participants	AB	Words	7-point scale anchored "not seen" at left and "maximal visibility" at right	Dichotomous consciousness

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Table A.1 (continued)

Number	**Study/Experiment**	**Participants**	**Paradigm**	**Type of target stimulus**	**Measure of consciousness**	**Findings**
6	Ramsøy and Overgaard (2004)	5 normal adult participants	Masking	Geometric shapes (variable colour and position). Features reported separately	PAS with four categories	Graded consciousness
7	Sergent and Dehaene (2004) *Experiment 2*	10 normal adult participants	Masking	Words	21-point scale anchored "not seen" at left and "maximal visibility" at right	Graded consciousness
8	Overgaard et al. (2006)	14 normal adult participants	Masking	Textured oriented-element displays	PAS with four categories	Graded consciousness
9	Sandberg, Timmermans, Overgaard, and Cleeremans (2010)[19]	36 normal adult participants assigned to three conditions of 12 participants each	Masking	Geometric shapes	1. PAS with four categories 2. Confidence ratings with four categories 3. PDW with four values	Graded consciousness

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[19] Data from this study was re-analysed in another study (Sandberg et al., 2011, *Experiment 1*). While the method of analysis differed, both studies came to the same conclusions. For that reason, the second study is not included here.

Table A.1 (continued)

Number	Study/Experiment	Participants	Paradigm	Type of target stimulus	Measure of consciousness	Findings
10	Nieuwenhuis and De Kleijn (2011) *Experiment 3*	14 normal adult participants	AB	Single numbers	7-point scale anchored “not seen” at left and “maximal visibility” at right	Graded consciousness
11	Naber et al. (2011) *Experiment 4*	8 normal adult participants	Rivalry	Dissimilar gratings with opposite movement	Analogue joystick	Graded consciousness
12	Sandberg et al. (2011) *Experiment 2*	11 normal adult participants	Masking	Geometric shapes	PAS with three categories	Graded consciousness
13	Windey et al. (2013)	20 normal adult participants	Masking	Coloured numbers	PAS with four categories	Graded consciousness
14	Ramsøy and Skov (2014)	49 normal adult participants	Masking	Brand names	PAS with three categories	Graded consciousness
15	Sergent and Dehaene (2004) *Experiment 3*	10 normal adult participants	Combined AB and masking	Words	21-point scale anchored “not seen” at left and “maximal visibility” at right	Combination of dichotomous and graded responses

(continued on next page)

Table A.1 (continued)

Number	**Study/Experiment**	**Participants**	**Paradigm**	**Type of target stimulus**	**Measure of consciousness**	**Findings**
16	Nieuwenhuis and De Kleijn (2011) *Experiment 2*	13 normal adult participants	AB	Words	PDW scale with seven values	Unimodal rating at maximum wager
17	Nieuwenhuis and De Kleijn (2011) *Experiment 4*	12 normal adult participants	AB	Single numbers	PDW scale with seven values	Spurious pattern of responses, but according to authors it suggests graded responses
18	Szczepanowski, Traczyk,Wierzchoń, and Cleeremans (2013)	18 normal adult participants	Masking	Emotional faces	1. PAS with four categories 2. Confidence ratings with four categories 3. PDW with four values	Graded conscious perception for confidence ratings, dichotomous for others

Appendix B: Link to Data Files

Raw data files available online:

https://www.dropbox.com/sh/xlogdgkcxhdykxu/AACsWqX3QjdK4U0ZTA0X8l1ea?dl=0

Password: CONSCIOUSNESS