# Spontaneous shifts of visual consciousness in stroke patients and healthy individuals: A binocular rivalry study.

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Master Thesis
Master of Philosophy in Psychology
Cognitive Neuroscience

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May 2013

# Acknowledgements

I would like to thank my supervisor Professor Bruno Laeng for all of the guidance and support throughout the master project. He has played an integral part in helping with all aspects of the thesis, from the planning, the data collection, the analysis, and the writing. The data was collected in collaboration with co-supervisor Kjersti Walle and took part within her PhD project. I am thankful for all of her help, in which she's been an irreplaceable partner in discussing the project details, testing patients, and performing analyses. I also want to thank co-supervisor Olga Chelnokova for all the comments and direction while writing the thesis, as well as the assistance of the stimuli used, provided by herself and Thomas Espeseth. I would further like to thank Jan Egil Nordvik for all his help and advice along the way, with the help during testing, as well as providing information regarding the neuropsychological tests. I also want to thank Frank Becker for providing patient information and for all the guidance offered over the last year. Lastly, I want to thank my friends and family for supporting me during this process and providing me with the inspiration I needed.

# Abstract

Binocular rivalry is a perceptual phenomenon producing random fluctuations in perception while the physical stimulus remains unchanged. As one can assess an individual's change in perception, binocular rivalry acts as a tool to allow one to gain better insight into the roles of perception and attention. The current study utilized a binocular rivalry paradigm to investigate the differences between 11 right-hemisphere stroke patients and 19 healthy control participants. Results indicated that stroke patients reported significantly fewer perceptual alternations than control participants. Moreover, the percent correct on the BIT neglect tests was predictive of how many perceptual fluctuations the patients reported. Additionally, multiple stimuli were presented, whereas half of them were simple Gabor patches, and the other half comprising of more complex real-world scenes. Fewer perceptual fluctuations were reported in the control group amongst one of the real-world scenes in comparison to the Gabor patches. Another main question the study addressed is how two basic rehabilitation practices (Limb Activation Training and Phasic Alertness Training) influence attention mechanisms during binocular rivalry in stroke patients. A trend was found in the patient group that underwent Phasic Alertness Training expressing a slight increase in the number of perceptual fluctuations during binocular rivalry.

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## Introduction

Throughout everyday life, millions of pieces of incoming information are processed without our conscious realization. When we look at the sky, our brain tells us it is blue without us having to think about it. It is our perception of this incoming information that helps us navigate and shape our lives. The perception of everyday objects gets encoded based on the best portrayal of the incoming information, which occurs when the two eyes match their respective percepts to form one image (Howard & Rogers, 1995). This encoding can occur when attention is focused on a certain stimulus. But must one be conscious of the stimulus as well? Consciousness and attention are two mechanisms that commonly get classified or merged into one entity (Posner, 1994; Mole, 2008; De Brigard & Prinz, 2010). Many researchers, however, debate they are two independent mechanisms (e.g., Hardcastle, 1997; Baars, 2005; Koch & Tsuchiya, 2007).

One tool used to examine the neural correlates of consciousness and attention is bistable percepts, in which there is no change to the physical stimulus, but perception is able to fluctuate. A well-known example is ambiguous figures, such as the Necker cube (Ellis & Stark, 1978; Blake & Logothetis, 2002), where there are two versions of the same image that can be perceived. While it has been found that one is able to control when one interpretation switches to the other (Girgus et al., 1977; Rock & Mitchener, 1992), it is also beneficial to study consciousness using a tool that, instead, causes spontaneous switching, such as binocular rivalry (Blake et al., 1971; Blake, 2001).

While two similar images, one presented to each eye, merge to form the best representation, what happens when one can see two different images simultaneously? How would this be encoded in the brain and how would this alter perception? Understanding perception and consciousness is an essential issue in order to recognize how the human brain functions. Furthermore, it is essential to study these mechanisms in individuals with brain damage to see how they are differently affected. This can be investigated in the situation of binocular rivalry in stroke patients.

## Binocular Rivalry

Binocular rivalry is an artificially created phenomenon where an unchanging stimulus creates a fluctuation in perception. This occurs when two dissimilar images are presented simultaneously, one to each eye, and the result is that only one image is perceived at a time (Breese, 1899; Fox, 1991; Blake & Logothetis, 2002; Seely & Chow, 2011). The two images take turns going between phases of dominance and suppression, spontaneously fading in and out of visual awareness (Fox & Herrmann, 1967), an occurrence that has been tested extensively within research. It occurs involuntarily for viewers with normal vision (Blake et al., 1971; Blake, 2001), thus making it a prominent tool in researching the neural correlates of consciousness (Crick & Koch, 1998; Lin & He, 2009).

It is possible for one percept to dominate over the other, leaving no perceptual trace of the second percept behind, or there can be traces of the suppressed image still visible, so the viewer can see a mixture of the two images (Hollins & Hudnell, 1980; Anstis et al., 1985; Brascamp et al., 2006; Klink et al., 2010). Seeing pieces of both images simultaneously is known as piecemeal rivalry (Lee & Blake, 1999; Wilson et al., 2001), an effect more likely to occur if the stimuli are presented at larger viewing angles (Meenes, 1930; Blake et al., 1992).

As perception and consciousness have shown such interest within cognitive neuroscience, it is exploring these mechanisms during perceptual bistability, like during binocular rivalry, that can help gain understanding into the neural underpinnings of visual awareness (Crick & Koch, 1995; Blake, 1997; Logothetis, 1998). Binocular rivalry is useful in that the physical stimulus remains unchanged, thus allowing the changes in perception to be studied. Though this phenomenon can be examined with other bistable percepts, such as ambiguous figures, binocular rivalry sets itself apart in that the two percepts alternate stochastically, without viewer control. Binocular rivalry is unique in another way in that it leaves the suppressed, thus not perceived, image on the retina, continuing the income of information while the dominant image is conscious to visual awareness (Alais & Blake, 1999).

## Background

**Willful switching.** Binocular rivalry was first discovered in 1593 by Porta (cited in Wade, 1998), and later researched by figures such as Wheatstone (1838) and Helmholtz (1925) (as cited in Blake, 2005, p. 7). As simple as this phenomenon is to induce, and as peculiar as most may find it, there is still much debate as to how exactly it occurs. There has been, for example, a long-standing debate as to whether one could control the dominance and suppression phases of images (Breese, 1899; as cited in Blake, 2005, p. 7). Hugrass and Crewther (2012) demonstrated that one was able to voluntarily control the alternation rate for stimuli involving motion, but not for those that were motionless, such as in traditional binocular rivalry. In another study by Meng and Tong (2004), it was found that participants were able to control the number of alternations during binocular rivalry up to 13% of the time, though this did not reach significance. Conversely, Lack (1978) reported that participants were able to control perceptual switches more substantially, and claimed that this is something most people could learn to do with enough practice (Lack, 1970). Overall, however, research has found that one has little control in deciding the rate at which an image becomes dominant. It has been demonstrated that one's 'strength of mind', or willpower, is not enough to cause voluntary switching while viewing these bistable percepts (Peckham, 1936; Blake et al., 1971; Meng & Tong, 2004; Slotnick & Yantis, 2005). There seems to be, however, an exception for those who are able to control the rate of rivalry. A study on Tibetan Buddhist monks revealed that with years of practiced meditation, they had the mental capabilities of remaining focused on a dominant percept for a prolonged duration (Carter et al., 2005).

In addition to willpower, eye-movements were examined to see if this had any effect on perceptual switches, an issue previously debated between Helmholtz (1925) and Hering (1964) (as cited in Blake, 2005, p. 7). Evidence first suggested that eye-movements were the reason for perceptual change rather than the neuronal signals in the brain (Sabrin & Kertesz, 1983). However, it was later found that eye-movements did not cause image changes themselves, though they may have an influence. Eye-movements were, in fact, found to increase during the time at which an alternation occurred (van Dam & van Ee, 2006) possibly causing some of the initial confusion of whether eye movements caused fluctuations or not. Though some debate still occurs in regards to eye-movements and other factors effecting perceptual change during binocular rivalry, these mechanisms do not seem to be the causation for alternation rate between percepts.

**Attention and consciousness.** Despite the fact that one may not be able to effectively control perceptual dominance during binocular rivalry, it has been demonstrated that one must be attending to the stimulus to be able to experience the phenomenon at all, with studies demonstrating that the level of attention can have an effect on the alternation rate (Meng & Tong, 2004; van Ee et al., 2005; Chong et al., 2005). Paffen et al. (2006), for example, found that a decrease in attention can result in a slowing of alternation rate. This was shown by administering tasks of varying degrees of difficulty while participants simultaneously took part in a binocular rivalry task. Results showed that the rate of task difficulty correlated with the number of alternations, with the more difficult tasks yielding fewer perceptual switches between the percepts (Zhang et al., 2011; Blake, 2012). Though attention is crucial, these studies also demonstrated that the rivalry phenomenon did not cease completely with diminished attention.

How would attention differ in an individual that has experienced damage to the brain, such as a stroke patient? One deficit in such patients is called unilateral neglect, which is a common result of stroke to the right hemisphere of the brain. This typically involves the disregard for stimuli in either the left or right visual field (the contralateral hemisphere to where the stroke occurred) or hemispace (left or right of the body midline), (Denes et al., 1982; Jehkonen et al., 2000; Cherney et al., 2001). Due to such impairments, stroke patients are likely to have slower reaction times and accuracy rates on a variety of tests compared to healthy controls. An example of this was demonstrated by Rengachary et al. (2011) who administered the Posner Task (Posner, 1980) to neglect patients. Results found that the severity of neglect was correlated with disengagement during the task. Poor performance could be due to decreased levels of attention, fatigue, or the inability to perceive part of his/her visual field. This example brings to light the importance of the continuation of research that relate factors influencing attention mechanisms in the brain, including how and where processing takes place.

**Neural mechanisms of binocular rivalry.** It has been proposed that the perceptual switches during binocular rivalry involve processes in the early stages of visual awareness in the primary visual cortex (Blake et al., 1980; Blake, 1989; Polonsky et al., 2000; Nguyen et al., 2001; Tong & Engel, 2001; Wilson, 2003). Simple Gabor patches, made up of intersecting horizontal and vertical lines, have been shown to yield low-order processing in V1 (De Valois et al., 1982). Neuroimaging data, for example, expresses early competition during binocular rivalry in area V1 (Logothetis et al., 1996; Tong & Engel, 2001;). Furthermore, this region has been shown to be associated with binocular perception and rivalry effects based on fMRI studies (Polonsky et al., 2000; Tong & Engel, 2001; Haynes et al., 2005; Meng et al., 2005; Lee et al., 2004, 2007).

Research, however, has also indicated that binocular rivalry involves higher-order mechanisms (von Helmholtz, 1866; Leopold & Logothetis, 1999). Neuroimaging studies found BOLD activation during image alternations in the extrastriatal visual cortex (e.g., the fusiform gyrus) as well as in parietal and frontal areas (Kleinschmidt et al., 1998; Lumer et al., 1998; Tong et al., 1998; Sterzer & Kleinschmidt, 2007).

Though the debate of low-order versus high-order mechanisms required during binocular rivalry is not completely resolved, the latest proposal is an integrative approach, involving both low and high-order mechanisms (Ooi & He, 1999; Blake & Logothetis, 2002). It has been proposed that low-level processes in V1 are responsible for the initiation and overall regulation of rivalry, but that these mechanisms are maintained by means of a feedback mechanism in higher cortical regions (Carlson & He, 2004; Watson et al., 2004). In addition, areas V1, V2, and V3 became active during perceptual suppression, supporting the idea of multi-level processing. Activations in early stages of visual processing were also found by Lin and He (2009), who proposed the partial-exemption hypothesis, which states that unconscious stimuli can be processed early in the visual stream, but the information is weaker than that which reaches higher cortical areas, such as neurons responding to dominant images during binocular rivalry. These data have been further supported by studies using repetitive transcranial magnetic stimulation (rTMS) to disrupt the intraparietal sulcus (IPS), resulting in longer dominance durations and irregular alternations (Kanai et al., 2010; Zaretskaya et al., 2010). This study suggests that the IPS influences perceptual alternations during binocular rivalry, a region further along the visual stream, supporting the idea that higher-order mechanisms are involved during binocular rivalry. Given that the parietal lobe has been implicated in the control of shifts of attentional focus, the above findings would suggest a probable link between neglect as a pathology of the parietal lobe function and disruptions of the phenomenology of binocular rivalry.

Finally, research with "split-brain" patients has also noted behavioral differences that may reflect lateralized specializations (Nebes, 1974). For example, it has been posed that the right-sided posterior parietal cortex's role in visual spatial attention (Mesulam, 1981; Hopfinger et al., 2000; Bisley & Goldberg, 2003) is especially relevant for distributing attention spatially (Mesulam, 1999; Driver & Vuilleumier 2001; He et al., 2007). However, findings with a binocular rivalry task were similar in split-brain patients compared to healthy participants (O'Shea & Corballis, 2003). Thus, if one hemisphere typically sends information to the other hemisphere during alternations (Pettigrew, 2001), this may not be the case in split-brain patients. This poses the issue of how patients with other types of impairments may perform on a binocular rivalry task. We surmise that stroke in the right hemisphere, especially if it decreases parietal lobe function, may particularly result in changes in the phenomenology of binocular rivalry.

## Stroke

As the leading cause of death in the United States (Roger et al., 2012), a stroke results from a lack of blood supply to the brain, resulting in a disruption in brain activity. A stroke can be caused by a blockage, reducing the overall blood flow (ischemic), or can be hemorrhagic (Kelly et al., 2003) causing debilitating outcomes that can be an overall frightening experience.

Many stroke patients experience attention deficits, and in more severe cases, it can result in unilateral spatial neglect, which is the disregard for information in the contralesional side of space (Denes et al., 1982; Jehkonen et al., 2000; Cherney et al., 2001). More specifically, one may neglect the left side of an object, known as object-based neglect, which is different from the neglect of the entire left visual hemisphere, known as egocentric neglect (Barrett et al., 2006). Additionally, it is possible for one to disregard a side of the body (asomatognosia), though the patient can re-learn that his left arm, for example, is his and not belonging to another (Feinberg et al., 2010). Moreover, a condition known as somatoparaphrenia can occur causing the patient to reject the idea that the arm belongs to him altogether, even with evidence (Feinberg et al., 2010).

One should note that, although both eyes receive information from both the left and right hemifields, they each also perceive their respective monocular fields. It may be that if one eye is impaired, the other eye could compensate. Thus, as stroke most commonly results in attentional deficits such as neglect, and in cases where a stroke leads to damage specifically to a part of the occipital lobe, the lesion may influence how much a person can see with one eye or the other.

Due to the more common attention impairments resulting from stroke, it may be likely, for example, for a neglect patient to leave the food on the left side of the plate untouched, to not draw the left side of an object, or to think the midpoint of a line is much farther to the right than it really is. This makes everyday activities, such as getting dressed, much more difficult without the help of another person. Driving, in particular, is something that has to be given up completely until the impairments are resolved, causing one to be dependent on the help of others.

The presence of neglect symptoms causes the patient to need to relearn everyday tasks, forcing the brain reorganize itself, and as a result rerouting once known tasks to areas of the brain that will allow the patient to perform them once again. Excluding cases where there is damage to the occipital lobe, these neglect impairments are not to be confused with any perceptual distortions with one's vision, but instead with *attentional* deficits caused by the stroke. Though these attention deficits are the most common, affecting 46-92% of all stroke patients (Barker-Collo et al., 2009), forms of impairment occupying other sensory modalities, such as auditory or motor, are possible. Most commonly, a right-hemisphere stroke can result in left-sided visual neglect. It is more common for left-hemisphere stroke patients to experience aphasia, which is the inability to produce speech. Furthermore, some may experience anosognosia, or the lack of awareness of having any deficit or disability at all (Cutting, 1978), though this is likely to diminish over time. Stroke patients can also experience hemiparesis, where he/she may have trouble moving the contralateral limb.

As any of these impairments can co-occur, in addition to these deficits, it is common for a stroke patient to experience a high level of fatigue, making a simple task become even more arduous. It is possible for these various symptoms to slowly subside as time passes, known as spontaneous recovery (D'Esposito, 1997), though as many as 50% of ischemic stroke patients still experience hemiparesis six months after stroke, and up to 46% still have cognitive deficits (Kelly-Hayes et al., 2003). Stroke numbers are predicted to continue to rise, creating a 24.9% increase in 2030 compared to 2010 (Heidenreich et al., 2011), making it imperative to continue researching changes in the brain after stroke in order to find the most beneficial rehabilitation techniques.

As it is common for stroke patients to experience attention deficits, it can be beneficial to further previous research on attention and perception during a binocular rivalry task in this patient group. With the administration of such a task to a group of stroke patients, one may be able to better understand the role of attention during perceptual processing. This can be further explored with the utilization of a rehabilitation technique during a binocular rivalry task to see how rehabilitation can affect attention mechanisms.

**Rehabilitation.** Due to brain deficits after stroke, it is crucial to begin a rehabilitation method as soon as possible to maximize the speed of recovery. Though patients suffering stroke can survive without rehabilitation, it can leave them chronically impaired. Because of this, rehabilitation is considered one of the essential steps to a healthy recovery.

A common rehabilitation practice is known as active Limb Activation Training (LAT). LAT is where the patient is instructed to continually move the arm or leg contralateral to the side of the brain lesion while performing a task. For example, one would move the left arm in the case of right-hemisphere brain damage. This leads to stimulation in the damaged region of the brain, thus temporarily improving performance in various types of tasks (Robertson & North, 1992, 1993), and evidence of these benefits has been expressed for even longer durations (Robertson & North, 1992, 1993; Harvey et al., 2003). LAT is a useful technique in that it does not require equipment, help from another, and is cost-free.

An alternative approach for stroke patients with paresis who cannot perform the movements required for LAT is a technique known as Phasic Alertness Training (PAT). This involves the sounding of various tones at random intervals on the contralateral side of the brain lesion to help increase stimulation in the damaged hemisphere while performing a task (Sturm & Willmes, 2001). Like LAT, this has been shown to temporarily improve task performance (Robertson et al., 1998). Though this requires a sounding device and may be more difficult to administer, as the patients cannot control it themselves, it proves to be quite advantageous for temporary improvement.

It has been found that damage to the attention system can create impairments in non-spatial attention, or global attention (Priftis et al., 2013). Due to the unique nature of binocular rivalry, being a non-spatial task resulting in stochastic perceptual fluctuations, one could see how rehabilitation during the task can influence global attention. In other words, as attention is oriented centrally in the visual field during the task, rather than to one visual hemifield, one can see how stroke affects central attention, and further, how rehabilitation may ameliorate attention deficits exhibited while performing the task. The current study proposes that the administration of a binocular rivalry task to stroke patients while undergoing LAT and PAT rehabilitation can further the examination of the role of perception and attention in unilateral brain damage.

## Binocular Rivalry in Stroke

**Background.** Though binocular rivalry has been studied extensively in the past, there have been few studies examining the phenomenon in impaired populations, especially in stroke patients. One study found significantly fewer perceptual fluctuations in stroke patients compared to healthy control participants. A significant difference was even found between those patients that had neglect and those that did not have neglect, with the number of perceptual switches correlating with neglect scores from the Behavioral Inattention Test (BIT) battery (Bonneh et al., 2004). Another study (Daini et al., 2010) confirmed differences in image alternation rate between healthy controls and stroke patients, but unlike the first study by Bonneh et al. (2004), there was no significant difference in stroke patients with neglect and those without neglect. This brought Daini et al. (2010) to conclude that the underlying processes driving binocular rivalry may be different than those involved in unilateral spatial neglect.

Currently, the issue remains as to how influential neglect is on perceptual fluctuations, or alternation rate, in a binocular rivalry task. In addition to administering a binocular rivalry task to controls and patients, Daini et al. (2010) showed images of varying complexity. Simple Gabor patches were presented, which consist of overlapping orthogonal gratings with varying spatial frequencies, Gabor percepts in motion were presented, and a complex composite image containing a real-world depiction/photograph of a woman's face overlapping with a house was shown. This more complex image has been shown to relate to higher-order processing that encodes semantic meaning (Gross et al., 1972; Kravitz et al., 2011). In comparing the simple Gabor patches to the complex face and house image, a significant difference was found in the control group between the numbers of alternations based on image type. The face and house image had significantly fewer perceptual switches than the simple Gabor patches in the control group whereas the patient group did not show this effect. This could be due to damaged regions of the brain from the stroke. Instead, the stroke patients exhibited an overall reduced rate of perceptual switching for both image complexities.

**Current study.** The current study examines performance of a group of stroke patients on a binocular rivalry task as well as in healthy control participants. Furthermore, LAT and PAT rehabilitation approaches are used to examine whether attention deficits can be alleviated during binocular rivalry, something that has never directly been investigated prior to this.

In the current study, binocular rivalry is induced with the use of composite anaglyph images and filtered glasses (see Figure 1).

*Figure 1.* Filtered glasses used in the study, with the option of clip-on glasses if the participant wore prescription lenses.

The composite images are created using the anaglyph technique. To create a monochrome anaglyph image, two images of chromatically opposite colors (red and cyan in this case) are superimposed. Viewing these “anaglyphs” through glasses of corresponding colors (in this case, cyan for the right lens and red for the left lens) results in each eye seeing a different image, as the other image would be filtered out by the corresponding colored lens of the glasses (Symanzik, 1993; see Dubois, 2001).

Based on the previously described results, it is hypothesized that stroke patients will have an overall fewer number of alternations compared to healthy controls. In addition, the study by Daini et al. (2010) presented a face and a house image and found that controls reported significantly fewer alternations compared to the Gabor patches, whereas this was not found in the patient group. As the current study presents four different complex images, or real-world scenes, it is predicted that alternation rate for the control group in particular will be slower in the real-world scenes, as well as the face/house image alone, compared to the Gabors. Moreover, overall differences in alternation rate are expected based on the varying degrees of impairments exhibited by the patients; a finding exhibited by Bonneh et al. (2004).

It is further hypothesized that the overall dominance rates will be longer in stroke patients than in control participants, since this measure acts as an inverse to the number of alternations. If the numbers of alternations are reduced in stroke patients, this will cause an increase in the amount of time spent with the left-eye image or the right-eye image remaining dominant, thus lengthening the overall duration of image dominance.

One reason for measuring possible changes in eye dominance in the patients is that these patients can show to acknowledge one side of their body to a lesser extent, such as in cases like somatoparaphrenia, and in right-hemisphere stroke these are predominantly left-sided impairments. If this is the case, information coming into the left eye, and in particular, the left-sided monocular field, may be influenced. Moreover, stimuli, e.g., Gabor patches and real-world scenes, are presented at a large 43-degree viewing angle to maximize the size of the image in the visual field. As it has been noted that larger stimuli can create a larger amount of piecemeal rivalry (Breese 1899, 1909; Levelt, 1965), some of the images are reduced to a 29-degree viewing angle, particularly the Gabor patches, for half of the participants. As mentioned previously, the Gabor patches may elicit lower-order processing compared to the complex stimuli, or real-world scenes. Due to stroke, and because the rivalry effect may be compromised in these patients, only the Gabors are altered and thus presented at 43-degrees for half of all participants and 29 degrees for the other half. Though all Gabors remain in the binocular visual field, if a bias towards the right eye's stimulus is present, causing the right eye to retain longer dominance durations, we would be able to capture the presence of such an effect. It could also be that the stroke patients have difficulty processing the real-world scenes, and if this is the case, the piecemeal effect due to the viewing angle may be problematic, thus negatively influencing performance. This was another reason only Gabors were altered. Though the Gabors are presented at two different viewing angles, we do not expect to find a difference in alternation rate in either group.

Similarly, there may be an influence on which percept is initially seen based on the ocular dominance of the individual. Because of left-sided deficits, it can also be predicted that the right eye will be most dominant, resulting in the patients seeing the first percept predominantly with the right eye.

Though binocular rivalry has not been used as a standard test to study the effectiveness of rehabilitation techniques in the past, it may prove to be beneficial in monitoring progress of stroke patients as well as how rehabilitation influences global, centralized attention mechanisms. Differently from most tests assessing visual function in stroke patients, the binocular rivalry task has no correct response and therefore there is less pressure on the patient to perform according to some standard. This may reduce the frustration that patients often experience during neuropsychological testing, which may further decrease a patient's performance or motivation to participate in the testing. Thus, by observing whether stroke patients report more perceptual alternations while performing a binocular rivalry task, when simultaneously undergoing rehabilitation, compared to receiving no rehabilitation, then we may have a manner to validate whether the rehabilitation approach can help ameliorate global attention mechanisms. Therefore, it is hypothesized that stroke patients receiving a form of rehabilitation will report more alternations compared to when those same patients are not receiving rehabilitation.

# Methods

## Participants

Participants were recruited through Sunnaas Rehabilitation hospital (Oslo, Norway), which is where all data collection took place. There were a total of 11 male unilateral stroke patients with right-hemisphere damage. Females were not recruited due to the low patient count at the hospital and since none of them had right-hemisphere damage according to their hospital journals. In addition, 20 healthy controls were recruited from the Sunnaas staff, with one participant who dropped out due to time constraints, leaving the final number to 19 control participants (8 males, 11 females) who did not significantly differ in age, education, or handedness. The ages ranged from 20-73 (M = 54.91, SD = 17.62) in the patient group, and from 23-67 (M = 48.53, SD = 11.17) in the control group. Level/Years of higher education ranged from 0-8 years in the patient group (M = 2.82, SD = 3.12), and 0-9 years in the control group (M = 5.03, SD = 2.85). Handedness was scored with the Edinburgh Handedness Inventory (Oldfield, 1971), where scores ranged from 33-100 (M = 88.73, SD = 21.59) for the patients, and -80-100 (M = 67.67, SD = 47.42) for the controls. A score less than -40 indicates left-handed dominance, and a score over 40 indicates right-handed dominance. Values in between, from -40 to +40, indicate one as being ambidextrous (both left and right hand dominant). Patient demographics and stroke information are presented in Table 1.

All participants had normal or corrected-to-normal vision. All patients and controls gave written consent for participation and were naïve observers of binocular rivalry, meaning they had no previous experience with the task. This study was carried out as part of a larger project (principal investigator Bruno Laeng, University of Oslo), which was approved by the Regional Ethical Committee for the South of Norway (REK-Sør-Øst), and funded by the Extrastiftelsen granting program of Helse og Rehabilitering. As part of the larger study, the Miles test (Miles, 1929) was used to find ocular dominance for each participant prior to being tested.

Table 1

*Patient Demographics*

| Patient | Age | Education | EHI | Impairment | TAS (Weeks) | Etiology | Localization |
|---|---|---|---|---|---|---|---|
| 1 | 68 | 3 | 100 | 0 | 16 | BI | BG |
| 2 | 73 | 0 | 33 | 0.5 | 19.57 | BI | MG |
| 3 | 69 | 0 | 90 | 0.5 | 14.14 | BI | FP |
| 4 | 20 | 8 | 100 | 0.5 | 9.71 | BI | FTP |
| 5 | 68 | 0 | 90 | 0.5 | 17.29 | BI | FPO |
| 6 | 26 | 2 | 100 | 0.5 | 8.29 | ICH | F |
| 7 | 58 | 0 | 100 | 1 | 8 | BI | FP |
| 8 | 55 | 6 | 63 | 1 | 11.14 | ICH | BG |
| 9 | 61 | 0 | 100 | 1 | 13.71 | ICH | FP |
| 10 | 61 | 6 | 100 | 1 | 7.43 | ICH | BG |
| 11 | 45 | 6 | 100 | 1 | 13 | ICH | FO, BG |
| Patient Mean, SD | 54.91, 17.62 | 2.82, 3.12 | 88.73, 21.59 | | 12.57, 4.04 | | |
| Control Mean, SD | 48.53, 11.17 | 5.02, 2.85 | 67.67, 47.42 | | | | |

*Table 1.* Education = Number of years of higher education; EHI Score = Edinburgh Handedness Inventory (Left<-40, Ambidextrous = -40-40, Right > 40); Impairment (0 = No impairment, 0.5 = Mild impairment, 1 = Neglect); TAS = Time after stroke; ICH = Intracerebral hemorrhage; BI = Brain Infarct; BG = Basal Ganglia; F = Frontal; P = Parietal; T = Temporal; O = Occipital.

## Materials

**Questionnaire.** Upon consent, each participant answered a questionnaire form (see Appendix A) that was part of a larger study to ensure he/she did not qualify for any exclusion criteria. The questions were concerned with the participant's vision (e.g., whether prescription glasses or contact lenses were worn, and what strength), if he/she were colorblind, and if there were any prior surgeries or central nervous system damage. There were additional questions concerning the larger portion of the study if the participant was interested in taking part, which included an fMRI scan. Prior to recruitment, patient health reports were assessed to ensure participation was optimal (no seizures prior to stroke, no drug or alcohol abuse, no central nervous system disease, and no other factors that could affect the brain).

An additional questionnaire was administered to the patient group prior to each testing session in order to ensure the patient was feeling alert enough to perform the tasks for the day (see Appendix B). Questions concerned fatigue, caffeine intake, allergies, and if there have been any falls since the previous testing session. None of the patients had to reschedule test sessions and none of them had injuries due to falls.

**Neglect tests.** Each stroke patient completed a series of neglect tests to determine the degree of attentional deficit and the extent of possible existing unilateral neglect. Tests from the conventional portion of the Behavioral Inattention Test (BIT) (Wilson et al., 1987) were administered, which included line bisection, line crossing, star cancellation, letter cancellation, figure copying, and representational drawings. A total score was tallied which indicated the extent of attentional impairment. For this study, full scores of 146 signified no impairment, reduced scores signified the presence of an attention deficit, and those scores falling below 130 qualified as having unilateral spatial neglect, the cutoff stated in the BIT manual. Overall, 5 patients were scored as having neglect, 7 were found to have mild attention impairments, and the remaining one patient got perfect scores, signifying no impairment (see Table 2).

Table 2
*Neglect Test Scores*

| | | Cancellation | | Drawings | | | |
|---|---|---|---|---|---|---|---|
| Patient | Line Crossing | Letter | Star | Copying | Rep. | Line Bisection | Total BIT |
| 1 | 18,18,36 | 20,20,40 | 27,27,54 | 4 | 3 | 9 | 146 |
| 2 | 18,18,36 | 19,19,38 | 27,27,54 | 4 | 3 | 9 | 143 |
| 3 | 18,17,35 | 20,19,39 | 27,27,54 | 3 | 2 | 9 | 142 |
| 4 | 18,18,36 | 17,17,34 | 27,26,53 | 4 | 3 | 6 | 136 |
| 5 | 18,18,36 | 20,20,40 | 26,27,53 | 3 | 1 | 6 | 139 |
| 6 | 17,18,35 | 19,18,37 | 27,27,54 | 4 | 3 | 9 | 142 |
| 7 | 18,18,36 | 15,15,30 | 21,26,47 | 3 | 3 | 9 | 128 |
| 8 | 16,18,34 | 0,7,7 | 21,24,45 | 0 | 0 | 0 | 86 |
| 9 | 13,18,31 | 1,12,13 | 17,27,43 | 2 | 1 | 0 | 90 |
| 10 | 13,17,30 | 6,17,23 | 25,26,51 | 4 | 2 | 9 | 119 |
| 11 | 18,17,35 | 6,20,26 | 0,17,17 | 3 | 2 | 0 | 83 |

*Table 2.* Neglect scores in the conventional Behavioral Inattention Test. Line Crossing, Letter Cancellation and Star Cancellation: First score is total correct on left side of page, then total correct on right side of page, then total correct overall; Figure/Shape Copying: Total correct out of 4; Representational Drawing: Total correct out of 3; Line Bisection: Total correct out of 9; Total BIT score: Total correct out of 146.

The Bell's Test, another cancellation task, was also administered (Gauthier et al., 1989), as this test may be more difficult for a neglect patient because of a larger number of distracter stimuli compared to the star cancellation test. The same 5 patients who scored as having neglect on the BIT tests also scored below the cutoff on the Bell's test (5 or more bells on either side not identified), an additional measure qualifying them as having neglect.

Furthermore, perimetry was administered, which is a visual field test where one fixates centrally on a black screen and reports the appearance of spots of light appearing in unpredictable locations at different eccentricities. Trials consist of between 2-4 dots that flash on the screen and the patient has to indicate the location of each dot. This test was administered to 9 of the 11 patients for visual field testing (two patients were not tested due to time constraints). This test was chosen to detect the possibility of hemianopia, a condition in which a stimulus in half of the visual field is not detected due to vision impairments rather than attention deficits as in neglect. Though some patients had reduced scores for the left visual field, none of the tested patients were found to have hemianopia (see Table 3). All tests were administered and scored according to the guidelines printed in their respective manuals.

Table 3
*Perimetry*

| | Left | Right | |
|---|---|---|---|
| Patient | Upper, Lower | Upper, Lower | Total |
| 1 | 15, 15 | 15, 15 | 60 |
| 2 | 15, 15 | 15, 15 | 60 |
| 3 | 15, 15 | 15, 15 | 60 |
| 4 | 15, 15 | 15, 15 | 60 |
| 5 | 15, 9 | 15, 15 | 54 |
| 6 | 15, 15 | 15, 15 | 60 |
| 7 | -- | -- | -- |
| 8 | -- | -- | -- |
| 9 | 14, 10 | 15, 15 | 54 |
| 10 | 7, 5 | 15, 13 | 40 |
| 11 | 10, 6 | 15, 15 | 46 |

*Table 3.* Perimetry scores divided into four quadrants, with the total correct out of 15 in each quadrant, beginning with the upper left and lower left, and followed by the upper right and lower right. Total score out of 60. Perimetry was not administered to patients 7 and 8.

**Neuropsychological tests.** Neuropsychological tests were administered to 10 stroke patients to determine basic intellectual functioning. One patient was not tested due to time constraints. A verbal vocabulary test from the Wechsler Abbreviated Scale of Intelligence (WASI) test battery was administered with a mean score of 8.6 (SD = 3.44, min = 4, max = 16), indicating levels somewhat below the mean of 10. In addition, the non-verbal matrices test from the WASI battery was administered, with patients scoring an average of 7.7 (SD = 2.98, min = 4, max = 14). Overall, patients scored within the range of normal intellectual functioning.

**Vision test.** Vision was tested using the Snellen eye examination test (as cited in Westheimer, 1965) while the patient was sitting at a distance of 165 cm, the distance in which he/she would be sitting from the test stimuli. It is common for the elderly to experience poor vision, especially after stroke. Though the patient is not required to read text during the task, the eye test was administered to see if the patient could identify the top five lines, which would verify his/her correct identification of objects in the complex images during binocular rivalry. This mark was specifically decided based on the size of the stimuli in the additional tasks the participant would take part in as part of the larger study. All patients passed the exclusion criteria of the vision test.

## Experiment

**Stimuli.** A total set of eight composite rivalry images were used, in which four consisted of different Gabor patches (overlapping orthogonal gratings of varied spatial frequencies), and the remaining four were photographs of real-world scenes, including the overlap of a face and a house, a frog and a lion, a cat and a sunflower, and a cactus and a pineapple (see Appendix C). Images were created with Anaglyph Maker version 1.08, created with C++Builder5 (Sekitani, 2001). Each image was paired with an abstract ‘filler’ image, or baseline image, of matched luminance that was shown preceding the stimulus image (see Figure 2). This was to prepare the participant for viewing the anaglyph. The baseline images were created in Matlab, version 7.11.0.584. All images had a 1200x800 resolution.

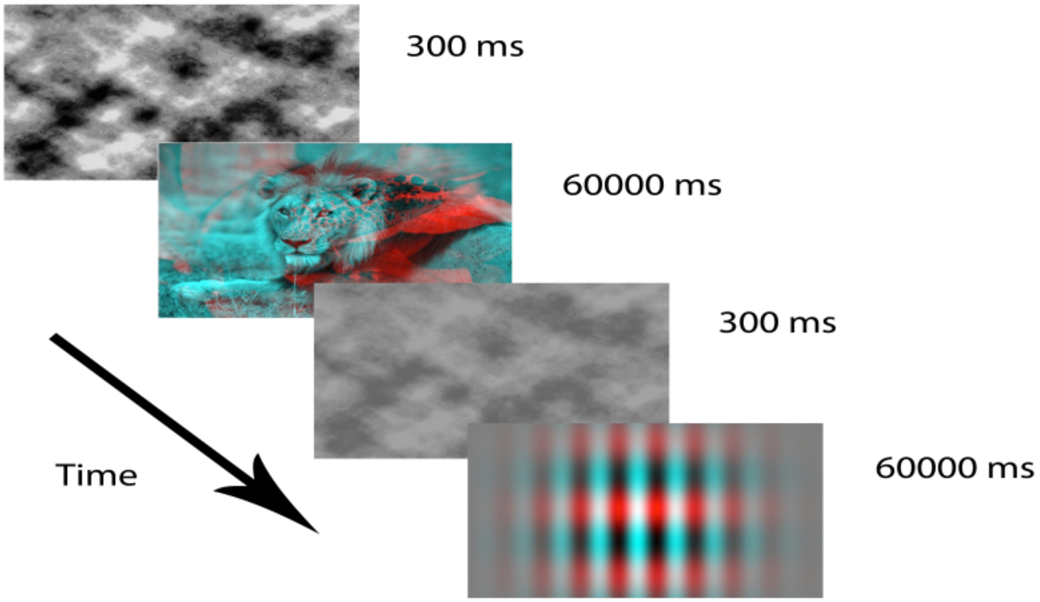

*Figure 2.* Presentation of anaglyphs, beginning with a baseline image shown for 300 ms, followed by the anaglyph for 60,000 ms until all 8 anaglyphs have been presented.

In addition, two contrast values were calculated for each image, as each image is presented twice in opposing red-cyan colors (see Table 4). Contrast values were found by using the Michelson formula. Luminance values were obtained in Adobe Photoshop CS6 Extended, version 13.0. The mean contrast values for the real-world scenes ranged from 45.5% - 70.5% (M = 60.25, SD = 10.60), whereas the means for the Gabors ranged from 73.5% – 92% (M = 84.50, SD = 8.13).

Table 4
*Stimulus Contrast*

| | Contrast % | | |
|---|---|---|---|
| Image | A | B | Mean |
| Cat/Flower | 65 | 57 | 61 |
| Face/House | 64 | 77 | 70.5 |
| Lion/Frog | 39 | 52 | 45.5 |
| Pineapple/Cactus | 50 | 78 | 64 |
| Gabor 1 | 74 | 73 | 73.5 |
| Gabor 2 | 88 | 90 | 89 |
| Gabor 3 | 84 | 83 | 83.5 |
| Gabor 4 | 95 | 89 | 92 |
| RWS Mean, SD | 60.25, 10.60 | | |
| Gabor Mean, SD | 84.50, 8.13 | | |

*Table 4.* The contrast in percent listed for each image, where A and B represent the same image in opposing red-cyan colors. Means and standard deviations (SD) listed at the bottom of column A are for all real-world scenes (RWS) combined and Gabor patches combined.

Anaglyphic images were made in cyan-red colors and viewed with color-filtered glasses, ordered from 3D Stereo (www.3Dstereo.com, Las Vegas, NV). The experiment was generated using Experiment Center 2, version 3.0, provided by Sensomotoric Instruments (SMI, Berlin, Germany). Stimuli were presented by means of a NEC NP43 Projector system onto a white screen on the wall.

***Eccentricity.*** Stimuli were presented at a 20-degree eccentricity, which yielded a viewing angle of 43-degrees. Images were shown in this size to see if this had any influence on perception for stroke patients. Though the stimuli did not reach the monocular viewing fields, viewing anaglyphs of this size may influence how the images alternate in stroke patients.

***Periphery.*** Though the eccentricity was set at 20-degrees, some of the stimuli were presented differently. Specifically, as Gabor patches may require lower-order processing, some participants (6 patients, 10 controls) viewed Gabors at a 29-degree viewing angle, and the remaining participants (5 patients, 9 controls) viewed the same Gabors which yielded a viewing angle of 43-degrees, the same as the real-world scenes. This was done in order to examine if image size in low-order percepts revealed any alternation differences in unilateral stroke patients. Though stimuli do not enter the monocular visual field, if there was favoritism to one eye due to stroke, altering the viewing angle might reveal an effect.

**Procedure.** Participants were seated at a fixed distance of 165 cm from the screen, which was distance the stimuli would be projected. Windows and curtains were closed and lights were turned off to keep a constant level of illumination and to avoid external distractions. Participants were told that they would see a series of 8 images that were made up of two different, but overlapping percepts. They were also told to look at the images while keeping their eyes open and to keep his/her gaze relaxed but over the central region of the image. In other words, there was no fixation point and eye movements away from the center of the image were permitted for the duration of the task. Participants were then given instruction to verbally respond each time one image became dominant and the other became suppressed; the participant was to say the name of the dominant image. Participants were told to verbalize which image was most dominant even though pieces of the alternate percept may be visible simultaneously. When viewing the face and the house, for example, the subject would say ‘face’ when the face became dominant, and ‘house’ when the house became most dominant. When viewing the Gabors, participants reported the direction of the lines (‘vertical’ or ‘horizontal’) when that one became dominant. If a patient was uncertain of which direction was horizontal and vertical during the Gabors, the interviewer used a hand demonstration to express the difference. A pair of red and cyan filtered glasses was given to the participant to wear. If prescription glasses were worn, a pair of clip-on filtered glasses was put over the prescription lenses.

After eventual participants’ questions were answered, the participant viewed a practice image to ensure understanding of the task. After the experimenter was sure the participant understood the task, the eight anaglyphic images were presented one at a time for 60 seconds each, each preceded by their matched baseline image shown for 300 ms. The participant indicated the moment one image became dominant, and continued verbalizing the pattern of dominance over the entire 60-second period. At the time of response, a key was pressed by the interviewer to record the answers. The same interviewer recorded data for all participants. Anaglyphs were presented in a pseudo-randomized order.

Each participant was tested on two separate occasions, each session occurring within the same week, or 7-day period, of the other. One reason to test participants on two separate occasions is to keep the testing time to a minimum. Stroke patients, in particular, may become fatigued quickly, which can lead to a decline in attention, and thus performance. Additionally, some participants may be prone to getting eyestrain. During each test session, opposing colors of the anaglyphic images were presented from the session prior. In other words, the same images were shown at each testing period, but with opposing colors (see Figure 3).

This was done to help reduce any noisy effects produced by the filtered glasses, such as differing in the color filtration between the red and the cyan lenses. It was noticed, for example, that by closing one eye at a time that the cyan lens filtered the cyan image slightly better than the red lens filtered the red image.

Data were pooled together between the test sessions for each participant and comparisons were made between controls and patients.

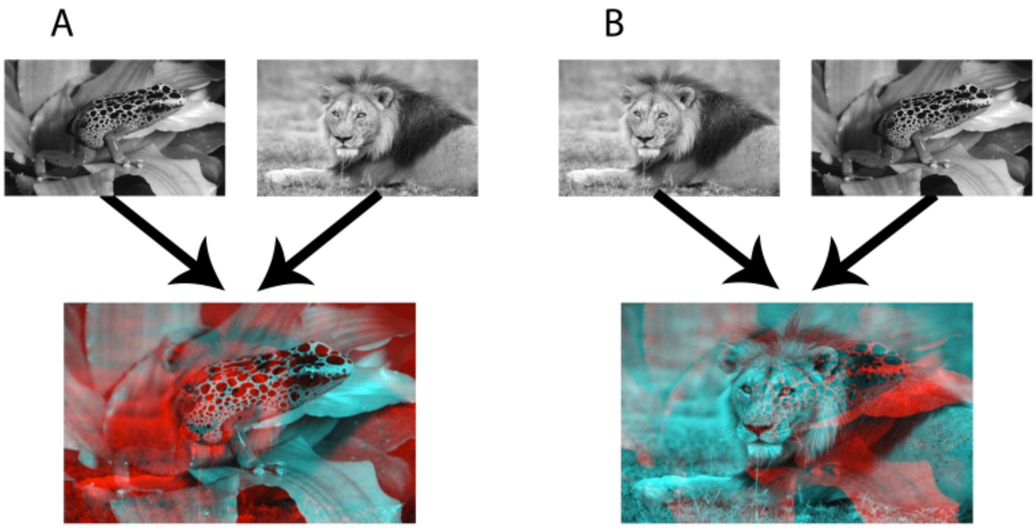

*Figure 3.* A) A frog and a lion image overlapping to create an anaglyph; B) The same lion and frog overlapping to create the same anaglyph of opposing red-cyan colors.

**Rehabilitation.** Stroke patients were asked to participate for an additional two weeks in order to assess the effects of attention functioning during rehabilitation, meaning that testing would occur over a three week period. Due to some patients leaving the hospital before the three-week period, five patients completed only week one of the study, whereas a total of six completed all three weeks. Rehabilitation took place in either the second or third week, depending on which group they had been randomly assigned. This setup was to help control for spontaneous recovery as well as for the maintenance of rehabilitation effects one week after treatment. The second and third week of the study paralleled the first week, involving two separate testing sessions each week, with the only difference involving a rehabilitation technique. Rehabilitation methods were assigned based on whether the patient was able to perform movements for active Limb Activation Training (LAT) or not. Two right-hemisphere stroke patients were assigned LAT and were instructed to hold a metal device in the left hand, moving it continuously while viewing the anaglyphs. The remaining 4 patients had hemiparesis and were unable to move the left arm or leg, and thus were assigned to Phasic Alertness Training (PAT). Different tones were made with a metal device at random intervals of about 1-4 seconds in the patient's left field of space. LAT and PAT were ongoing throughout the entirety of the binocular rivalry task.

## Analysis

The data was analyzed using IBM SPSS Statistics, version 20.0 and Statview® commercial software. The cut-off level of statistical significance was determined at the 0.05 alpha level. The average number of alternations for controls and patients were analyzed by averaging the number of perceptual switches for each image type (Gabor patches and real-world scenes). Responses involving piecemeal rivalry, or a mixture of the two percepts, were not counted. Specifically, alternation rates in Gabors were examined based on whether they were presented at a 29-degree viewing angle or a 43-degree angle. Image complexity, the face/house in particular, was also compared to the Gabors to assess average alternation rate for patients and controls. The alternation rate in the control group alone was further examined using a paired-samples t-test. The average duration of dominance was also examined. Dominance rates were calculated by averaging the total amount of time the left versus right eye was dominant. If the right eye, for example, perceived the percepts on average for a longer duration, it was calculated as most dominant (Hunt et al., 2012). In addition, the number of alternations was examined based on the percentage correct on the BIT test battery within the patient group. The number of alternations during rehabilitation for each patient was compared to the number of alternations without rehabilitation in the same patients. Further, the first percept seen (with the left or right eye) was analyzed to see if the ocular dominance of the individual could be playing a role, which was examined with both patients and controls.

# Results

## Periphery

A two-way between-within subjects ANOVA was performed to examine alternation rate with Group (patients, controls) as the between-subjects factor and Gabor Size (43 degrees, 29 degrees) as the within-subjects factor. There was no significant main effect of group on Gabor size, $F(1,26) = .191$, $p = .666$, indicating the size of the Gabor did not influence perceptual fluctuations. As alternation rates were not found to differ between Gabor sizes, all analyses were grouped together and not separated by the size of the Gabor.

## Alternations

A mixed between-within subjects ANOVA was conducted to compare the number of alternations with Group (patients, controls) as the between-subjects factor and Anaglyph Type (Gabors and real-world scenes) as the within-subjects factor. There was a main effect demonstrating that controls had a significantly higher number of alternations compared to patients, $F(1,28) = 31.758$, $p < .0001$, partial eta squared = .531, for both Gabors and real-world scenes (see Figure 4). No interaction effect was found between group and anaglyph type, $F(1,28) = 2.051$, $p = .163$, partial eta squared = 0.68. There was no significant main effect of anaglyph type, Wilks' Lambda = .996, $F(1,28) = .110$, $p = .742$, partial eta squared = .004, indicating no difference in alternation rate between Gabors and real-world scenes.

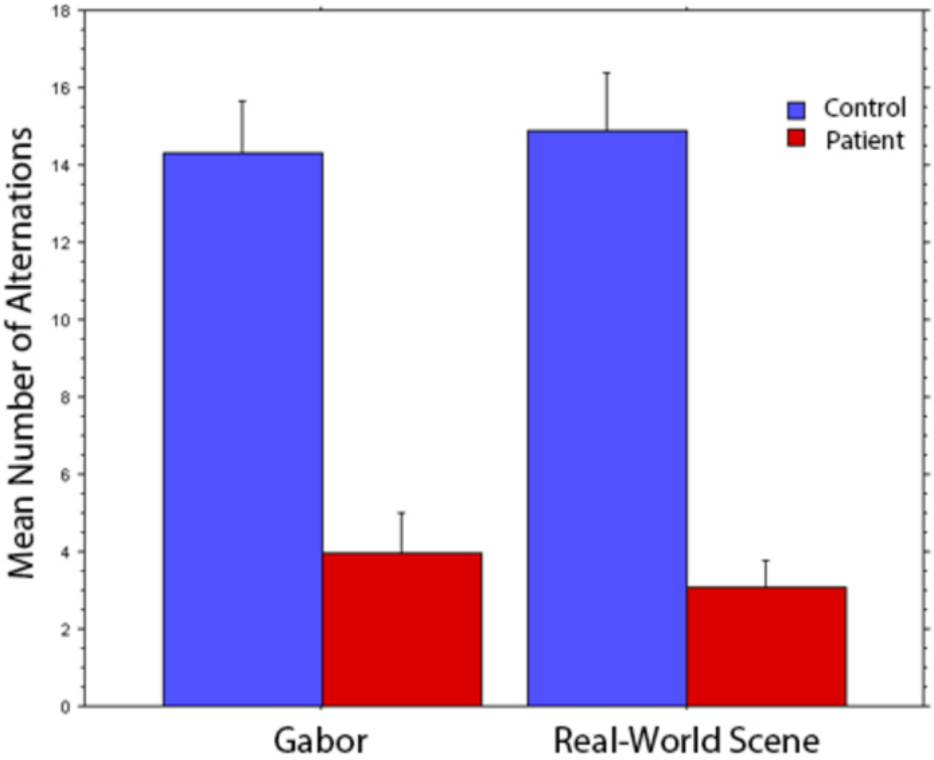

*Figure 4.* Mean number of alternations in patients and controls per 60-second period for Gabors and real-world scenes. The error bars indicate standard error.

**Face/house.** A mixed between-within subjects ANOVA was performed to assess differences with Group (patients, controls) as the between-subjects factor and Anaglyph Type (Gabors, face/house) as the within-subjects factor. This analysis examined whether differences in alternation rate were found between the Gabors and the face/house image, as the face/house image was found to alternate significantly slower than Gabors for control participants in previous findings (Daini et al., 2010). There was a significant interaction effect found between group and anaglyph type, Wilks' Lambda = .766, *F*(1,28) = 8.547, *p* = .007, partial eta squared = .234, which shows there were significantly more alternations in controls than in patients, and significantly more alternations in Gabors than in the face/house anaglyph for controls, whereas this was not found in the patient group (see Figure 6). A paired-samples t-test was conducted to confirm the significance of alternation rates in control participants in the Gabors and the face/house image. There was a significant difference in the two image types, with Gabors (M = 14.30, SD = 5.96) yielding significantly more alternations than the face/house anaglyph (M = 9.30, SD = 4.48), *t*(18) = 6.29, *p* < .001.

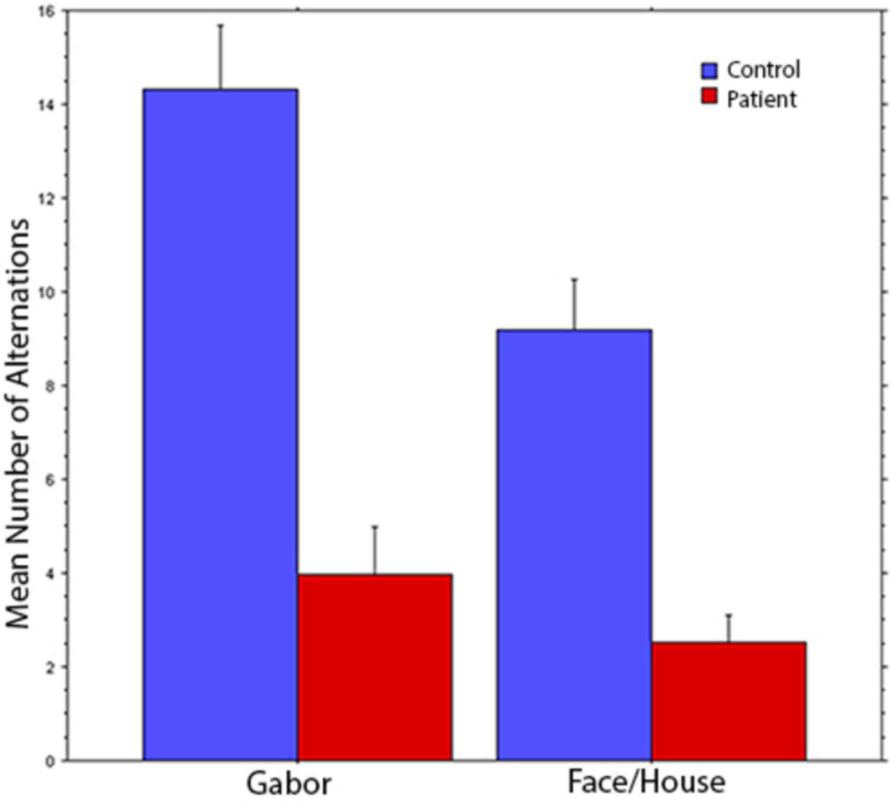

*Figure 6.* Mean number of alternations in patients and controls per 60-second period in the Gabor patches and the face/house anaglyph. The error bars indicate standard error.

**Neglect scores.** A simple regression was used to examine how the total percent correct on the BIT battery correlated with the number of alternations in the patient group.

The number of alternations expressed a positive correlation with the total BIT score (R =.45), with a 20% of variance in alternation rate ($R^2 = .20$) explained by the percentage correct on the BIT, *F*(1,20) = 5.049, *p* = .036 (see Figure 5). Though one patient stood out with a larger number of alternations compared to the rest of the group, the correlation remained significant when removing this case from the analysis, *F*(1,18) = 4.641, *p* = .045.

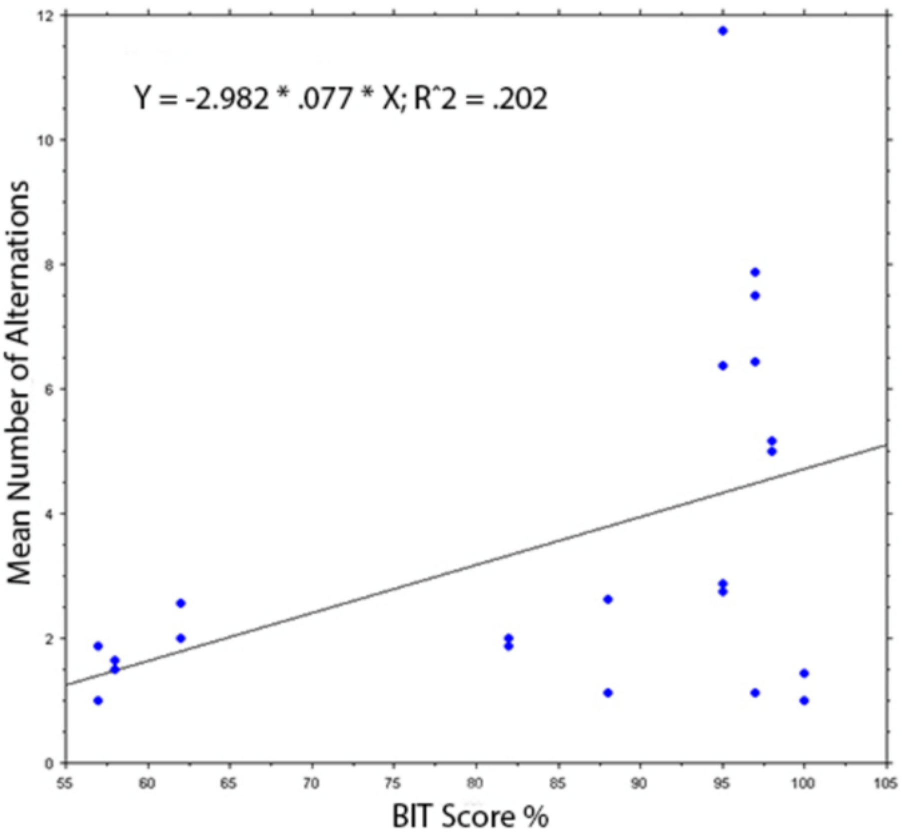

*Figure 5.* Mean number of overall alternations per 60-second period in both Gabors and real-world scenes in patients correlated with the total percent correct on the Behavioral Inattention Test (BIT) battery.

**Rehabilitation.** Alternation rate was assessed during rehabilitation using a mixed between-within subjects ANOVA with Group (no PAT, PAT) as the between-subjects factor, and Anaglyph Type (Gabors, real-world scenes) as the within-subjects factor. No significant main effect was found for group, *F*(1,3) = 7.50, *p* = .072, though the data expressed a trend towards significance with patients reporting a higher number of alternations during PAT rehabilitation compared to no PAT rehabilitation. LAT was not analyzed separately due to the small patient group of two people.

The mean alternation rate was plotted for each patient with and without rehabilitation (PAT and LAT), including the control group as a whole (see Figure 7), which shows the trend towards a higher number of alternations during rehabilitation, particularly in the PAT patients.

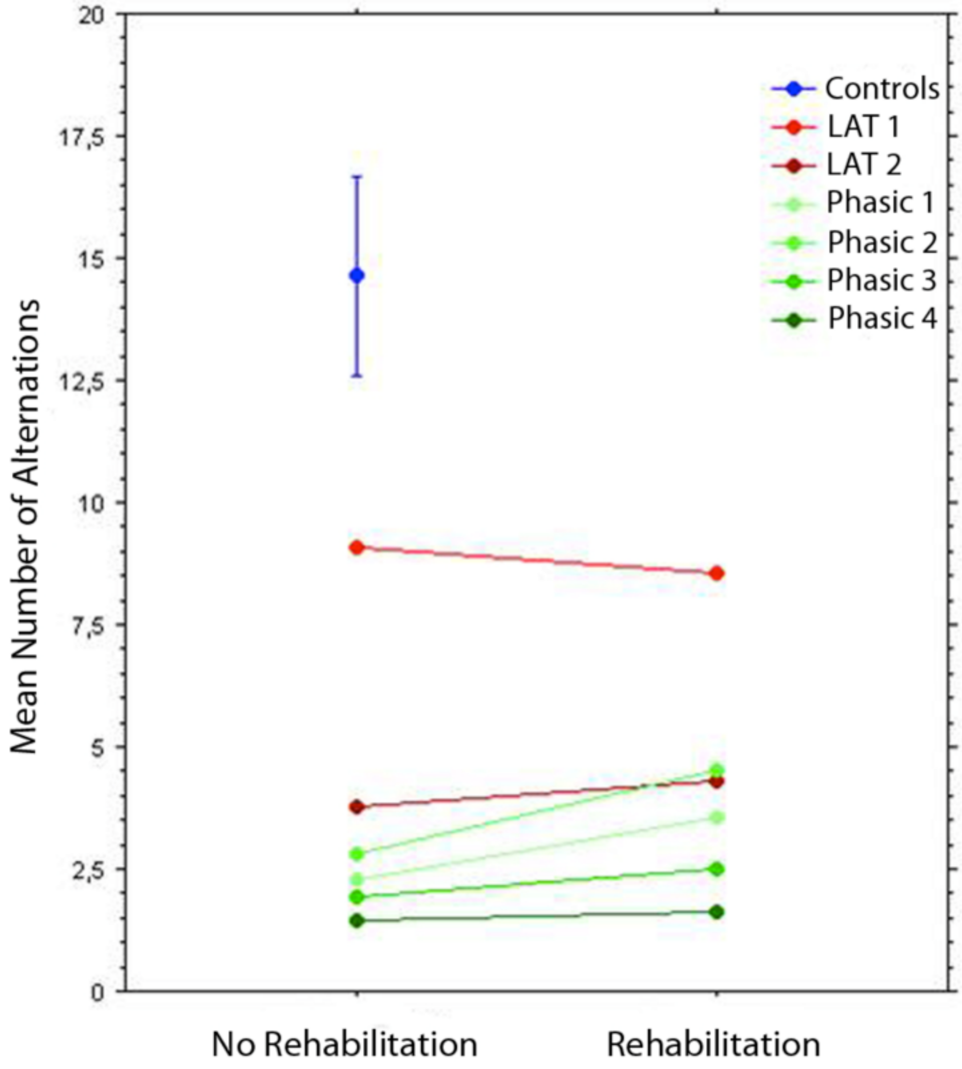

*Figure 7.* Mean number of alternations per 60-second period in each patient before rehabilitation and during rehabilitation. The controls' mean alternation rate (blue circle) is plotted collapsed as a group; the bars show the 95% confidence interval around the controls' mean. Red circles identify patients who underwent LAT rehabilitation, whereas green circles identify patients who underwent PAT or Phasic Alerting rehabilitation.

## Duration of Dominance

Duration of Dominance was analyzed using a mixed between-within subjects ANOVA with Group (patients, controls) as the between-subjects factor and Anaglyph Type (Gabors, real-world scenes) and Eye (left, right) as the within-subjects factors. Results expressed a significant main effect of group, *F*(1,28) = 41.881, *p* < .0001, indicating that controls had a much shorter overall duration of dominance than the patient group (see Figure 8). No other significant main effects or interaction effects were found.

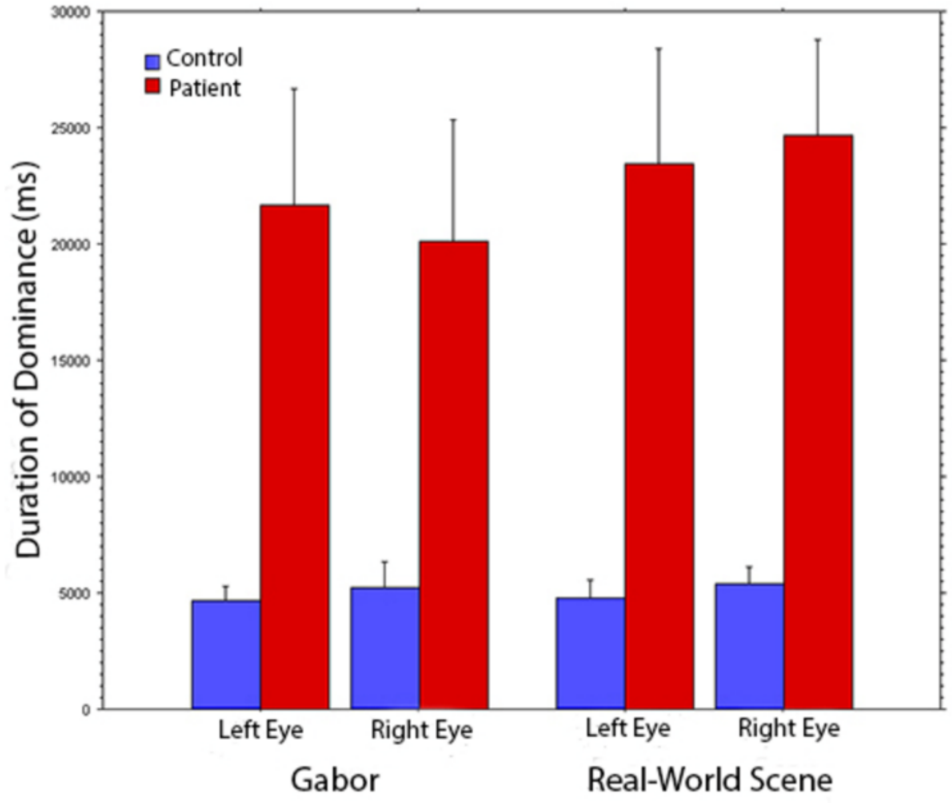

*Figure 8.* Mean duration of dominance per 60,000 ms in patients and controls in the left and right eyes for both Gabors and real-world scenes. The error bars indicate standard error.

## First Percept

A mixed between-within subjects ANOVA was performed to assess eye dominance of the first percept with Group (patients, controls) as the between-subjects factor and Anaglyph Type (Gabors, real-world scenes) as the within-subjects factor. There was no significant main effect found for group, *F*(1,28) = 2.646, *p* = .115, and no significant interaction effects found between group and anaglyph type, *F*(1,28) = .204, *p* = .655, and no main effect found for anaglyph type, *F*(1,28) = 1.899, *p* = .179, suggesting no difference in eye dominance between Gabors and real-world scenes when perceiving the first image.

# Discussion

## General Findings

A binocular rivalry task was administered to right-hemisphere unilateral stroke patients and healthy control participants. By studying binocular rivalry, a non-spatial task, one can examine global attention mechanisms that utilize the central region of space rather than the left or right visual field per se. By examining aspects of attention and perception during conscious processing during this task, one can assess where in the brain such processing takes place. It has been debated whether binocular rivalry involves mechanisms early in visual regions (low-order) or further along the visual pathway (high-order), though recent ideas are joining the two theories, thus positing an integrative approach (Ooi & He, 1999; Blake & Logothetis, 2002; Carlson & He, 2004). Higher-order mechanisms can become compromised after a stroke, such as in cases of parietal, temporal, or frontal lobe damage. If higher order mechanisms play a role in perceptual fluctuations during binocular rivalry, then a lesion to these regions may result in poorer performance levels.

The main findings indicated a significant difference in the number of alternations between controls and patients, with patients reporting significantly fewer perceptual alternations than controls. Patients also expressed a significantly longer duration of dominance compared to controls, which was expected, as this measure is an inverse relationship to alternations rate. Though two levels of image complexity were presented (Gabor patches and real-world scenes), no significant difference in the number of alternations was found based on the image complexity for either controls or patients. However, when assessing the face/house image on its own compared to the Gabor patches, as previously shown by Daini et al., (2010), controls were found to have significantly fewer alternations for the former compared to the Gabors. An additional finding was that PAT rehabilitation expressed a trend towards a higher number of alternations in the patient group.

## Perceptual Alternations

**Viewing angle.** Seven patients and ten controls viewed Gabors at a 29-degree viewing angle; taking up a smaller portion of the visual field than the real-world scenes, which were shown at a 43-degree viewing angle. The remaining participants viewed all images at the same 43-degree angle. This was in order to see if image size affected alternation rate. As noted by Blake et al. (1992), larger images induce more piecemeal rivalry, which may influence response rate of dominance in participants. Gabors, unlike real-world scenes, were administered in this manner to help understand if neglect or other attention impairments were affected while viewing an image requiring only low-level processing. Though all stimuli were shown within the binocular field of view, larger images approach the periphery even if not viewed in completely monocular regions. With this, there could be a difference in how images are perceived by those with attention deficits, especially unilateral spatial neglect. Results, however, indicated no significant difference in alternation rate between the two viewing angles for both patients and controls. This indicates that the severity of stroke may not influence alternation patterns between the 29-degree and 43-degree viewing angles. Due to this finding, data for both image sizes were analyzed together.

**Rate of perceptual alternations.** Consistent with the hypothesis, healthy control participants demonstrated a significantly higher number of alternations in comparison to stroke patients, paralleling previous research (Bonneh et al., 2004; Daini et al., 2010). Both image types, real-world scenes and Gabor patches, had a much slower rate of perceptual switching for stroke patients, another finding also exhibited by Daini et al.'s (2010) study, who also administered real-world scenes (complex stimuli) in addition to Gabors (simple stimuli).

Attention plays a key role in the influence of what is being perceived during binocular rivalry (Blake, 2001; Chong et al., 2005; Paffen et al., 2006). Though a decrease in attention may not influence alternations to the point of stopping them altogether, it does have an effect causing the rate of perceptual switching to slow significantly (Paffen et al., 2006). Stroke patients have a more limited attention span in comparison to healthy controls (Staub & Bogousslavsky, 2001), and because of this, it would be expected that the two percepts in an anaglyph image would alternate at a slower rate. Additionally, it is common for recovering stroke patients to experience a high level of fatigue throughout the day. Time is spent attending therapy sessions and learning about different types of rehabilitation techniques. It is likely for a patient to become tired and overwhelmed with the lifestyle change of trying to recover from a stroke. It is also common for patients to go through periods of feeling depressed, which is another factor influencing attention. Additionally, it has been shown that participants exhibiting a higher degree of negative affect are more likely to disengage from a task (Luu et al., 2000). Due to higher levels of negative affect in recovering stroke patients, it is not surprising to see that many have diminished attentional mechanisms resulting in responding poorly on a variety of tasks. However, as mentioned earlier, the binocular rivalry task has the advantage that there is no correct response to be given and, consequently, it reduced the risk that it would yield negative affect from the patient as a result of poor performance. Binocular rivalry goes one step further of other attentional tests to express how diminished attention affects pre-conscious perceptual switching, meaning that the suppressed image remains suppressed for longer durations while the dominant image remains dominant. Moreover, by using a non-spatial task, one can see that impairments due to stroke are not only affecting one hemisphere, being that binocular rivalry is presented centrally.

It is also worthy to note that while stroke patients perform slowly because of attention deficits, the control participants may be able to influence the rate of perceptual switching through eye-movements as well. Eye-movements are suspected to be of influence behind the rate of perceptual switching after one study showed that eye movements increased during a perceptual alternation (van Dam & van Ee, 2006), however there has not been evidence to claim that eye movements themselves cause the alternations. It may be possible, however, for a participant to direct his/her gaze to certain aspects of an image during piecemeal rivalry, thus trying to pull an image from a suppressed state into a dominant state. In addition, though one study expressed that the number of alternations can strengthen with task repetition, as if task exposure can act as a "priming" effect (Suzuki & Grabowecky, 2007), many others do not as readily agree

(Peckham, 1936; Blake et al., 1971; Meng & Tong, 2004; Slotnick & Yantis, 2005; Hugrass & Crewther, 2012).

**Level of impairment.** As the alternation rate in the stroke patient group differed significantly from the control group, there was also a significant difference found within the patient group. By correlating the percentage correct on the BIT test battery with the average number of alternations, it was found that the BIT scores were moderately predictive of alternation rate, with lower scores yielding fewer alternations. This parallels the finding by Bonneh et al. (2004) who also found a significant difference in the patient group, with neglect patients performing 2.5 times slower than stroke patients without neglect. It is noteworthy, however, that this was not found in the study by Daini et al. (2010). Overall alternation rate could be influenced by the fact that Daini et al.'s (2010) study included a Gabor patch involving motion, whereas the current study and the study by Bonneh et al. (2004) did not. This could be the reason why findings were different. It has been shown that one may be able to alternate at will if the stimulus involves motion (Hugrass & Crewther, 2012), which may have created a situation in Daini et al.'s (2010) study where all stroke patients were able to perform similarly, despite level of impairment.

***Types of attention.*** When addressing the level of attention impairment after stroke, it is important to note that there are different types of attention, some of which may be more lateralized than others. For example, it has been stated that spatial attention, or the ability to attend to a stimulus depending on it's spatial location (Vecera & Rizzo, 2003), is dominant in the right hemisphere, in which case spatial attention in particular may be disrupted after right-hemisphere parietal lesions (Mesulam, 1981; Corbetta, et al., 1993). Sustained attention, or the ability to hold one's attention on a stimulus (DeGangi & Porges, 1990), is another mechanism that has been shown to be dominant in the right hemisphere, which is supported by the idea of poor disengagement mechanisms after stroke (Morrow & Ratcliff, 1988; Losier & Klein, 2001).

It has been demonstrated in healthy individuals that the right hemisphere is necessary to maintain even short periods of sustained attention (Whitehead, 1991). Townsend and Courchesne (1994) explained it in terms of patients' attention acting as a spotlight, and anything outside of central focus is likely disregarded. As all patients in the current study had damage to the right hemisphere, where sustained attention is controlled, this may be one factor influencing why stroke patients experienced fewer perceptual switches.

Previous research demonstrated that stroke patients have difficulties refocusing attentional mechanisms. After hemispheric damage, if attention is focused on one stimulus, it is more demanding to disengage attention and reengage attention on a new stimulus (Posner et al., 1984; Morrow & Ratcliff, 1988; Friedrich et al., 1998; Losier & Klein, 2001). While viewing the face/house image, for example, and having attention initially focused on the face, it takes a much longer time for the attention system to switch to the suppressed image, thus not allowing the patient to see the house until after a longer period of time. This may be another reason why all stroke patients reported fewer alternations compared to controls. Disengagement mechanisms may be an influential factor contributing to poor scores on the BIT tests as well, thus being a predictive factor of alternation rate.

In addition, it could be that the large eccentricity resulted in more piecemeal rivalry, especially with real-world scene images, or complex stimuli. It might be that stroke patients in particular were less able to get an image to become fully dominant due to reduced attentional mechanisms in comparison to the controls.

**Stimuli complexity.** Control participants did not express any significant difference in the number of alternations between real-world scenes (complex stimuli) and Gabor patches (simple stimuli). However, when analyzing the face/house anaglyph alone and comparing it to the other Gabors, controls expressed significantly fewer alternations for the face/house image; a finding not exhibited in the patient group. Daini et al. (2010) also found that controls reported significantly fewer alternations in the face/house stimulus compared to the simple Gabor patches.

One reason the other complex stimuli did not elicit the same outcome in controls as the face/house could be due to the fact that viewing time for the other real-world scenes was about three times longer compared to the face/house image. In other words, alternation rate may have demonstrated a slower outcome in the face/house image because the participants did not view it as long as the other scenes combined. As was the case in the study by Daini et al. (2010), the face/house image was only shown for a short time of two minutes. It could be possible that the alternation rate in the face/house image would quicken with increased viewing time. Further, another aspect not to overlook is that each real-world scene image has a different contrast, whereas higher contrast images may remain dominant for a longer duration (Mueller & Blake, 1989). The face/house image had the highest contrast among the real-world scenes (shown above in Table 4), thus it could be that the image remained dominant longer, resulting in a slower alternation rate. Daini et al.'s (2010) study only included a face/house image and no other complex stimuli. Comparatively, in the current study, participants viewed complex stimuli for a longer duration overall. This fact along with the varied contrast levels between the different images may be enough to induce a difference in alternation rate between the face/house image and the rest of the real-world scenes. In other words, this could be why the real-world scenes as a whole resulted in faster alternation rates while the face/house stimulus did not.

It has also been shown that the human brain has specialized regions for processing different objects. For example, faces are processed in the fusiform face area (FFA) (Kanwisher et al., 1997) and places, such as houses, are processed in the parahippocampal place area (PPA) (Epstein & Kanwisher, 1998). Due to the specific regions of the brain that process faces and houses, the presentation of a face/house anaglyph during binocular rivalry has been studied using fMRI (Tong et al., 1998). Conversely, as there may be a region of the brain that processes animals, there is no specific region for processing, for example, lions or frogs specifically. This may be another reason why participants had a different alternation rate for the face/house image and not to the other real-world scenes.

Moreover, the image size may have more of an effect on how complex stimuli are perceived compared to simple stimuli. Daini et al.'s (2010) stimuli were presented between a 5.37 and 7.15-degree viewing angle, whereas the current study enlarged the images up to a 43-degree viewing angle. Increased amounts of piecemeal rivalry has been shown to result from larger stimuli (Breese 1899, 1909; Levelt, 1965), and thus may produce an outcome in the current study where a participant reports fewer alternations with real-world scenes than what actually occurred. Gabors appear to be easier for one to perceive, as one is clearer if he/she sees lines presented vertically versus horizontally. With complex stimuli, comments from individuals included issues such as seeing the face of the woman but instead of the hair, the house surrounded her, making it unclear which image was most dominant. With more piecemeal rivalry, the alternations or the reports of the alternations may have been reduced. Though overall alternations did not differ between simple and complex stimuli, it could have had an influence in the face/house image whereas the controls responded more conservatively.

Though actual piecemeal rivalry was not tracked in the current study, this could add some revealing evidence as to when images are actually switching between dominance and suppression versus remaining a patchwork of both. In the current set-up, participants were told to only report when one image became dominant, in which case it may have been difficult to tell if a participant was seeing piecemeal rivalry and just guessing at which image was dominant. By either tracking the amount of piecemeal rivalry, or by administering the same stimuli at a smaller viewing angle, one might be able to see how eccentricity and piecemeal rivalry influenced alternation rate of both stimuli complexities.

Even with the presence of piecemeal rivalry, studying binocular rivalry with both simple and complex stimuli may prove to be useful in gaining an understanding as to how stimulus complexity influences perceptual processing. When examining this phenomenon in stroke patients, it could reveal evidence as to whether high or low-order mechanisms are involved during perceptual fluctuations.

**Rehabilitation.** Results indicated that Phasic Alertness Training (PAT) yielded a positive outcome for stroke patients, with and without neglect, resulting in an increase in the number of alternations for a patient during rehabilitation compared to the same patient not receiving rehabilitation. Though the increase in performance was slight, and thus not significant, it revealed a trend that supports the idea of PAT being a beneficial technique in temporarily alleviating attention deficits. It has been shown that beginning rehabilitation practices sooner can yield more benefits in the recovery process (Cumming et al., 2009). The current patient group participated in the study with an average of 12.57 weeks after the stroke. Beginning rehabilitation sooner may yield improved results demonstrating the positive effect of rehabilitation on the attention system. Moreover, if PAT proves to play a significant role in ameliorating attention deficits during binocular rivalry, it would mean that patients' global attention is being improved, all while performing a non-spatial task. The benefit of testing patients on binocular rivalry during rehabilitation is that one would be able to see the overall progress of increased centralized attention, not just attention allocated to one visual hemisphere or the other.

The Limb Activation Training (LAT) group only consisted of two patients, a number too small to do an individual analysis on. The two patients tested expressed mixed results as to whether rehabilitation was helpful. One LAT patient seemed to improve, reporting a higher number of alternations, but the other LAT patient did not show the same trend. The patient showing a decrease in the number of alternations had to be frequently reminded to move the arm and hand for LAT during the binocular rivalry task. This could indicate that the physical act of moving one's arm and hand for an extended period of time became tiresome and distracting for this patient. There has been, however, evidence that LAT is a useful technique with the promise of producing even more long-term effects than just immediate amelioration. Harvey et al. (2003) studied the effectiveness of active LAT in chronic stroke patients (12 months post-stroke), and found a 46% improvement in neglect test scores after a one-month period of LAT training. With this evidence, LAT has demonstrated itself to be a beneficial approach in helping to improve attention impairments and other deficits produced by stroke, even in chronic stroke patients, who's symptoms seem to be more stable and thus may be more difficult to reduce. In the current study, including a higher number of participants in the LAT patient group may prove to demonstrate more of the positive effects that LAT has to offer. Though LAT did not show any significant benefits during binocular rivalry, such as helping to repair attention deficits resulting in a higher number of alternations, this method may produce results if practiced regularly.

It is also important to note that the PAT and LAT patient groups have been different from the beginning. Patients in the PAT group had more severe symptoms, with paresis being one of them. The LAT patients, on the other hand, were better functioning overall, requiring less help with everyday activities. One of the LAT patients in particular stood out by being much younger than the rest of the patients who underwent rehabilitation. As the number of perceptual switches increased during rehabilitation, it may be that the brain of a younger person is quicker to recover after injury, resulting in improved task performance. Also, for the two LAT patients, because impairments were not severe enough to cause paresis in the first place, they were able to take part in active LAT themselves. The patients in the PAT group will likely become rehabilitated over time and regain movement of the limbs, in which time they can switch to LAT as a self-controlled rehabilitation technique. In fact, PAT requires some external tool (or a therapist) that can periodically alert the patient, whereas LAT has the advantage that it can be self-administered. It would be of interest to test the PAT patients over time and see how performance during binocular rivalry changes when PAT rehabilitation is replaced by LAT.

**Duration of dominance.** The average dominance rate prior to an alternation or perceptual switch was computed for each image. As expected, patients experienced a significantly higher duration of dominance for Gabor patches and real-world scenes compared to healthy control participants. This measure was only examined as it acts as the inverse of alternation rate. With a low number of overall alternations, it would be expected for patients to experience a longer duration of dominance, meaning that one of the eyes is remaining dominant for a prolonged amount of time. Results also indicated there was no difference between the left and right eye in the rate of dominance, which could signify that stroke may not have an influence on eye dominance in a binocular rivalry task, at least in the sample that was tested here. With attention deficits and neglect occurring in the left visual field, one may suspect the left eye to become more suppressed while the right eye retains the dominant image for longer. However, as results indicated, the left eye was just as dominant as the right eye. This may indicate different processes involved in attention mechanisms after stroke and its influence on ocular dominance.

**First percept.** As no difference was found between the left and right eye when analyzing the duration of dominance, there was also no difference between the left and right eye when perceiving the first image for both Gabors and real-world scenes. Based on ocular dominance of the individual, as collected from the Miles test (1929), it was expected that there might exist a difference in which image the participant saw first. Further, it was expected this would be altered for the stroke patients. Because the patients all have right-hemisphere damage, it was expected that the information coming in the left monocular field would be reduced, thereby creating a situation where the right eye would either dominate longer, or be most dominant upon viewing the first image. As the study demonstrated, there was no difference between the eyes for the patient group or the control participants, suggesting that stroke may not have an influence on ocular dominance during binocular rivalry, though it remains unclear how overall eye dominance is influenced by stroke.

## Implications for Future Research

With few studies existing on the influence of stroke during binocular rivalry, future research would benefit from continuing investigating the binocular rivalry paradigm in stroke patients. It is beneficial in that it has the advantage of utilizing a non-spatial task so that one can assess the influence of centralized attention mechanisms. Moreover, by examining attentional factors in healthy participants, one can further such research with stroke patients. For example, it has been shown that with normal levels of attention, healthy participants were found to have a laterality effect in one study. Specifically, Tripathi and Mukundan (2004) found notable differences in participants who underwent a binocular viewing task. They were instructed to respond to a stimulus that appeared on the screen by pressing a key. Results showed a laterality effect, with more accurate responses to stimuli on the right side, but shorter reaction times to stimuli on the left side. These findings may be due to the brain sending information from one hemisphere to the other when there is trouble processing the incoming information (Hellige, 1979). The right hemisphere in particular has been shown to manage visuospatial information, or the manner in which one spatially interprets the world around themselves (Merrell, 1957). It would be advantageous to examine how varying levels of attention could influence this laterality effect in normal participants, and further, one could utilize this method with stroke patients to assess performance, on a visuospatial task for example, and how severity of stroke plays a role.

Moreover, using fMRI to study attention mechanisms in stroke patients may prove beneficial in assessing where in the brain these processes take place. One could test binocular rivalry, for example, before and after periods of rehabilitation. Future research would benefit by focusing on administering a binocular rivalry task over time while incorporating rehabilitation, similar to the paradigm used by Harvey e al. (2003). In that study, patients were required to practice LAT for one month and were given attention tests at various intervals. Instead, one could test binocular rivalry before, during, and after rehabilitation to see how performance levels change during the task with LAT. By comparing this to a patient group not receiving LAT, one could examine the influence of LAT on the attention system in stroke patients. By having participants undergo fMRI, this would lead to more findings about how attention mechanisms differ in stroke patients over time. Such a study could yield outcomes helping to determine influences of rehabilitation on centralized attention mechanisms and how the brain is encoding the incoming information.

As severity differs per individual, those with more severe symptoms resulting from stroke may require a longer recovery time. The rehabilitation process, though necessary, can be tiresome for such patients, yet daily repetition of rehabilitation exercises is the best way to help ameliorate the negative effects. Providing a proper rehabilitation approach curtailed to specific individuals to help reduce deficits while administering a non-spatial task, like binocular rivalry, can help tap into the properties of the reduced or neglected mechanisms in the brain that control attention and perception. It would also benefit the patient by reducing global attention impairments that occur centrally, not just in one visual field. It is likely that the best type of rehabilitation for one person is not the most valuable for another.

Further research could also bring a stronger focus to image complexity, with the administration of both complex and simple stimuli, thus requiring both high-order and low-order processing. In addition, rehabilitation approaches can work at trying to pinpoint how to improve perceptual fluctuations during binocular rivalry in stroke patients, especially in more complex stimuli. Utilizing eye-tracking during a binocular rivalry task is one example to learn how eye-movements influence fluctuation rate. It would also be helpful to reduce the viewing angle, thus minimizing piecemeal rivalry. Further, it is worthy to note that the contrasts of the real-world images were not controlled. It has been demonstrated that the rate of binocular rivalry alternations increases as the contrast of the image increases (Mueller & Blake, 1989). Providing images where this factor is controlled would strengthen results. In addition, as the filtered glasses have some disadvantages, one may want to use a different approach altogether. Instead of using glasses where both eyes are initially presented with both images, though images are filtered with the lenses, one could use a dual-monitor setup with a mirror arrangement. This means each eye is presented with one image only. This would rid any problems caused by crosstalk, creating a better environment for rivalry overall. Furthermore, the projector used in the current study was brand new with a fresh bulb so that the colors were projected properly. Making sure the full range of colors is being presented is a critical factor, whether it's coming from a projector or a computer monitor. One must also use equipment that is capable of providing the full color range, as some devices do not do this properly. Generating an optimal situation consisting of a smaller viewing angle, no crosstalk effects, and the full spectrum of colors being displayed properly in the images are examples that could strengthen future research based on anaglyphs.

It would also be of benefit to test chronic stroke patients, thus providing a measure that could show global attention deficits can be improved over time. The current study included patients with a stroke onset within six months prior to testing. Chronic stroke patients may respond differently during binocular rivalry, and may also require a different type of rehabilitation technique, which is something worth investigating.

In addition, a patient control group matched with the rehabilitation group would be advantageous, meaning a patient group that does not receive rehabilitation. This concept could go one step further to suggest a control group of healthy individuals that do undergo rehabilitation to distinguish how this would influence rivalry. It could be that "rehabilitation" speeds attention in control participants as well, thus increasing the alternation rate.

## Limitations

There is no way to be certain as to whether patients can accurately report when one image becomes dominant over the other. Like in Bonneh et al.'s (2004) study, including a control experiment to ensure patients could report perceptual switches accurately would have been preferred. This can be achieved, for example, by showing overlapping images that change contrasts, thus making sure the patient is responding at the correct times depending on which picture is brightest. There has also been evidence that eye-movements can influence perceptual switches, though they may not be the cause themselves (van Dam & van Ee, 2006). Though patients were instructed to focus on the image centrally and keep the eyes open, some may have had more rapid eye-movements, resulting in more alternations. Reporting of dominant images in the current study was especially difficult with the large 43-degree viewing angle, causing a high amount of piecemeal rivalry. If a participant were conservative in his/her responses, then fewer perceptual switches would be reported, appearing to alternate more slowly. Instances of piecemeal rivalry were not registered, but including this could determine the proportion of time a participant was truly unsure which image was more dominant. Reducing the viewing angle would reduce patchwork and allow one to better determine which image was more dominant.

It was also found that increased viewing time may influence alternation rate, thus increasing fluctuations (Suzuki & Grabowecky, 2007). It could be possible that it was not rehabilitation that was resulting in more reports of perceptual switches, but instead the amount of time the patient had been exposed to the task. This is another reason it would be beneficial to include a healthy control group that receives the same rehabilitation techniques as the patients, as well as a group of patients that does not undergo rehabilitation. Both groups would be of benefit to assess alternation rate and the factors attributing to fluctuation speed, including other contributing factors like spontaneous recovery.

The present study was only able to focus on 11 patients in total, in which only 6 of whom participated in rehabilitation practices. One must also be aware that the present patient group is not a representative stroke patient sample. Further research would benefit from including a larger sample of stroke patients, with a higher number of participants in both LAT and PAT groups. Testing an equal number of males and females as well as left and right-hemisphere stroke patients is another way of strengthening results, as the current study only included men with right-hemisphere lesions.

Another limitation concerned the contrast of the images. It is natural for an image to contain brighter and darker regions in a non-systematic arrangement. The house, for example, is darker than the sky in the background, whereas the woman's face is brighter than her surrounding hair. The rate of alternations can be influenced by contrast, as the more contrast an image has, the larger percentage of time it may remain dominant (Mueller & Blake, 1989). Contrast values, presented above in Table 4, were quite varied for the real-world images, ranging from 45.5% - 70.5%, whereas the contrast for Gabors ranged from 73.5% – 92%. This shows that Gabor patches had a much higher contrast overall. If one tries to change the real-world scenes to have more stable contrasts, the entire image looks askew. Because it is usual for one to perceive the image with a higher contrast for longer, the uncontrolled contrast values create a weakness influencing the rate of rivalry. The inability to control for contrast, especially in the real-world scenes, proves to be one weakness of the study that should not be overlooked in future research.

Another factor to take into account is “crosstalk”, or “ghosting effects”, that are exhibited by the glasses. It was observed during piloting that the red lens filters the red image a little worse than how the cyan lens filters the cyan image, thus resulting in the initial dominance of the cyan lens. In other words, one of the images may not be filtered 100% creating a situation with more piecemeal rivalry. Though this is an important factor to consider when using these lenses, the lenses did not seem to differ in filtration quality to a significant amount, otherwise one might suspect the overall dominance rates to be right-eye dominant, whereas no difference was found between the eyes. However, these issues can be minimized by using polarized lenses and images or avoided altogether by restructuring the experiment to involve a dual-monitor setup with mirrors where one does not have a crosstalk problem at all. It is also important to have the images properly prepared. In the current study, images were in JPEG format, which may not produce the best image quality. By investigating other image formats, one would be sure the colors of the images are not being contaminated, as this can occur in poorer quality images.

## Conclusion

By utilizing a binocular rivalry paradigm, it has been demonstrated that centralized attention mechanisms have been compromised in stroke patients, indicating that attention impairments are not specifically a deficit belonging to only one visual hemisphere. Stroke patients performed more poorly on a binocular rivalry task, in which fewer perceptual switches were reported than those in healthy control participants. Furthermore, and for the first time, this study shows the possible benefits of PAT rehabilitation during a binocular rivalry task, resulting in a trend of increased perceptual fluctuations in stroke patients, thus temporarily ameliorating centralized attention impairments.

It is essential for future research to examine the influence that viewing angle and contrast, for example, would have on the response rate in stroke patients. Nevertheless, the findings show promise of a positive trend in ameliorating attention impairments in stroke patients and improving global attention mechanisms. By continuing to investigate attention and perception with a binocular rivalry paradigm in stroke patients, it is possible to create a further understanding of overall consciousness after stroke.

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# Appendix

Questionnaires are written in Norwegian, as they were presented to the participants in this format.

## A. Questionnaire asked prior to project participation.

### Spørreskjema

Vennligst fyll ut skjemaet innen neste gang vi møtes. Du kan gjerne få hjelp av familie, dersom du er usikker på noen av svarene. Dersom det fortsatt skulle være usikkerhet rundt noen av spørsmålene, kan vi gå gjennom det sammen når vi møtes neste gang. Noen av disse spørsmålene er forholdsvis personlige, men husk, vi har taushetsplikt.

| | |
|---|---|
| Deltakernummer: | |
| Fødselsdato: | |
| MRI-dato: | |
| Dato for slagtilfelle: | |
| Tidligere slag? | |
| Tidligere oppdaget skade på sentralnervesystemet? | |
| Utdanningsnivå (antall år utover vgs): | |

| | |
|---|---|
| Har du pacemaker? | |
| Er du operert I hjertet? | |
| Er du operert I hodet? | |
| Har du cochleaimplantat? | |
| Har du operert øynene? | |
| For kvinner: Er du gravid? | |
| Er du klaustrofobisk? | |
| Har du gjort arbeid med sveising eller sliping av metallplater?<br>Vennligst spesifiser. | |

| | |
|---|---|
| Har du noen gang hatt noen metalldeler eller fragmenter under huden eller i øyet?<br>Vennligst spesifiser. | |

| | |
|---|---|
| Bruker du reseptbelagte legemidler?<br>Hvilke?<br>For hva? | |
| Bruker du psykiatriske medikamenter?<br>Hvilke?<br>For hva? | |
| Bruker du for tiden ulovlige rusmidler?<br>Hvilke?<br>Når brukte du sist ulovlige rusmidler?<br>Hvor ofte bruker du disse? | |
| Har du brukt ulovlige rusmidler tidligere?<br>Hva slags?<br>Hvor lenge siden?<br>Hvor ofte? | |

| | |
|---|---|
| Briller eller kontaktlinser? | |
| Hvis ja, hvilken styrke (venstre)? | |
| Hvis ja, hvilken styrke (høyre)? | |
| Hvis ja, har du noen dybdeavvik? | |
| Er det noe annet som svekker synet ditt? Stær, glaucoma, etc. | |
| Er du fargeblind?<br>Hvis ja, hvilke farger har du problemer med å oppfatte eller distingvere? | |

**Informasjon om hendthet**

Vennligst informer om hvilken hånd du foretrekker å bruke (I hvert fall før slaget) i de følgende aktivitetene ved å krysse av i riktig kolonne

Der preferansen er så sterk at du aldri ville bruke den andre hånden, med mindre du absolutt ble tvunget til det, sett 2 kryss i samme kolonne.

Der preferansen ikke er like sterk, men den ene hånden foretrekkes framfor den andre, sett ett kryss i den ene kolonnen.

Dersom du er helt likegyldig til hvilken hånd du bruker, sett ett kryss i hver av kolonnene (altså ett i høyre og ett i venstre kolonne).

Noen av aktivitetene som er oppført nedenfor krever bruk av begge hender. I disse tilfellene er det angitt i parentes hvilken av hendene vi er ute etter, altså en bestemt del av oppgaven som denne hånden gjennomfører.

Vennligst prøv og svare på alle spørsmålene, og bare la det stå tomt hvis du ikke har noen erfaring i det hele tatt med objektet eller oppgave.

| Hvilken hånd bruker du når du: | Venstre | Høyre |
|---|---|---|
| Skriver | ☐ ☐ | ☐ ☐ |
| Tegner | ☐ ☐ | ☐ ☐ |
| Kaster | ☐ ☐ | ☐ ☐ |
| Klipper | ☐ ☐ | ☐ ☐ |
| Pusser tennene | ☐ ☐ | ☐ ☐ |
| Kniv (når du ikke har gaffel) | ☐ ☐ | ☐ ☐ |
| Skje | ☐ ☐ | ☐ ☐ |
| Kost (den øverste hånden på skaftet) | ☐ ☐ | ☐ ☐ |
| Tenne en fyrstikk (hånden som holder fyrstikken) | ☐ ☐ | ☐ ☐ |
| Åpne glass/boks (hånden på lokket) | ☐ ☐ | ☐ ☐ |
| Total: | | |

## B. Questionnaire asked to each patient prior to each testing session.

**Hvordan føler du deg?**

- Deltakernummer: _________
- Week: ____ Part: _____
- Date: ______________
- Dominant øye: _________
- Spørsmål som stilles før eksperiment:

o Hvordan føler du deg? ____________________
____________________

o Hvordan har du sovet i natt? ____________________
____________________

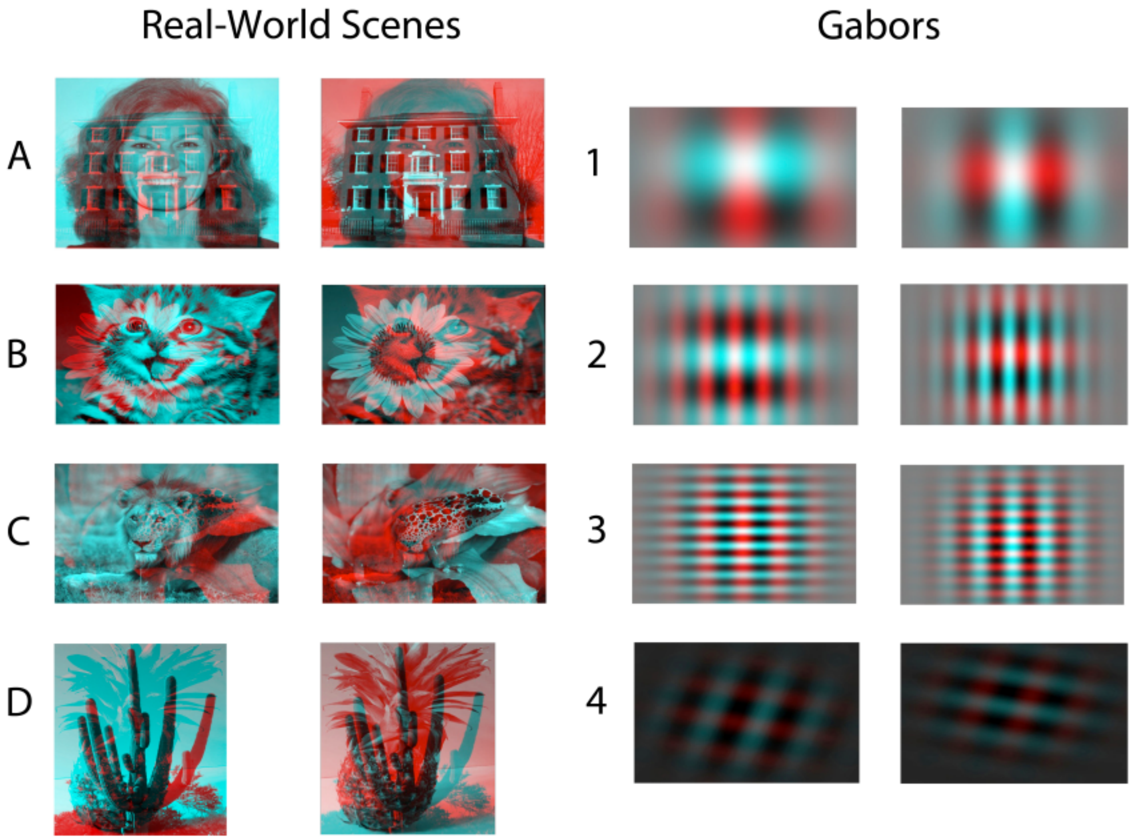
o Hvor mange kopper kaffe har du drukket i dag? ____________________
____________________

o Har du falt eller skadet deg etter at du kom til Sunnaas?
____________________
____________________

o Hvis relevant – har du på deg kontaktlinser i dag? ____________________
____________________

o Har du allergi? (som påvirker fuktigheten i øynene?) ____________________
____________________

### C. Anaglyph images used in the experiment, each presented twice with opposing cyan-red colors.



The real-world scenes on the left consist of each of the four anaglyphs used in the study, presented twice in opposing red/cyan colors, and are as follows: A) Face/House, B) Cat/Flower, C) Lion/Frog, and D) Pineapple/Cactus. The Gabor patches on the right are the four Gabors used in the study, also presented twice in opposing red/cyan colors.