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Semester:
LiD10 2021

Title:
Reactive Lighting for Digital Books

Project Period:
Spring 2021

Semester Theme:
Master Thesis

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N/A

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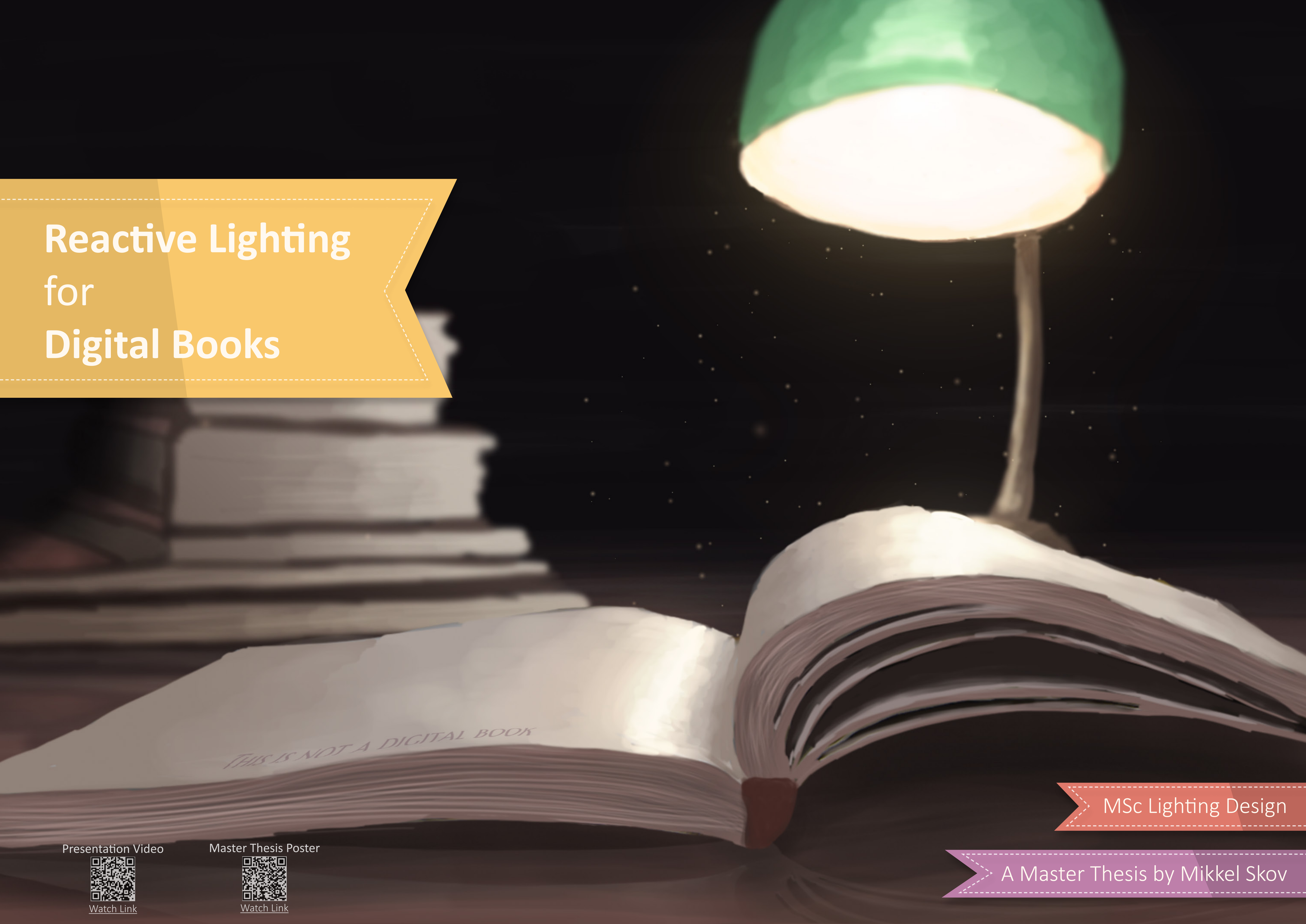
Abstract

Book reading has numerous positive side effects, yet the amount of time that people spend reading is decreasing. Science has proved that the neurological processes of generating mental images, e.g. when reading, are similar to those of perceived images, thus visual perception may affect visual imagery- and vice versa.

The present study investigates how reactive light can enhance text-based experiences, herein audio- & e-books, and ultimately make people spend more time on such media. A design framework was developed based on 'motivated lighting' principles, used in stage lighting, in which light qualities are selected based on text cues. An experiment was developed, with the initial aim of getting a brief understanding of how light and stories correlate, and to evaluate if light has an effect on imagery, emotions and motivation. In the experiment, subjects were presented to different types of ambient light, while listening to audio-stories of different moods. Qualitative and quantitative data was collected from self-assessment and heart rate.

The combination of experiment findings and literature reveal that darkness is best utilized to improve imagery, whereas reactive lighting may enhance experiences by increasing motivation and emotional response - if used correctly. The conclusion of this investigation supports light as a tool to enhance story experiences, while opening up for more questions that deepen the understanding of the relationship between visual imagery and visual perception.

Reactive Lighting for Digital Books



MSc Lighting Design

A Master Thesis by Mikkel Skov

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PROLOGUE

Chapter 1
Introduction

1.1 Problem Background

Over the last few decades, the world has seen a radical shift in entertainment preferences. Video-games, television and social media have become highly popular, and even though the sales of digital books (audio- and ebooks) are growing (BBC News, 2012; Perrin, 2016; Saxo, 2018), the overall time that people spend on reading is decreasing (Bog- og Litteraturpanelet, 2018). In Denmark, a study from 2018 reveals that the amount of people who never read has been static over the last eight year [16-17%] (Bog- og Litteraturpanelet, 2018), but the people who do read, read less often and spend less time reading.

Reading is one of the most beneficial exercises for the brain, as it is a complex process that activates parts of the brain with high importance, resulting in better information flow (Kourkouta, 2018). The span of benefits is wide and includes topics such as improved comprehension, enlargement of vocabulary, better general knowledge, enhanced social skills, lowered feelings of loneliness, and even improvement of the respiratory system and automatic body functions- the list goes on (Berns et al, 2013; Clark & Rumbold, 2016; Kourkouta, 2018; Whittingham et al, 2013). Additionally, Rizzolo et al. (2009) found that 30 minutes of reading a day reduces stress significantly. These positive side effects are valid both when reading text-based books and listening to audio-books since many of the same areas in the brain are activated (Deniz et al, 2019; Wager, 2016; Whittingham et al, 2013). The benefits are also seen in guided imagery due to visual imagery being a part of the cognitive process (Singh, 2017). As opposed to reading, it may feel less time consuming to sit back and watch TV, yet this form of entertainment sees contradicting effects (Takeuchi et al, 2015). Thus, the decrease in hours that people spend reading is worrying.

The question arises if light can be utilized to enhance the reading experience and make people spend more time reading for pleasure- or even nudge the non-readers to start reading. Light technologies are advancing rapidly, and smart-lighting systems, like Philips Hue or Lifx, are spreading to homes all over the world. With modern LED technology, it is fairly easy to develop a system which controls brightness and color of light, and which is synchronised with other media, such as digital books. In contrast to ordinary books, media that use screens, such as TV, computer and mobile devices, all make use of light to tell a story, while light may also be used to enhance performances in theater plays and concerts. In books, however, the light and colors are only generated in the reader's mind. If it is possible to synchronize light with books, what effect will it have on the reader? Will the light work as support for the story, making it easier to imagine the story-world and be drawn into the book - or will it work against the mind of readers in case the light does not match up with the mental visualization that the reader develops? Or even worse; will the dynamic light pull the reader out of the book and draw the attention to the room in which they find themselves? The questions are many, and to try and answer those with the most importance, this project was conducted.

To sum up the investigation, an initial problem statement was developed. The presented problem statement has been refined throughout the project to give a more accurate description of the project aims.

Problem Statement

"How can reactive lighting enhance book- reading & listening,
and make people spend more time on text-based experiences?"

The present paper explains the process of answering this question by combining known and new knowledge, while utilizing modern lighting technology. The word '*reactive*' is carefully chosen and is defined as: "*to be reactive is to be ready to react or respond to something else*" (Vocabulary.com, n.d.), implying that the light may be dynamic and controlled by e.g. the words in the stories, rather than staying static or following a predetermined dynamic cycle.

Figure 1. Digital books includes smart-devices, e-readers and audio-books.

1.2 Methodology

The underlying process of this thesis is illustrated in fig. 2. The methodology is presented to give an initial, overall understanding of the project and how the results were gathered. The aim of the project was not to develop a final lighting system for digital books, but to understand the relationship between light and word-based stories through knowledge and experimentation.

1.3 Thesis Structure

The thesis consists of three parts. Part I provides information and sets up a framework, working as an initial answer to the problem statement, as well as being the spine of the experiment. Part II tests the framework by applying it in an experiment where new knowledge is generated. Part III combines the literature, framework and experiment findings to finally answer the problem statement, while providing suggestions for further work.

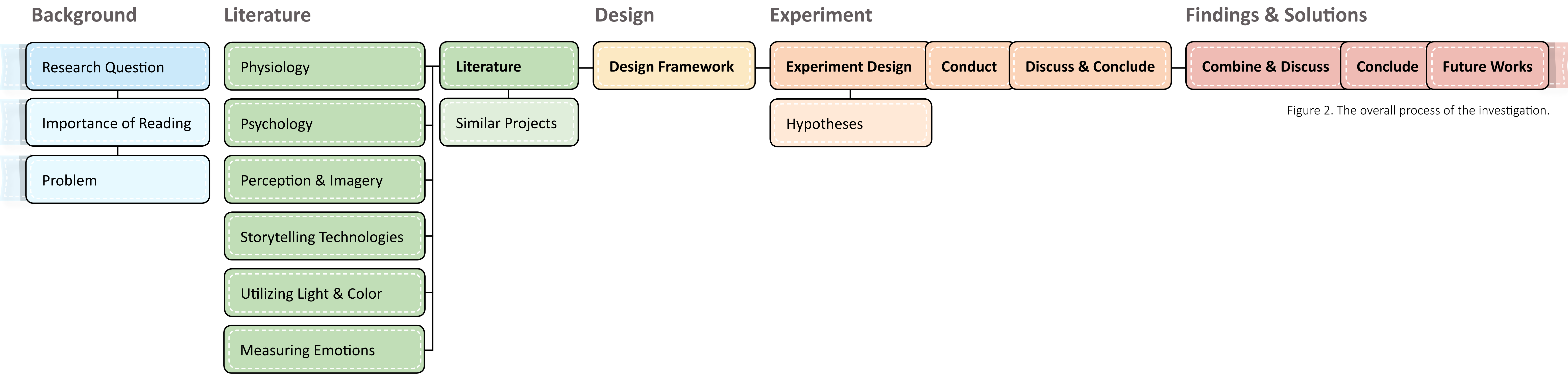

Figure 2. The overall process of the investigation.

PART I

Chapter 2

Literature Review

This literature review is aimed at getting a deeper understanding of the processes happening in readers' heads when reading or hearing stories, and when receiving visual input from light. In other words, the presented literature attempts to identify the differences and similarities between the images which are seen with the eyes and the images generated in the mind, with and without visual input. What is visual imagery and what is visual perception? Additionally, the topics are elaborated with overlapping important topics needed to answer the problem statement.

This chapter contains illustrations that ultimately underlines how perceived images can give similar understandings to written text, and may work together to create enhanced comprehensions of the literature points.

2.1 Psychology & Visual Imagery

The human mind is incredibly complicated. Noone experiences an event the same way, or sees and understands the world exactly as it is (Reddy & Pereira, 2016). Everything our eyes see is not actually how it appears to be, but are images generated in our minds, highly influenced by associations and previous experiences, as well as the individual, physical structure of our eyes, brains and bodies (Block, 2007; Boyce, 2014; Cugelman et al, 2020; Eysenck & Keane, 2020; Singh, 2017; Uusitalo et al, 2009). One person might see the color of a dress as green, while another might see it as blue, depending on expectations and associations, if for example the person is used to dresses being respectively green or blue. Likewise are the images of objects often created by associations (Alumit & Sagi, 1997; Eysenck & Keane, 2020; Singh, 2017; Strauss et al, 2009), meaning that when someone see an orange on a table, the person only glance at the approximated color and shape, and what is seen in the mind is based on the orange color that the person are used to when thinking of an orange. Likewise are the illustrations in this chapter nothing but simple shapes and colors, but the mind associates them with real objects and creates meaning. That is also part of the reason why people understand abstract art and images differently. It is a natural choice, which the brain uses to save energy, so that it is not required to examine, learn and understand everything over and over, but instead it is only necessary to associate the object with previous experiences (Strauss et al, 2009). However, images are not only generated in one's mind when seeing things, but also when reading books, hearing stories, when meditating and inventing stories, or when thinking of past experiences (Chang et al, 2013; Long et al, 1989; Perfetti & Bolger, 2004; Perky, 1910; Singh, 2017; Stauss et al, 2009). That is partly the reason why a book can be understood differently

from person to person. The associations, experiences and imagery level that one reader has, generates different images from another reader (Long et al, 1989).

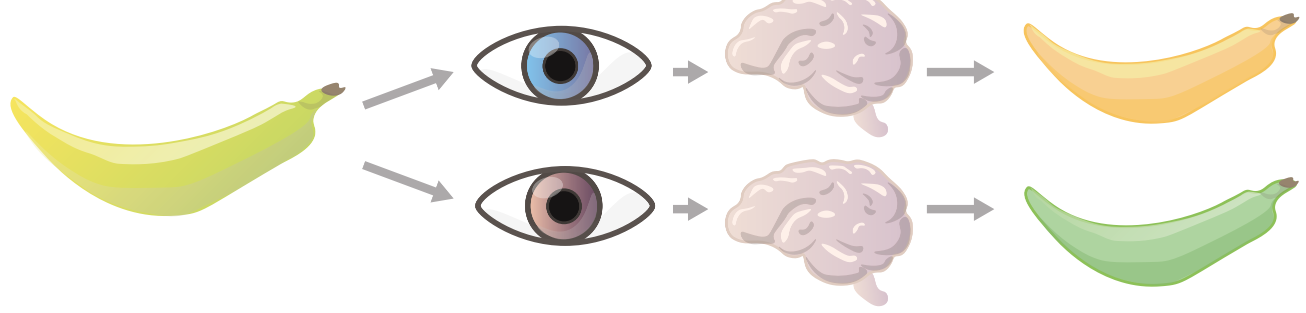

Figure 3. Colors of objects are subjectively understood. This figure illustrates how the color of a banana may be perceived differently due previous experiences and associations. Such psychological factors are one of the reasons why working with light and colors can be complicated.

Visualization, also known as visual imagery, is the act of creating images in the mind. Imagery in general may also include other sensory modalities such as smell, sound, touch and taste (Arbuthnott et al, 2002; Long et al, 1989; Perky, 1910; Waller et al, 2012). The mind is always trying to prepare for, and predict, what will happen next, which is one of the areas where visual imagery is important (Chang et al, 2013; Eysenck & Keane, 2020; Strauss et al, 2009). For example when a golf player predicts where the ball will go when swinging the club, or a painter pen-sketches or mixes paint, visual imagery is necessary. Generation of such visual imagery can be aided by reading, meditating or utilizing guided imagery, which all includes overlapping factors.

A study from 2018 investigated how guided imagery could lower anxiety levels of participants (Nguyen & Brymer, 2018). According to their study, it is widely known that spending time in natural environments has many benefits on mental health and wellbeing, herein anxiety suppression. However, for many people, nature is often not available. Therefore, the researchers investigated the effect of guided imagery, using an audio recording of a custom-made script, mentally guiding subjects through both an urban and a natural environment. The results revealed that both of the two mental environments lowered anxiety levels, in which the natural environment created the lowest levels. This implies that there are similarities between imagery and the physical world, allowing the body and mind to react as if the person were

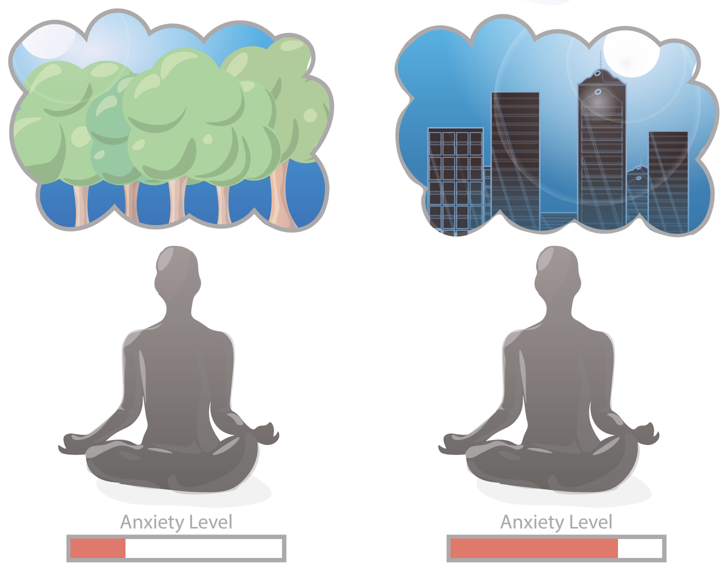

Figure 4. Illustration of how guided imagery may affect anxiety levels, due to connections to the physical world. Lower anxiety levels may be seen when imagining natural environments compared to imagining urban spaces.

physically present. When collecting and assessing data, the team used both a qualitative questionnaire, asking what images the subject saw in their mind, and quantitative questionnaires, such as Marks' Vividness of Visual Imagery, which is explained in the next section.

Marks (1973) investigated differences between subjects' reported levels of visual imagery and their actual level of imagery. To do this, he developed a tool, which he named Vividness of Visual Imagery Questionnaire (VVIQ [version 1]). It consists of four "items" - specific areas to visualize - including a relative/friend, a sunrize, the front of a known shop and a natural scene. In each of the four items are four detailed subareas, on which the subjects shall focus, such as appearance details, specific weather conditions and colors. After being presented to a subarea (16 in total), the subjects have to self-report how vivid the image, generated in their mind, is. This is a 5-point rating system, which can be seen in fig. 5.

Table 1. ***The rating scale used in the Vividness of Visual Imagery Questionnaire***

Rating	Description
1	'Perfectly clear and as vivid as normal vision'
2	'Clear and reasonably vivid'
3	'Moderately clear and vivid'
4	'Vague and dim'
5	'No image at all, you only "know" that you are thinking of the object'

Figure 5. The 5-point rating scale of VVIQ (Marks, 1973).

Other imagery assessment tools exist - some similar, and some including other sensory aspects than only visual imagery (MacInnis, 1987; Kihlstrom et al, 1991). Furthermore, there are a few concerns that egocentric bias can affect the results of VVIQ, but it is, however, the most widely used method to assess visual imagery (Allbutt et al, 2011).

Guided imagery is a strong tool which, to some degree, share similarities to how perceived images are processed (Arbuthnott et al, 2002; Borst & Kosslyn, 2008). Guided imagery may even be more powerful than real life events, due to the fact that imagery can be controlled, meaning that the person can exclude negative aspects. Additionally, the ability to connect with fictional characters sees many connections to real events, and might be considered similar to social acting, whereas personal growth may be a result (Shedlosky-Shoemaker et al, 2014).

As stated by Long et al (1989), visual imagery is utilized, not only under guided imagery, but as previously stated, also when reading, ensuring better story comprehension. The visual imagery is affected by text arrangements and text features, where "image" building" text can aid comprehension

and memory. Darusman (2012) investigated the correlation between guided imagery- and reading-comprehension and found the results from the two types of input to be similar, indicating that similar responses are seen whether the words are heard or read. These aspects are elaborated in chapter 2.3.

2.2 Perception's Impact on Imagery

According to a study by Perky (1910), visual perception influences visual imagery. The results were found from experiments in which physical inputs were gradually given to the subjects, via fading images on a white screen, which affected their internal images subliminally. E.g. were the subjects told to imagine a banana, where one subject was surprised to see an upright banana instead of the horizontal orientation that he had aimed for - or another who was surprised to see an image of an elm leaf when trying to visualize a maple leaf. This occured without any of them noticing the physical input from the screen. On the other hand, reports of image details were made, even though the physical images were blurred and included only color and simple shapes (e.g. a red circle representing a tomato), indicating that imagery was added to the perception as well.

Segal & Nathan (1964) partly replicated the experiment, and had similar results, yet only when the visual stimuli was very faint. If too strong, subjects would be aware of the stimuli (it should be noted, that an increased suspension for experiments had generally developed in the nearly 40 years since Perky's experiment). The subjects who did perceive the objects, realizing that they were present on the screen when the increasing stimuli was high enough, found their imaginary object different from the perceived object. Segal & Nathan further state that the level of stimuli is important for the findings of Perky to be true, while also the mental state of subjects are important. Another interesting, yet not solid, example is the result from an experiment, in which the subjects were presented to images that differed from the imagery task. Segal found, in 1972, some of the subjects to imagine a New York sunset when told to imagine a New York skyline while a representation of a tomato was induced into their perception (as cited in Berendzen, 2014; Nigel, 2014).

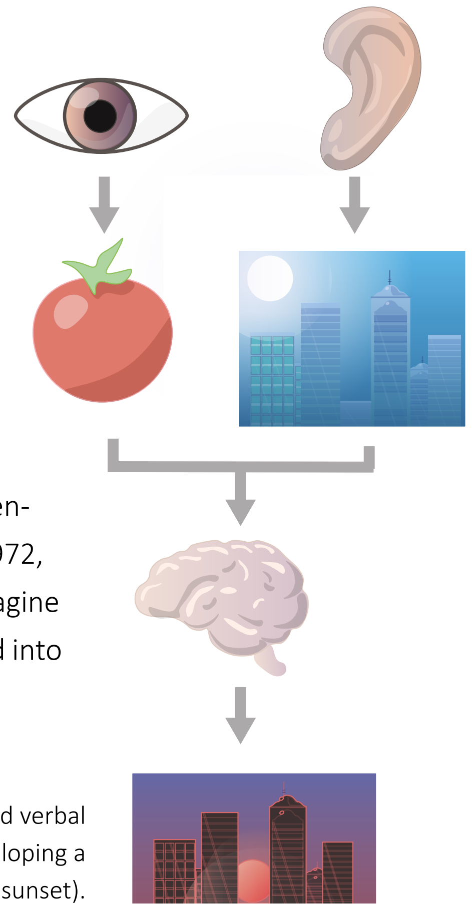

Figure 6. Illustration of the theory stating that visual input (tomato) and verbal input (New York skyline) may affect each other in the mind when developing a mental image (New York sunset).

The findings of Perky and Segal are being discussed widely as multiple replications failed to achieve the same results. Furthermore, the connection between perception and imagery is a highly complicated subject, where researchers achieve different results with different experimental approaches (Hopkins, 2012; Segal & Gordon, 1969; Waller et al, 2012). This implies that there are connections between perception and imagery, but that they are not indistinguishable.

Other findings state that imagery of color (excluding shape and motion) enhances color-identification tasks (Cochrane et al, 2019), while visual imagery is suppressed by colored (incl. white) background luminance, since visual perception seems to prime imagery in such specific cases (Chang et al, 2013; Sherwood & Pearson, 2010). Sherwood & Pearson (2010) further suggest that imagery might be best utilized in completely dark environments. Additionally, it is indicated that people with low-level imagery are less affected by sensory input, than high-level imagers (Keogh & Pearson, 2011). It should be noted that the mentioned results are found from performing specific visual tasks that don't include immersive story experiences, but they do, however, present evidence that perception alters imagery- and vice versa.

2.3 Physiology

First, it is important to briefly recap what light is. The term 'visible light' is referred to as the spectrum of electromagnetic energy (photons) that our eyes react to and our brains can process. The visible span ranges from around 400nm to 700nm, whereas the areas outside the visible spectrum are X-rays, ultraviolet, infrared, microwaves and radio waves etc. (Cugelman & Cugelman, 2020; Dunham, 2015). Basically, each frequency is its own "color" (see fig. 7), while white light is perceived when the cones, reacting to red, green and blue light, are evenly stimulated. Black is the lack of visible light reaching the eye.

Figure 7. Spectral power distributions of visible light. Note that illustrated colors are not accurate.

However, colors don't exist in the physical world- not as how color may be understood, that is. Simplified, colors are generated in the mind when electromagnetic input activates the photoreceptors in the eyes, which converts and forwards the signal for further image processing in the brain (Boyce, 2014; Dunham, 2015; Eysenck & Keane, 2020; Wilson et al, 2007). In other words, the visual system "*provides us with an internal (and conscious) representation of the external world.*" (Eysenck & Keane, 2020, p.55).

An example of this visual color processing is found in the fact that humans see colors when being presented to the actual wavelengths, but also when blending adjacent frequencies. For example is the color, known as yellow, seen both when the eye receives the actual wavelength (~590nm), but also when mixing two individual signals: a red (~660nm) and a green (~520nm) light. The two frequencies are not physically blending, but are part of the process in the brain. Another example is the color known as *magenta*. Magenta is the combination of blue (~470nm) and red (~660nm) light- the lowest and highest part of the spectrum- and can not be seen without mixing these two colors. In other words, magenta doesn't have a wavelength of its own, which is a phenomenon known as extra-spectral, or non-spectral, color, meaning that the color doesn't physically exist, but is first developed when blending and processing signals in the brain (Stoddard et al, 2020). This information, concerning image processing in the brain, is needed to understand how everything that is perceived is merely developed images of the consciousness. Without human brains to further interpret and make meaning, the light would simply be a combination of colors, shapes and motion with no meaning.

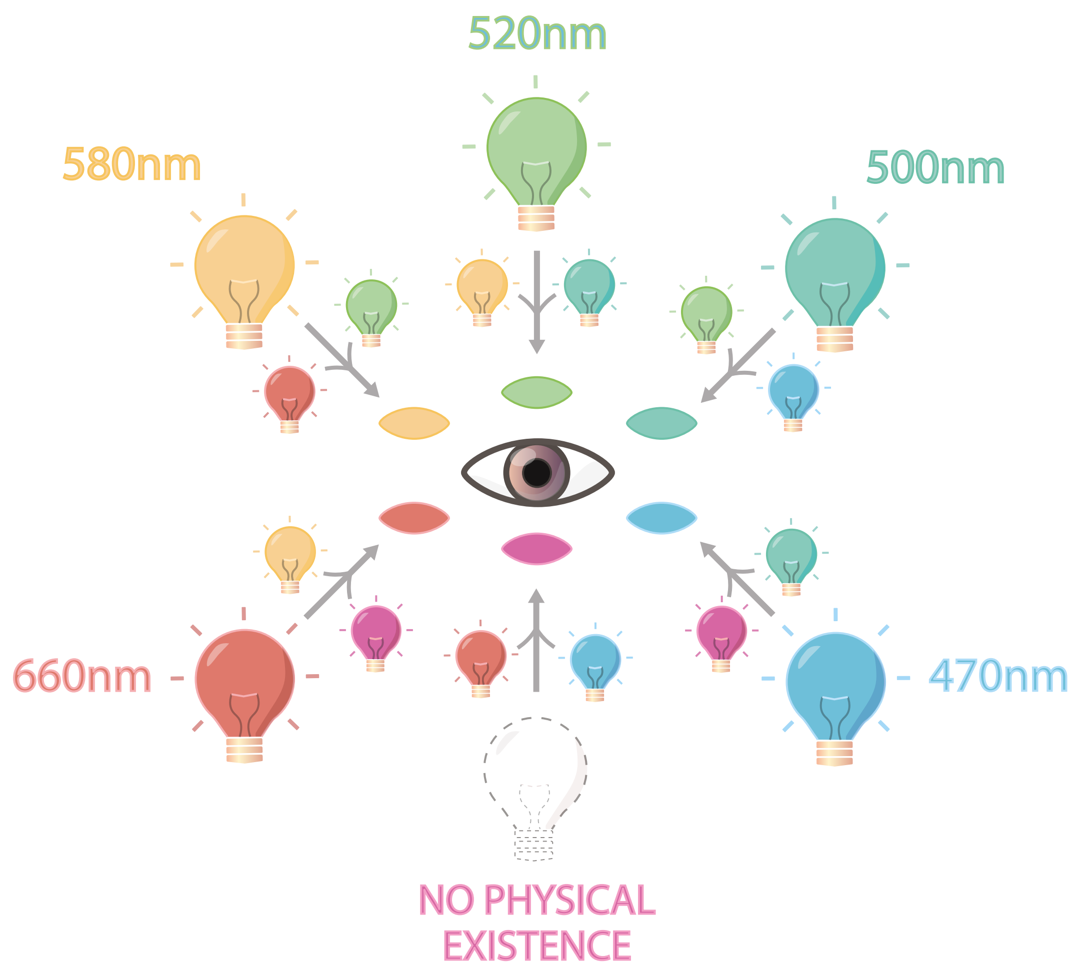

Figure 8. Illustration of how humans see colors based on either color blending in the mind or physical wavelengths of colors. Magenta doesn't physically exist and is only mentally developed from color blending. Note: colors used are representative and are not accurate.

The human brain is highly complex, and scientists are nearly scratching the surface of understanding how the brain works, yet much research has already been done on visual perception and visual imagery (Eysenck & Keane, 2020; Waller et al, 2012). Even though most brain processes are interconnected, it is possible to find specific areas of the brain with higher activation under specific visual tasks. This leads to the neural processing of vision and imaging. The visual perception makes use of multiple stages of cell activation in the brain, where some neural pathways see higher activation under processing areas like colors, form, movement etc. (Eysenck & Keane, 2020). In visual imagery, similar processes are used, involving the same brain areas, but in different ways. These similar patterns may even cause confusion when one has to figure what is perceived and what is imagined, which is famously known as *hallucinating*. When hallucinating, people are not aware that what they see is not generated by their perception, but is a higher activation of the imagery areas, why they truly believe that what they “see” is “real”. A similar phenomenon is known as Anton’s Syndrome. This is found in blind people under occurrences where they forget about their blindness and falsely believe that their imagery is visual perception.

Even though visual perception and imagery influence each other, it is important to make clear that there are still differences, and that researchers disagree on how identical the two types of visual processing are (Eysenck & Keane, 2020).

Studies on brain activity under reading reveal that written words are recognised and decoded, and afterwards converted into audible words in the mind. This is called phonological processing. Hereafter, content-comprehension begins. This is, of course, very simplified, as most brain areas are involved when reading, due to the fact that content-comprehension affects everything from emotional state, sensory mechanisms, imagery, etc. (Kweldju, 2015; Perfetti & Bolger, 2004; Singh, 2017). Similar to visual imagery, reading is rather subjective, biased by reading experience and sentence comprehension. Furthermore, the eyes skip to the next word faster than the brain finishes the reconnision-processing on the previous word, which results in sentence assumptions (Perfetti & Bolger, 2004; Strauss et al, 2009). Due to this, sentences might be understood differently, while also the imagery will be different, which makes stories quite unique in the mind, even with the same input available.

“At the same time the brain turns the selected input into perceptions. So what we think we see is in fact more important than what we actually see, and that explains why proficient reading is such an efficient and effective process of writers and readers transacting to exchange meaning”

-Strauss et al, 2009, p.31

As stated previously in the report, no living being sees the actual reality as it truly is- and no one sees the world the same. Optical illusions is a fine method to underline this fact. One person might see a bird in Fig 9.1 and a white cup in fig. 9.2. Another might see a rabbit and two purple faces. The mind may even continually jump between the two understandings of the images, or be biased of what they were

told to see first. The pictures stay static, but the understanding of them changes. Fig. 9.3 shows two tables, which to most people appear to have tabletops that are different in size. However, they are precisely the same size, while only the mind is being tricked. In other words, these tables are understood differently from how they are in “reality”.

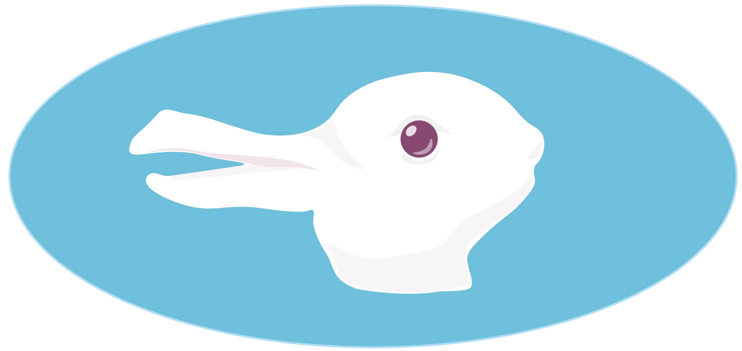

Figure 9.1. Is this a bird or a rabbit?
(recreation of the duck-rabbit illusion)

Figure 9.2. More details are added to the vase, but the mind will still see silhout faces.
(recreation of the Rubin’s Vase, originally developed by Edgar Rubin)

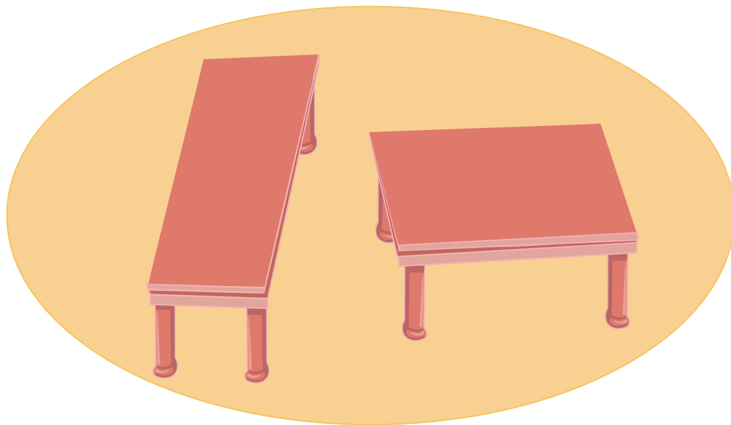

Figure 9.3. The table tops are the same size, but our minds make up a “false” perception.
(recreation of the Shepard tables, originally developed by Roger N. Shepard)

Even if people were not biased, the signals (light), received by the eye, do not show the present moment of reality, but instead it shows various moments of the past (Blom et al, 2020; Strauss et al, 2009). What one sees when looking at their shoes is light that was reflected from the shoes a tiny fraction of a second ago (distance and speed of light), before reaching the eye. Likewise, when staring at the moon, one sees about 1.3 seconds into the past, due to the long distance that the light has to travel- and the delay increases the further away an object is. Added to this is the delay of the brain processing the input. Therefore, the question might arise, if it’s actually possible to see the present of reality, as the perceived reality changes depending on where the observer is located, even though the actual events stay static. In any case, it comes down to the point, that the present of the reality that one perceives is developed in the brain and stored as unique stories, experiences, or representations of the world in our memories(Strauss et al, 2009)- similar to the stories that one reads or are being told.

2.4 Measuring Emotions

In order to understand how light, imagery and stories affect emotions, it is important to know how measurements of emotional state can be conducted and how emotions can be evaluated.

If one has to measure the emotional state of a person, no "golden standard" exists (Mauss & Robinson, 2009). However, from their investigation, Mauss and Robinson recommend measuring emotions with dimensional factors, such as "valence" (a.k.a. "pleasure" (Russel & Barrett, 1999)), "arousal" and "approach-avoidance" (a.k.a. "dominance" (Russel & Barrett, 1999)). Dimensional factors are more universal than discrete emotions such as joy, fear, depression etc.

An investigation by Russel & Barrett (1999) concludes that self-assessments may be the best indicator of dimensional factors of emotional state, whereas "pleasure" and "arousal" levels should always be included. However, it is important to note that self-assessments are not always sufficient, and should ideally be supported by other measures.

A popular tool to utilize self-assessment of emotional state is the SAM test, developed by Bradley & Lang in 1994. It consists of three questions- one in each dimensional factor- asking subjects about their pleasure, arousal and dominance level. SAM is, in its origin, a 5-scale test based on five drawings in each question, visualizing the level of pleasure (1-5), arousal (1-5) and dominance (1-5) in each answer. The subjects simply decide how they felt during (or after) an experiment, selecting their pleasure level (unhappy/annoyed- happy/pleased), arousal level (calm/sleepy- excited/wide-awake) and dominance (submissiveness-dominance) (Bakker et al, 2014). However, according to Bakker et al (2014), the norm has become to leave out dominance in research, and focus on the 2-dimensional model.

The results of the SAM test can afterwards be mapped into discrete emotions. This allows us to assess the emotions with recognizable words (Russel, 1980; Tsonos & Kouroupetroglou, 2008). Russel's circumplex, as can be seen in fig. 10, maps out some of these discrete emotions based on the 2-dimensional model (Russell, 1980). The circumplex aims to make it easy to understand what the results of e.g. a SAM test means.

For objective measurements, tools such as heart-rate monitoring, EEG, sweat-measures, eye-tracking, respirational measures and body/ face observations can be helpful, yet these require specific physical tools.

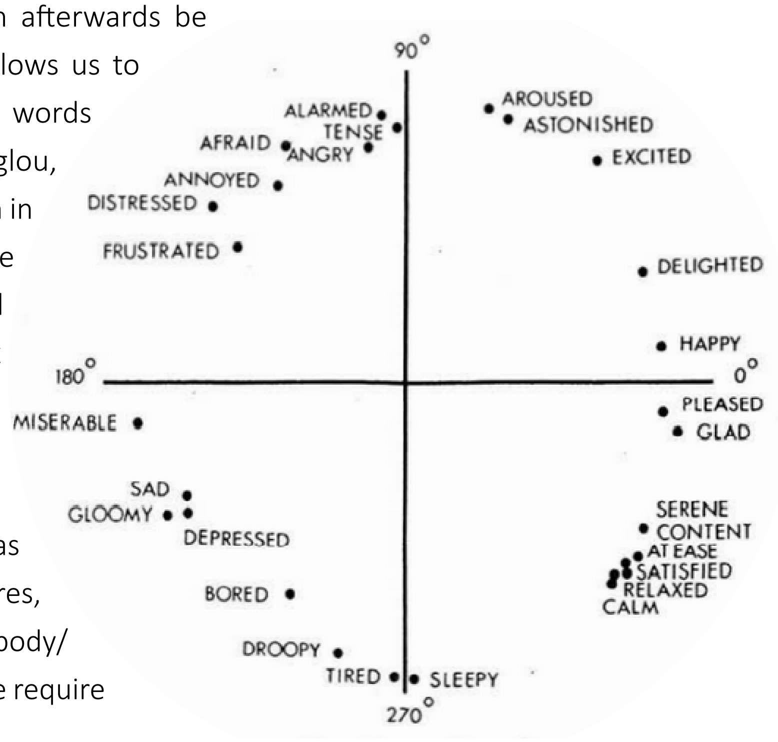

Figure 10. Russel's circumplex with circular mapping of discrete emotions, based on a 2-dimension model. Pleasure on the X-axis and arousal on the Y-axis (Russel, 1980).

2.5 Light on Emotions

This section is simplified to monochromatic-perceived light, meaning that only *one* selection of light frequencies is used at once. First of all, it is important to make clear that there exists no perfect list of how people are affected by light and colors. Naturally, this is a topic that has been investigated by various researchers, who have revealed results that may be used as guidelines, yet the results from different studies have contradicting results. In this section, results from different researchers are stated in order to find useful guidelines that can help answer the problem statement.

When assessing light, it is often referred to as *white* light and *colored* light. White light is mostly seen in everyday use, which is also the spectrum of light that the sun provides. It ranges from cold to warm color temperature (CCT). Warm white light has, in some research, proven to calm down people, why it is often found in places like cozy cafes and restaurants, while cold white light seems to increase energy levels and concentration, and is often used in workspaces (Dunham, 2015; Mills, 2007; Park et al, 2013; Reid, 2001; Tregenza & Loe, 2014; Zhu et al, 2019). However, CCT is highly related to the brightness, making simple conclusion difficult when combining the two, as for example low-brightness versions of warm and cold light may see opposite emotional effects to high-brightness versions (McCoughan et al, 1999; Park et al, 2013; Zhu et al, 2019). Furthermore, as these researchers note, contradicting experiment-results exist, while other researchers found no significant differences at all when assessing CCT and brightness. Additionally, people may perceive the brightness less or more intense depending on their emotional state (Zhang et al, 2016).

Colored light is a bit more complicated. In contradiction to sunlight, colored light is rarely generated naturally- not before refracting or reflecting from a colored surface (Boyce, 2014). Therefore, if following the principles of Block (2007), the associations with these unnatural light colors have to be developed through fictional experiences, as for example when green light is associated with poisonous chemicals or red light with the light from hell. However, color associations may also come from natural elements, like when a sky and the sea is blue, green colors are seen in a forest, or orange colors are released from a candlelight- colors which, again, are naturally generated from reflecting or refracting white light, but to some extent are also seen in natural chemical processes. As with, the association with colors are rather subjective (Küller et al, 2009; Ou et al, 2004), whether it was naturally generated or a result of fiction.

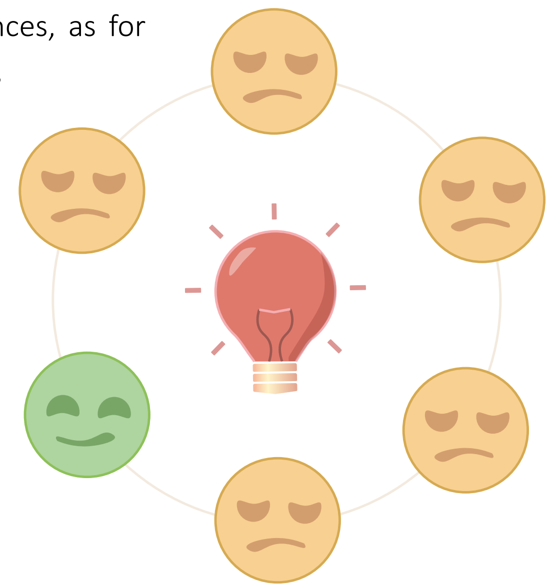

Figure 11. Illustration of how red light may affect people in general. However, the emotional responses are subjective, why a one-size-fits-all design can not be made.

Understanding what effects colors can have on emotions is important when working with colored light. Red and yellow are often found to be most arousing while also being the least pleasurable (Dunham, 2015; Valdez & Mehrabain, 1994). Blue and green is found to be most pleasurable, resulting in lower arousal levels, yet green may also be arousing (Dunham, 2015; Skov[1], 2020; Valdez & Mehrabain, 1994; Wilms & Oberfeld, 2018). However, as Valdez & Mehrabain (1994) notes; brightness and saturation are rarely controlled in such color investigations, which is problematic as these variables can change the association and influence of a color. Studies that did take these aspects into consideration found that brighter and more saturated colors increased both pleasure and arousal (Guilford & Smith, 1959; Kuijsters et al, 2015; Valdez & Mehrabain, 1994; Wilms & Oberfeld, 2018), yet these results are not linear and can see opposite effects if too much/little saturation or brightness is used.

In conclusion, there are many implications when assessing light and emotions, making it difficult to predict exactly how people are affected by colors, as many factors influence the effect. A way of working with light, however, is elaborated in chapter 2.6.

2.6 Utilizing Dynamic Light

Artificial dynamic lighting is found in a lot of modern entertainment, from music concerts to theater plays. It is also what one sees when watching a movie or playing a video game, both in the setup of light in the production, but also the pixels of light that leave the screen.

The craft of designing with light is not linear and can never be done to perfection (Dunham, 2015; Reid, 2001). In theater, lighting designers spend years, trying master the art of lighting a stage, but one part is often kept a rule:

"...the lighting, as well as all the other elements of the scene, must combine to create a single cohesive environment that creates a "true" world of the play. A play that requires a night scene must be lit in some fashion that would be suggestive of night."

-Dunham, 2015, p. 11

In his book, Dunham (2015) mentions many different areas that need to be considered when designing stage lighting, herein e.g. mood (producing emotional responses), rhythm (transitions) and many aspects that require characters and objects. The key step to assess these functions is a script analysis (Dunham, 2015; Reid, 2001). It consists of a scenic break-down which, first of all, states the locations and time frames of the scenes. Specific light settings can be developed if a scene is played out in e.g. a hospital or in a forest hut, while the time of day, the year of century and weather conditions likewise provide light clues. However, a direct statement of light conditions in the script will always prime, e.g. if a character talks about the golden sunlight or is blinded by the blue light from a magical lantern.

There are two styles of lighting to consider: motivated lighting and non-motivated lighting. Motivated lighting attempts to represent realistic lighting from real light sources, which is most often used since it is easily relatable. The light settings may be exaggerated to some extent, if required. Non-motivated lighting, however, is not bound to such rules and aims to influence mood in a more abstract way, where light qualities can be controlled freely to generate certain responses (Dunham, 2015; Reid, 2001). This is often seen in concert- and performance-art lighting, and may be based on similar guidelines as seen in chapter 2.5 on altering emotional state.

Finally, the genre of the story might be considered for an overall theme. In example, brighter light may be chosen for a comedy or less saturated light for a tragedy. Additionally, the target group can be considered, while also the difference between adjacent lighting settings should be assessed due to the vision adaptation that happens in the eye and brain (Reid, 2001).

Another type of media in which additional lighting recently has been attempting to enhance the experience is TV- and computer screens. In other words, colored dynamic light that is cast onto the surrounding wall behind the screens. A popular version of this is Ambilight, found on many Philips TV's, which analyses screen data and illuminates the rear wall with colors that "enlarge" the screen and create a more immersive experience (Bruyneel & Lanoye, 2012). A small-scale experiment by Weffers-Albu et al (2011) tested the effect of Ambilight and found that the added light results in higher values of both self-report and physiological measures, compared to traditional TV. Thus, it is implied that ambient lighting may potentially see an effect in media that don't require screens.

Chapter 3

Design Framework

People read for multiple purposes, either to gain new knowledge or for contemplation (OECD, 2000). One may assume that readers want to be drawn into the book, sensing the characters and the storyworld. Being fully immersed in a book may also strengthen the learning process, while enhanced visuals, which may generate from immersement, allow for better comprehension and recall (IARE, 2003; Oczkus & Rasinski, 2018). This can be referred to as an immersive experience. To make clear what that is, the definition of the word ‘immersive’ is stated below from three different dictionaries:

“Noting or relating to digital technology or images that actively engage one’s senses and may create an altered mental state“ (Dictionary.com, n.d.)	*“Seeming to surround the audience, player, etc. so that they feel completely involved in something”* (Cambridge Dictionary, n.d.)	*“Providing, involving, or characterized by deep absorption or immersion in something (such as an activity or a real or artificial environment)”* (Merriam-Webster, n.d.)

Thus, light should help create that immersive experience, aiding the readers to reach the mental state of being present in the storyworld, creating imaginative images instead of perceived images. The presented framework was developed to support the reader’s visual imagery and emotional response with input signals from light, based on modern technology.

3.1 Framework Overview

In order to answer the problem statement, a design framework was developed, based on information from the literature chapter, in combination with additional research. The solutions in the framework are briefly discussed, and will be discussed further in chapter 5. The design framework provides initial solutions that will be applied in the experiment (part II), which will provide results for discussion of a final answering of the problem statement. The framework will therefore change or adapt over time as new information is gained, and should not be seen as a final design.

From chapter 2, it was found that visual perception and visual imagery share similarities, whereas light may affect visual imagery. Thus, one may assume that light should support imagery, making it easier for the user to create their mental images with help from external input. Dynamic lighting is prefered over static, first of all to support the different associations within the storyworld, yet also since static light conditions may have a negative effect (Dunham, 2015).

The framework follows the principles of stage lighting, where visual information is extracted from a script (in this case a book) and light qualities are selected based on that information. This framework, however, takes a step towards automation. Furthermore, it is limited to only *one* light quality at once, excluding the possibility to e.g. have a red and a blue light present simultaneously. The framework overview can be seen in fig. 12. Each part is elaborated in the remaining chapter before ending with a couple of text examples.

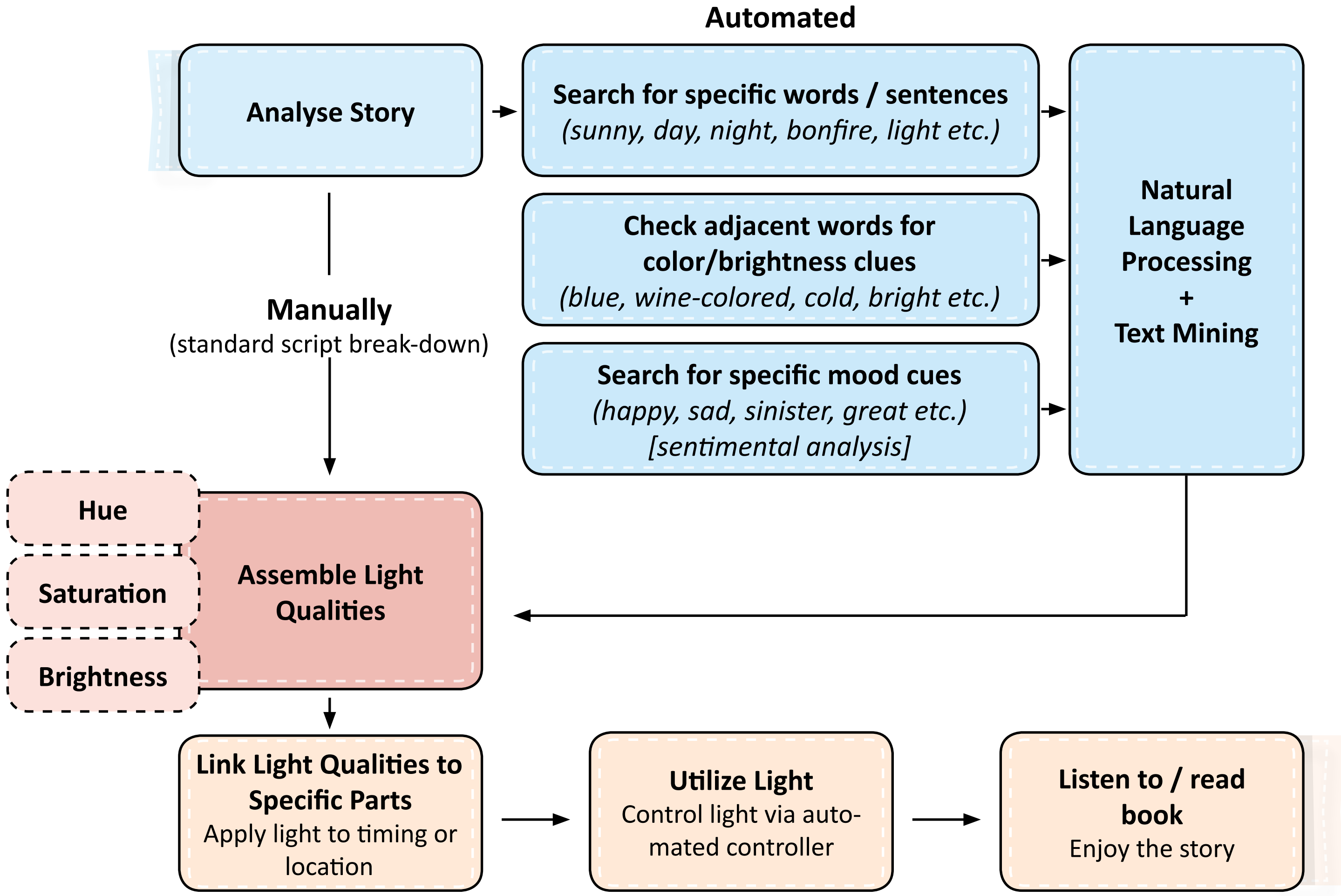

Figure 12. Diagram of design framework.

3.2 Text Analysis

Naturally, a text analysis can be done manually by publishers, lighting designers or the users themselves, extracting visual information from the story and selecting light settings. However, that is a time-costly process. Hence, it is suggested to benefit from Natural Language Processing (NLP) and text mining, which can be used to break down text. NLP is a collection of protocols, in which computers convert unstructured text into meaningful data, which may learn and adapt when combined with machine learning (Edureka, 2018; IBM Cloud Education, 2020). In this framework, the concept of NLP will be used to find predetermined root keywords about the light conditions (and mood) and understand if the keywords actually represent the overall lighting (or mood) of a scene. In other words, it automates the procedure of a manual script breakdown.

Mitri (2020) developed a software named Story Analyzer, in which they used a NLP library, along with visualization libraries, to extract elements from stories, and abstractly visualize actions and connections between characters, and the correlation to time and place. The project didn’t extract visual cues, but it did provide evidence that visual extraction should be realistic, even for advanced sentences.

In order to run a text-analysis of audio-books, NLP can convert speech to text while keeping the audio timing linked to the specific text locations (IBM Cloud Education, 2020). As an example, the syncing of text and audio can be seen, in practice, in Amazon’s Whispersync technology, where audiobook timing and ebook location are linked (Audible, n.d.). This makes a shared automated system realistic for both audio- and ebooks.

3.3 Light Quality Assembling

Light qualities are selected, based on text cues found in the story analysis. A Cue Hierarchy (see fig. 13) is needed. If a Prime cue is found, the light qualities are set based on this, and if not, it continues to search for Visual Association cues. If such is not found either, it searches for a Mood cue, and finally it selects a default light quality if no cues are found in the text. Each word cue is described in the remaining chapter. Examples of the cues, utilized in sentences, can be found in each section.

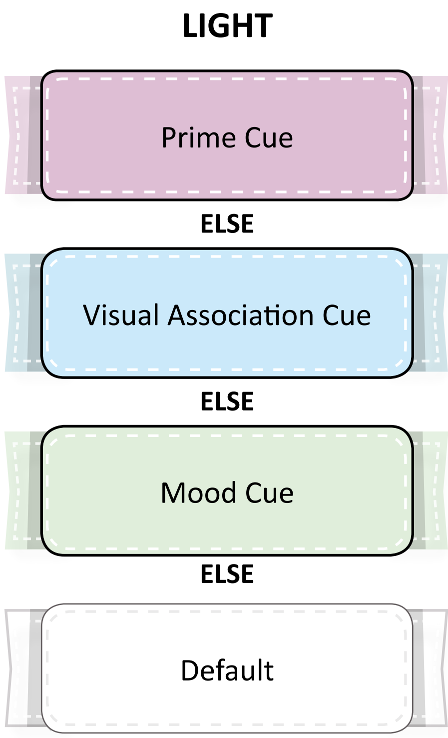

Figure 13. Cue Hierarchy.

3.3.1 Prime Cues

If following the guidelines of a script break-down for stage-lighting, mentionened in chapter 2.6, some written cues will always prime and determine the light settings. For example, if a text mentions that the light is “blue”- the hue of the light should be blue. If the text states that light conditions are “vibrant”, saturation should be high. If the text mentions that the light is “bright”, the brightness should be high, etc. These direct cues ensure that the light supports the users’ imagery, as it must be assumed that their imagery is to some degree based on these solid prime cues. Prime cues can control hue, saturation and brightness individually.

The words that Prime cues consist of have to be defined manually. A database of these words has to be created, along with their meaning (the word “blue” is connected to blue hue, “bright” ensures high brightness etc.).

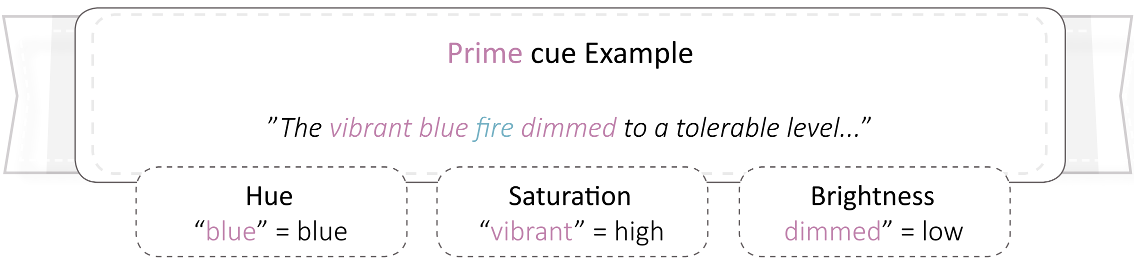

Figure 14. Prime cue example.

3.3.2 Visual Association Cues

Continuing the stage-lighting guidelines, motivated lighting is likewise used next. Visual Association cues require text cues of the light conditions, such as “sunlight”, “bonfire” or “polar light”- or indicative text cues such as “overcast”, “outside at nighttime” or “summer day”. In other words, cues that refer to light conditions without them being said as directly as Prime cues, based on the visual associations, in order to support imagery.

To utilize this system, a database of predetermined light qualities must be created, based on assumptions of the light qualities, of which the users associate the given cue. For example, if the word “polar light” appears in a text section, the system checks the database and finds that “polar light” has been mapped with e.g. *hue = cold green, saturation = medium & brightness = medium*. Naturally, associations vary from person to person, why this database could, ideally, be developed from the average of many participants- and later even grouped, so e.g. a database could exist for different age groups, nationalities or story genres. The list of important words to map in the database can be found from text mining, which extracts and finds the most common words.

In books, colors are often referred to as nouns (e.g. “*...the lantern released a strange light, the color of the sea.*”). In such cases, an image-search can be done, which will search for the specific word and extract the color of the images found. This was tested on 50 nouns (*[word] + “color”*) on Google Image Search and the results imply that this will most of the time give correct results, yet a deeper investigation is needed to fully develop such a system.

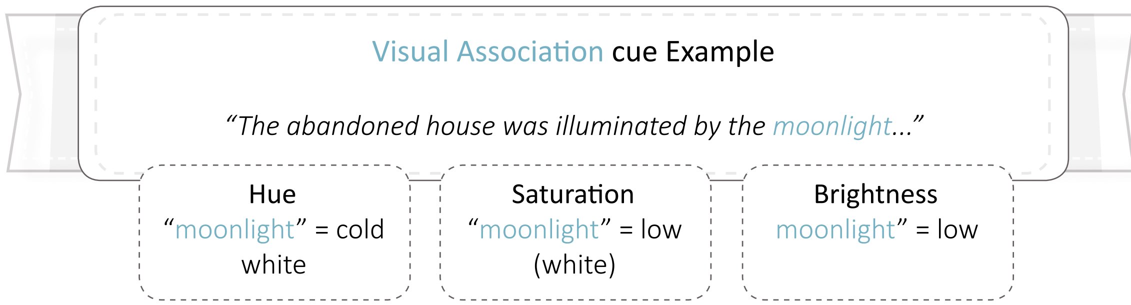

Figure 15. Visual Association cue example.

3.3.3 Mood Cues

The next cue in the hierarchy is Mood Cues which, as the word indicates, is an extraction of mood from the text. This is used when the two previous types of cues are not found in the text. The light qualities will be set to support the mood of the story, which in stage-lighting is referred to as non-motivated light - the more abstract lighting. However, limitations must be included to avoid conflicts and unwanted control of the users’ imagery. Calming down a user with blue light might result in confusion if the user imagines that the characters of the story sit in front of a fireplace, in case the text analysis found only a mood cue indicating that the atmosphere is “calm”. Additionally, the knowledge of the effect on emotional state from colored light, of various brightnesses and saturations, is very limited (see chapter 2.5). These issues can be eliminated by removing color (hereunder hue and saturation), leaving only brightness to be controlled. The use of CCT could also be problematic, as the ratio between CCT and brightness is quite complicated when it comes to mood (see chapter 2.5). Thus, a default white is suggested, while the brightness will support the mood of the story. A predetermined mood database will be required for Mood Cues to be utilized.

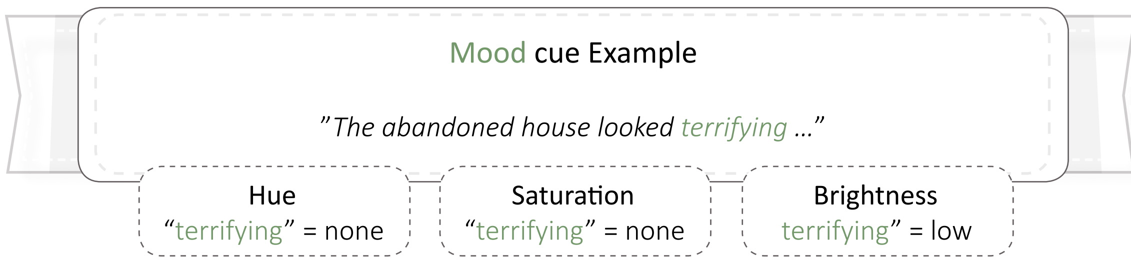

Figure 16. Mood cue example.

3.3.4 Standard / Default

Finally, if the text analysis fails to extract any atmosphere information, a default white light is suggested. The CCT should be neutral/intermediate ~ 3300K (see table 1), while brightness is suggested to be medium. Neutrality is prefered to avoid contradicting effects from CCT and extreme brightness settings, due to the unknown factor of association and mood. The exact CCT could be based on location due to national preferences.

Color Appearance	**Correlated Color Temperature**
Warm	below 3.300 K
Intermediate	3.300 to 5.300 K
Cool	above 5.300 K

Table 1. Lighting standard definitions of CCT (prEN 12464-1:2019)

3.4 Transitions & Dynamism

In order to maintain the highest level of focus on the story, transition between light qualities should be considered, as well as the effects available from dynamic light (e.g. thunder flashes or candlelight flicker).

Dynamic light effects can potentially enhance associations with specific visuals, such as fires or polar lights. However, it comes with the risk of pulling the text-receiver out of the story due to the increased attention, which dynamic light causes to itself compared to static (D'Egidio et al, 2014; Gerathewohl, 1953). Therefore, static light is suggested, excluding dynamic light effect, with only the transitions between light settings being dynamic.

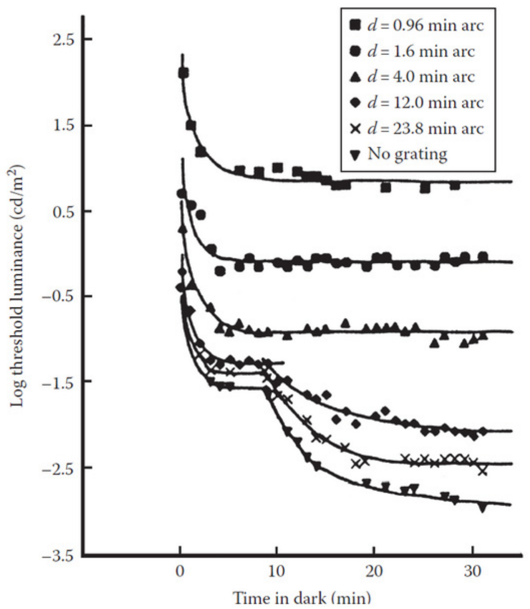

Figure 17. Darkness adaptation correlation with time in minutes (from Boyce, 2014, after Brown et al, 1953).

Light/darkness adaptation consists of multiple physiological and psychological processes that occur over periods of 200ms to one hour (Boyce, 2014). As illustrated in fig. 17, much of the adaptation happens exponentially within the first few minutes, indicating that transitions can be conducted rather swiftly. Adaption does, however, highly depend on the degree of light change.

Light transitions in stage lighting may be gradual and unobserved, or dramatic and apparent to the audience, thus disrupting the flow- hence, transitions are of high importance (Dunham, 2015). For the design framework, both audio-book listening (without reading-light) and e-book reading (with reading light) have to be considered in terms of assessing the degree of light changes between light qualities. Based on the wide color-variance that a monochrome transition can create (not considering reading light), the transition has to be slow enough to not steal focus, yet being fast enough to not confuse the user

with the inbetween settings that a direct transition will include (e.g. transitioning from red to green will result in a period of yellow). A double-transition, first changing to white or black, would eliminate the in-between-color issue, but comes with the risk of unwanted light attention. Due to the lack of direct guidelines about transition timing, a duration of three seconds was chosen from a subjective transition test by the author of the paper.

3.5 Utilizing the Light

When the text analysis has been completed (presumably through a computer or mobile application- if not manually), the system can be utilized with either audio- or ebook, controlling the light according to the time (audio-book) or location (ebook) [equivalent to pages in paper books]. The system may be connected to a home system with color&white smart-lamps, controlling the already incorporated light in the home. Alternatively, a custom fixture could be developed for the purpose. A brightness limit could be set on application setup, depending on room size, amount and placement of lamps. Since the light qualities are mainly predetermined by humans, an else important aspect as the eyes' sensitivity to color is not required to assess.

To avoid glare, the lighting is suggested to be diffused and ambient (with high uniformity), avoiding discomfort and thereby unintended mood affection. When reading a book from an e-reader, which doesn't have built-in light (as opposed to a phone or a tablet), a task light is required. For this, one can refer to lighting standards, in which reading light is suggested to be around 500lx (see table 2), but is naturally dependent on personal preferences.

	Em	**UGRL**	**Uo**	**Ra**
Library reading area	500	19	0,6	80

Table 2. Lighting standards for reading. EM = illuminance on task light. UGRL = glare threshold. Uo = uniformity. Ra = color rendering (prEN 12464-1:2019)

To simplify the system, so that the reading light is not required to be part of the controlled lighting, the task light is suggested to be static and set by the user to a prefered brightness, which also eliminates reading frustrations. However, this creates another problem: since the ambient light is dynamic, while the task light is static, it is impossible to include glare measures for visual comfort. The effects of this problem are unknown and will require specific testing and problem solving.

PART II

Chapter 4
Experiment

4.1 Introduction

An experiment was conducted to test the effect of the design framework. Additionally, the experiment was designed to get a better understanding of how light affects imagery, and to get feedback on light preferences from the subjects. From the framework, Mood cues were excluded to focus only on the more important Prime and Visual Association cues.

In order to design the experiment, and to assess the results, six hypotheses were developed:

1. Light influences emotional state when listening to stories.
2. Light influences visual imagery when listening to stories.
3. Light influences short-term memory when listening to stories.
4. People can visualize better in complete darkness when listening to stories.
5. People prefer reactive light when listening to stories.
6. Incorrect lighting creates annoyance and confusion.

These hypotheses were aimed at testing if the framework made the stories more immersive (thus enhancing imagery-level and short-term memory, while affecting emotional state according to the moods of the stories). Additionally, it tested the claim of Sherwood & Pearson (2010), stating that complete darkness is best for visual imagery. Finally, the results should provide information to help find target groups for such a lighting system, based on feedback, in case subjects did or did not like the reactive light.

4.2 Method

This chapter explains how the experiment was designed using a mixed methods approach, and how it was conducted in order to collect the data that is used in the discussion, which lead to the findings that is used in the remaining thesis.

4.2.1 Overview

In fig. 18.1, the overall experiment design is illustrated. Five guided imagery scripts were developed and recorded, after which the design framework was applied. The experiment was then conducted and data were collected, analysed and discussed.

The order of experiment steps, concerning the actual conduction, is illustrated in fig. 18.2. The procedure was initialized with initial questioning and introduction to the experiment, questionnaires and subtraction-tasks, followed by a short breathing exercise. Afterwards, an imagery-level test (VVIQ) was conducted, whereas the results were used to divide subjects into test groups. Five audio stories were played, beginning with a subtraction task and ending with a questioning round. The rules of the lighting changed in each story, depending on the test group. A final round of short-term memory questions and feedback were asked in the end. Each step is elaborated in the remaining chapter.

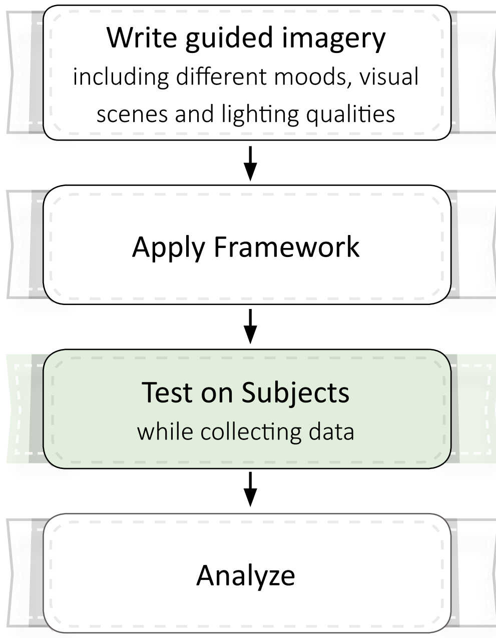

Figure 18.1. Overall process of experiment development.

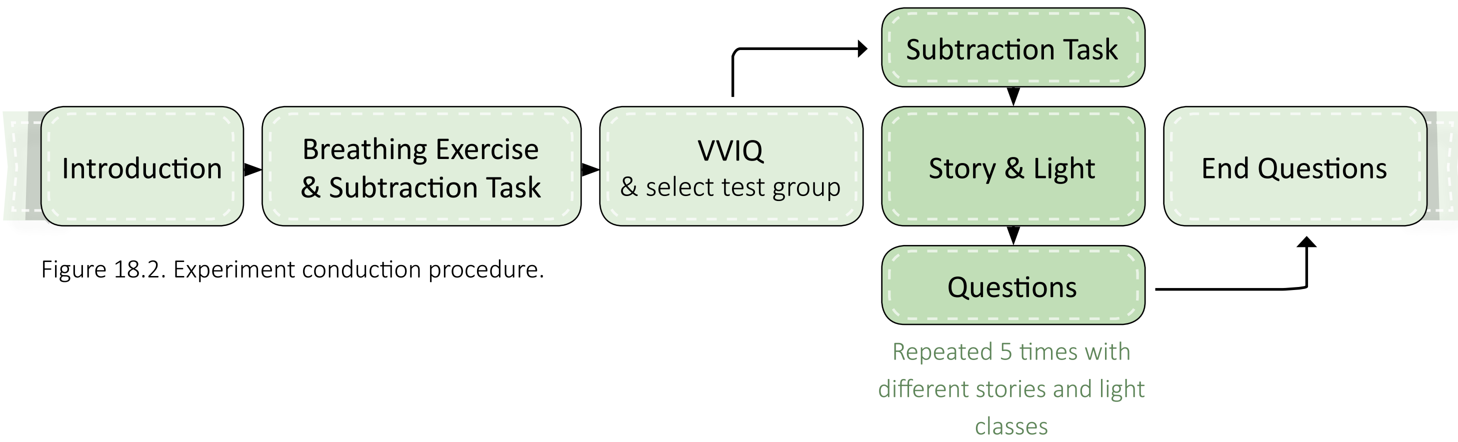

Figure 18.2. Experiment conduction procedure.

4.2.2 The Script

As mentioned in the literature chapter, guided imagery is beneficial when assessing imagery. It has been widely used in physiotherapy, but also in scientific studies (Hall et al, 2006). Therefore, a guided imagery script was created for the experiment, consisting of five stories. The stories were continuations of each other to allow for easier story adaptation, each with a different mood (see chapter. 4.2.3). Furthermore, each story followed a three-part structure, with each part containing different visual settings and amounts of word cues (see table 3). The first part included one auditory, one sensory and one olfactory word cue (allowing for easier immersement), whereas part two and three only contained visual cues. Part three allowed for more imagery control to fully test the effect of the light.

Story Part 1	Story Part 2	Story Part 3
Other sensory cues Prime Cues Visual Association Cues	Only visual cues Visual Association Cues	Only visual cues No color & brightness cues

Table 3. List of word cues in each of the three parts included in each story.

As is the norm (Hall et al, 2006), the script was written in first-person, present tense, and guided the subjects through an imaginary world. The stories were aimed to be neutral, objective, not author-biased (Hall et al, 2006) and something that most people can relate to and associate themselves with. The storyworld was set in a fantasy/adventure-inspired setting to allow for different light conditions. Story elements such as plot and conflicts were left out due to the short story durations, while the focus on visual guidance was embraced. Additionally, presentations of human characters were excluded to avoid influential variables. The stories had no other use than provoking imagery and benefit from the effects which such media generates.

The stories were recorded with a calm female voice, and edited to ensure equal durations for each part and each story. The stories were each approx. 4 minutes in total (download link in appendix).

It should be noted that the author of this paper has personal experience in meditating, hereunder with the use of public guided imagery for pleasure, and has previously written guided imagery scripts for various clients. Furthermore, the script development was based on knowledge from a bachelor degree in storytelling and storyworld visualisation, as well as sparetime novel writing.

4.2.3 Script Moods

The five moods used in the five stories were selected according to their high difference in pleasure and arousal, according to Russel's Circumplex. The mood selections can be seen in figure 19.

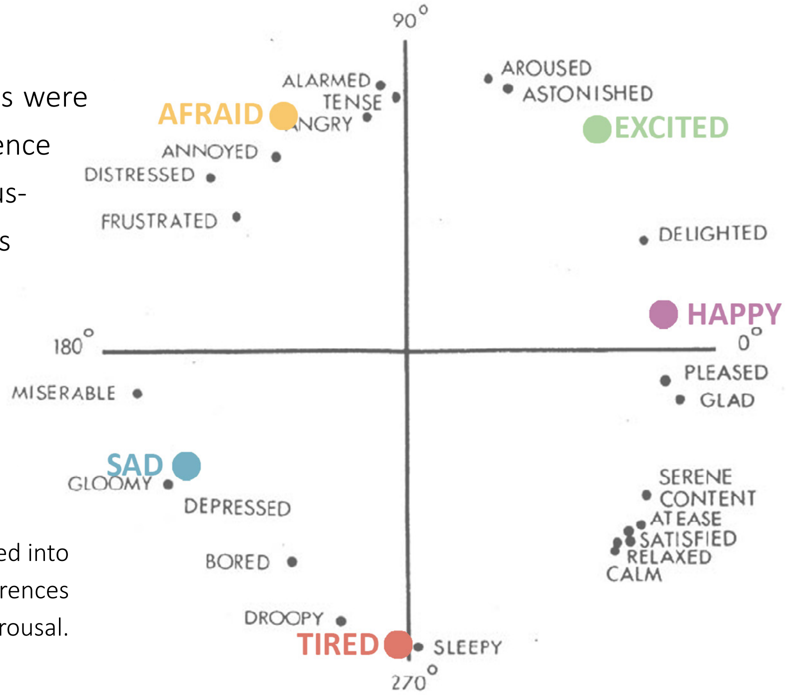

Figure 19. The selected moods plotted into Russel's Circumplex to illustrate differences in pleasure and arousal.

Assuming that guidelines on influencing people with percieved images can be used to provoke similar emotional responses in mental imagery, the scripts were guided by the following litterature (table 4). Additionally, emotional responses were affected by word cues, e.g. when telling people that they feel tired or their eyes are heavy, while also specific story-contexts were selected to embrace the mood of each story.

Happy & Excited	Tired / Sad	Afraid
Joyful scenes can be created by scenic locations (Seresinhe et al, 2019), allowing for far view and natural settings. A study by the author of this paper (Skov², 2020) supports this theory, revealing that scenic scenes with grass, trees and sunlight may create happy scenes. From chapter 2.5, it was further found that saturated colors creates higher affection.	Sleepy and sad scenes can be achieved by using a softer style, and slow visual rhythm and pacing (Block, 2007). Taking inspiration from traffic, it is known that monotone scenarios (roads) result in tiredness and low concentration (Road Traffic Technology, n.d.). Context can further aid the degree of sleepiness and sadness.	Horror settings can be achieved by creating lonesome or enclosed spaces. It generates the emotional state of feeling uneasy and trapped. Unnatural lighting may create tension and suspense (Park, 2018). The study by Skov² (2020) further indicates that brightness should be dark to medium, with dark areas that allow for something to possibly lurk in the dark.

Table 4. Brief literature review of how to visually create specific moods in images.

4.2.4 Breathing Exercise

A breathing exercise was used to make subjects feel more relaxed in the experiment, and to allow for better concentration (Bing-Canar, 2016; Ma et al, 2017). The exercise further aimed to normalize initial emotional states. It consisted of a four seconds inhale, seven seconds of held breath and eight seconds of slowly exhaling (shorter durations were allowed if subjects were struggling)- repeated three times.

4.2.5 Subtraction Task

In order to partly eliminate influence of previous light settings, imagery and story aspects, a subtraction task was used to "clear" a part of the short-term memory; Peterson & Peterson (1959) found, through an experiment, that only 10% of recalled items were correct after 18 seconds of delay, in which the subjects had to count backwards in threes or fours. Their findings were based on memorisation of three letters, but it may be assumed that the method can be used in other aspects of short-term memory as well, why it was used before each round of stimuli / story in this experiment.

4.2.6 Light Classes

Five light-setting classes were carefully developed, herein two static control classes and three reactive test classes. These were light settings in which specific rules were applied, based on the framework. Each light class was used in each story at least once. Due to the story structures (that included visual cues), the light-settings tested only Prime and Visual Association cues. The rules of each class are listed below.

- No Light**. Complete darkness, investigating the effect of no visual input.
- White Light**. Static white light, 2700K (based of nordic warm light preferences and prEN 12464-1:2019). Used in order to measure effects with "standard" illumination if listening to audiobooks in a calm living-room (~ 10lx*)
- Dynamic Light A***. Full effect of applied framework (no brightness limits: up to 60lx*), testing Prime cues and Visual Association cues.
- Dynamic Light B***. Limited effect of applied framework (minimal brightness: up to 1lx). Used in order to assess if subtle changes affect the listener without provoking attention to the light.
- Dynamic Light C***. Contradicting the colors of the applied framework (brightness limits: 20-60lx*. Increased saturation.). Used to measure how significantly "incorrect" light settings affect listeners.

**Measured vertically on task area / white screen*
***Static control light classes*
****Reactive test light classes*

4.2.7 Variables and Measurements

The experiment was designed using a mixed method approach. In table 5 are listed the independent, dependent and controlled variables that were tested. In table 6, the different methods and tools for measuring the dependent variables are listed, while the questionnaires and questions can be found in the appendices (in Danish). Besides the listed variables, age, gender and imagery levels were collected as initial questions.

VARIABLES

Independent	Dependent	Controlled
Light (hue, saturation, brightness)	Arousal Pleasure Heart-rate Imagery level Imagery feedback Short-term memory Feedback on light classes	Story Audio Experimental setup

Table 5. List of variables included in the experiment.

MEASUREMENT TOOLS

Quantitative	Qualitative
Arousal* Pleasure* Imagery Level* Lux Levels (Testo 540)** Heart-rate (Garmin Vivo Active 3 Music)**	Feedback on Imagery Memory End-questions Feedback on light classes

**Self-assessment (subjective)*
***Objective*

Table 6. Measurements included in the experiment and tools for measuring them.

The collected data was sorted and evaluated in Excel, and quantitative data was further assessed in Orange Data Miner. Visualization of heart rates for comparisons was created in GoldenCheetah software.

4.2.8 Setup

The design framework was manually applied to the stories in order to ensure correct light settings. A playback system was created in Processing, allowing for precise time tracking (required to synchronize with the heart-rate tool), automated setting of light conditions (depending on selected test group) and easy control of the experiment due to automation (download link in appendix). The system was connected to two Philips Hue White&Color (3rd gen/BT) lamps, which was synchronized with the audio of the stories.

A chair for the subjects was placed in the middle of a room. In front of the chair, at a distance of 1.5 meters, was placed a blank, white screen. This was to eliminate influential factors from the room, letting the subjects focus on the screen. Behind the chair, the two Philips Hue lamps were placed at a height of 1,5 meters. Windows were sealed to ensure absolute darkness.

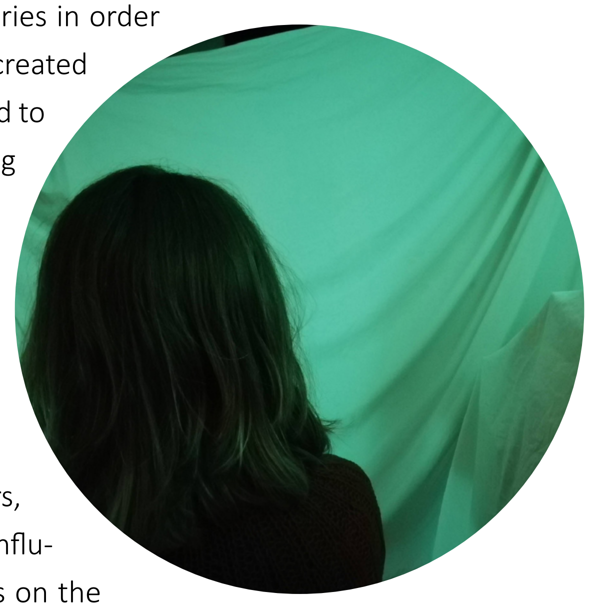

Figure 20 . Image of the experiment.

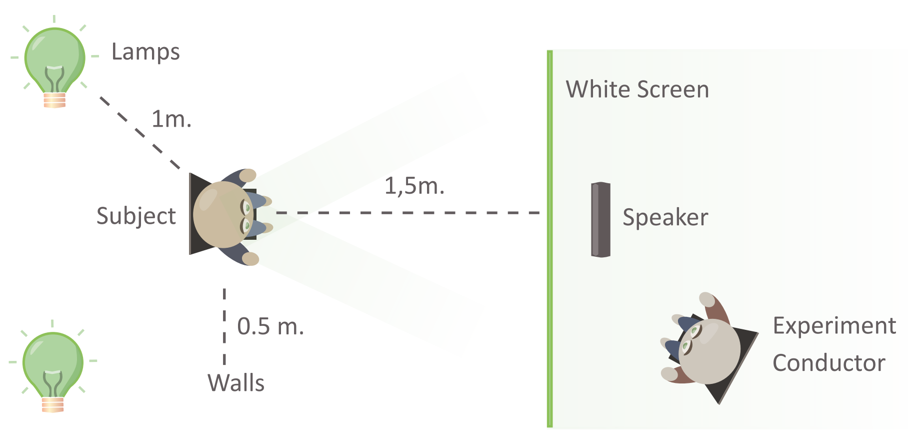

Figure 21 . Experiment setup.

4.3 Results & Discussion

In this chapter, the results are presented, evaluated and discussed to answer the hypotheses and extract knowledge for further answering of the overall problem statement. The results and discussion are combined due to the high importance of the qualitative data. The chapter ends with an evaluation of the experiment and the collected data.

4.3.1 Subjects

Ten subjects participate in the experiment (five male and five female). Due to Covid19 precautions, these were friends and family members of the author, three in the age group of 50-60 and seven in the age group of 25-35. All were natives, speaking fluent Danish. No imagery-level scores (VVIQ) were considered "low" (< 2.5), while four was considered "medium" (2.5- 3.5) and six was "high" (> 3.5). Evaluation of gender and age patterns reveal no useful findings.

4.3.2 Quantitative Assessment: Stories

In order to evaluate if the different light classes enhanced the emotional responses according to the stories' intent, the overall results of each story is compared (see table table 7). This reveals whether the stories generated the targeted emotional states or not.

In fig. 22, pleasure and arousal levels of each story is mapped onto Russel's circumplex. The diagram illustrates and reveals that the five stories achieved their targeted emotional state when compared to each other. Likewise did each story come close to what was expected from the circumplex. Mainly in arousal levels, story 2 and 5 break with the expectations. Whether that is the result of the stories, the experiment setup or a result of chance is unknown, yet this is not a major concern due to the relatively high variance. When combining the circumplex diagram and the low p-values, the goal of emotional states of the stories appears to be successful.

Story	Pleasure	Arousal
1 (happy)	4.00 (± 0.60)	3.50 (± 1.02)
2 (sleepy)	2.50 (± 0.70)	2.65 (± 0.84)
3 (sad)	1.80 (± 0.60)	2.70 (± 1.00)
4 (scared)	2.20 (± 1.00)	3.90 (± 0.94)
5(excited)	3.80 (± 0.70)	3.60 (± 0.66)
P Value (N = 50)	p = 0.000	0.015

Table 7. The mean results of pleasure and arousal and of each story. Standard deviations are shown in parentheses. P-values between story results, using all values (thus, not the means), are given in the final row.

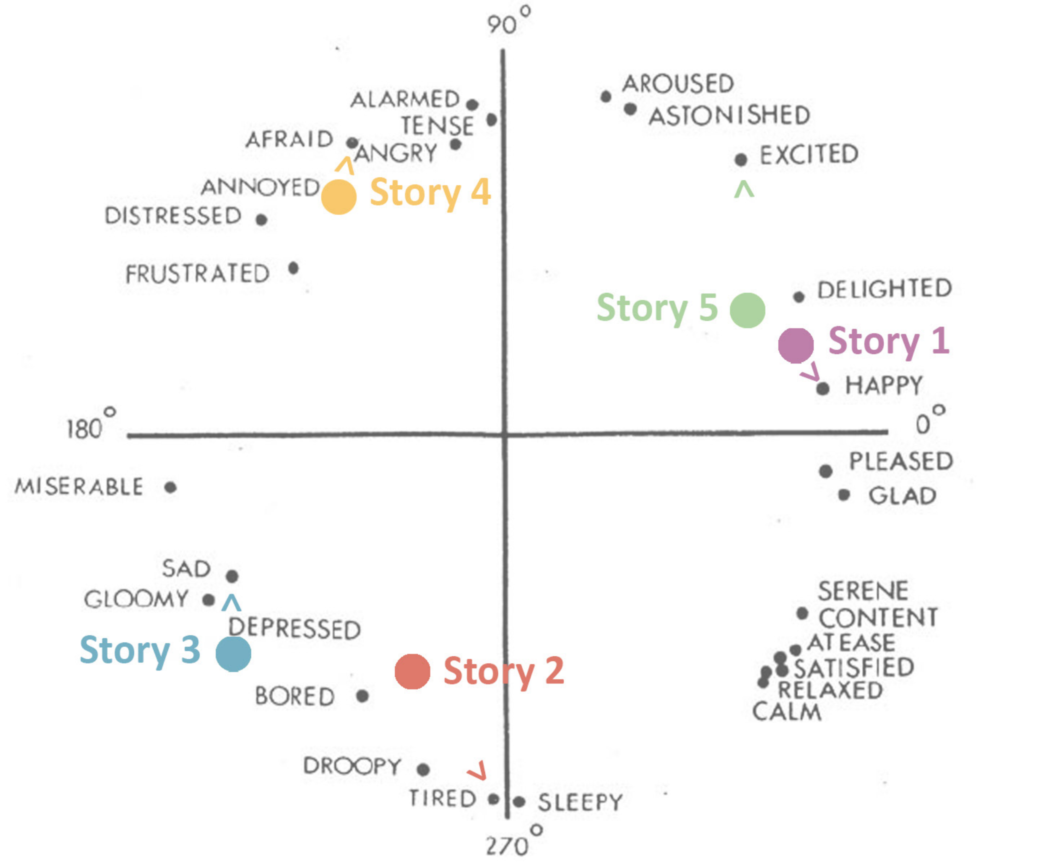

Figure 22. Each story mapped onto Russel's Circumplex, angled in relation to their pleasure (horizontal) and arousal (vertical) level means. The arrows point towards the targeted emotional state of each story. Variance is excluded.

4.3.3 Quantitative Assessment: Light Classes

In order to investigate how each light class influenced the participants, fig. 23 was created to illustrate the differences between the light classes in each story, and to evaluate whether the dynamic light class enhanced (or decreased) the emotional response as expected.

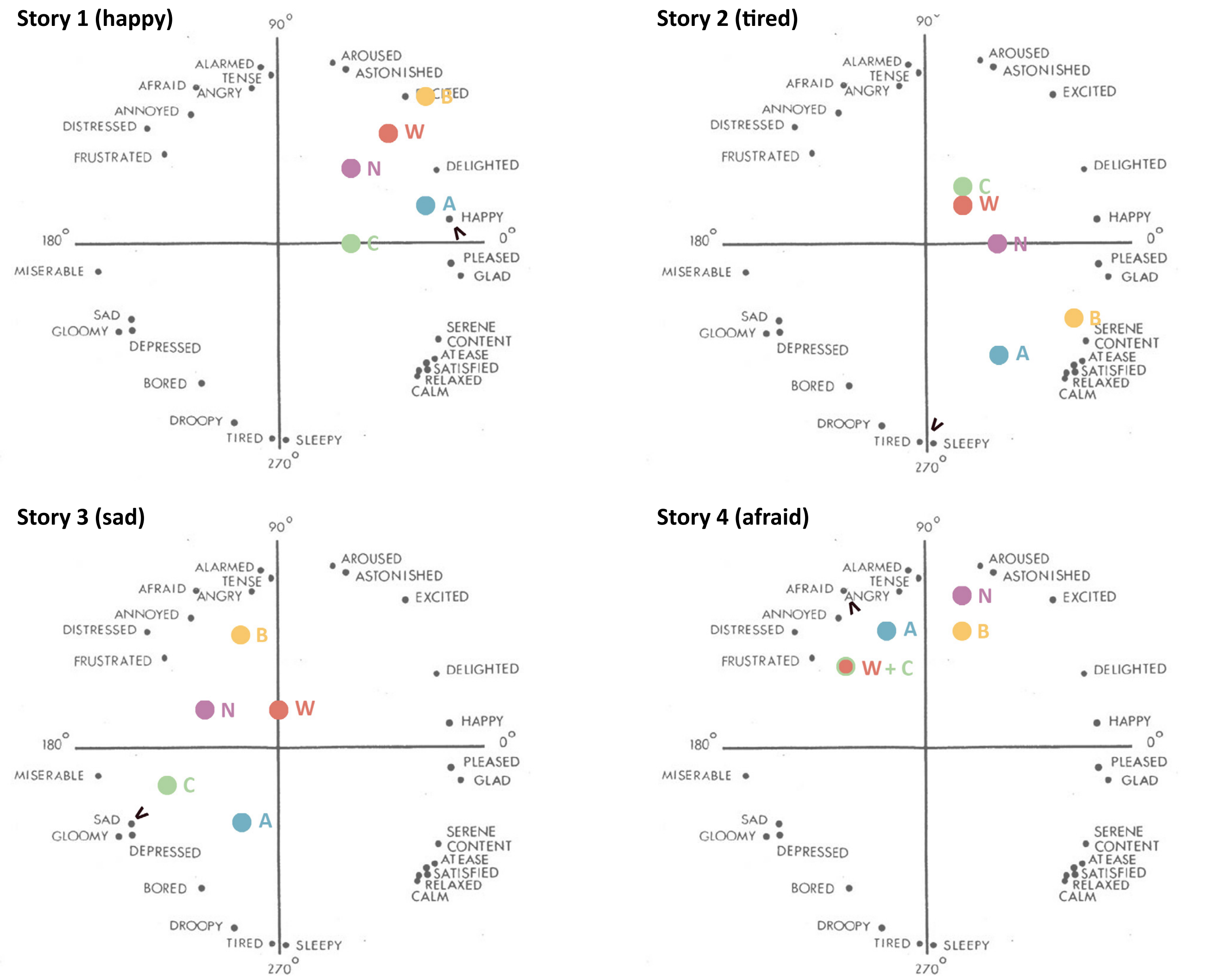

Figure 23. Each story, relatively mapped onto Russel's Circumplex, with the means of the pleasure (horizontal) and arousal (vertical) levels of each light class. A black arrow marks the targeted levels.

N = No Light.
W= White Light.
A = Dynamic A.
B = Dynamic B.
C = Dynamic C.

Examining fig. 23, a pattern can be found in Dynamic A: in all but one story (story 3), this light class achieved results closest to the target. This indicatively confirms the expectation stating that motivated lighting enhances the effect of the stories, concerning emotional state. Compared to Dynamic B (minimum brightness), the brightness-changes appear to be important in order to achieve enhanced emotional responses.

The expectation that incorrect light colors create annoyance (lower pleasure & higher arousal) doesn't seem completely to be true when assessing these quantitative results. No significant pattern is found in Dynamic C (complementary hue) concerning arousal. This light class does, however, achieve the lowest pleasure levels in each in all stories (see also table 8). The lower pleasure level could be useful if used correctly in certain stories or genres, and could be the reason why this light class landed closer to the target in Story 3 (sad).

Light Class	**Pleasure**	**Arousal**	**Imagery**
No Light	3.10 (± 1.10)	3.40 (± 0.80)	3.70 (± 0.80)
White Light	2.90 (± 0.90)	3.40 (± 0.92)	4.00 (± 0.60)
Dynamic A	3.20 (± 1.20)	3.10 (± 1.22)	3.60 (± 0.70)
Dynamic B	3.60 (± 1.10)	3.50 (± 1.28)	4.30 (± 0.80)
Dynamic C	2.50 (± 1.10)	2.95 (± 0.72)	3.80 (± 0.90)
P Value (N = 50)	p = 0.317	p = 0.752	p = 0.312

Table 8. The mean results of pleasure, arousal and imagery levels of light class. Standard deviations are shown in parentheses. P-values between light class results, using all values (thus, not the means), are given in the final row.

No other indications are found between the remaining light classes concerning each story. It should be noted that the differences are not significant due to the relatively little comparative data, as well as the exclusion of variance in the figure. Therefore these findings should only be considered indicative.

4.3.4 Quantitative Measurement: Heart Rate

The first analysis of heart rate (HR) is investigating the dispersion of HR in each light class. In other words: how much do the HRs in average change when subjects are presented to different light classes? This information could potentially tell something about how concentrated and/or affected subjects were by the story, whether that was due to the stories, the lighting or both (Appelhans & Luecken, 2006; Deusen, 2019; Farnsworth, 2019). The used measuring tool didn't provide information on actual heart beats (RR intervals), but only HR averages over time. Thus, to do this analysis, the Coefficient of Variation (CV) of this data was calculated for each data cell, ensuring normalized values for comparison.

$$CV = \frac{subject\ HR\ standard\ deviation}{subject\ HR\ standard\ deviation\ mean}$$

Illustrated in fig. 24.1 are the raw CV's of each light class, normalized to compare with other figures. However, story and individual subject dispersions affect these raw values; In fig. 24.2 and fig. 24.3, the CV's are normalized (division) by, respectively, story means and individual subject means. These show the CV's independently of story and subject influences, in case that specific stories, or certain subjects, increase/decrease CV's in the relative light class.

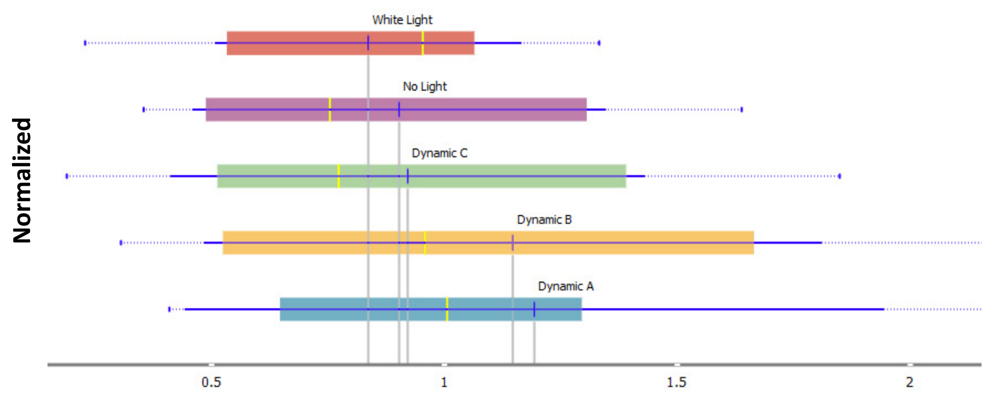

Figure 24.1. Normalized raw values of HR dispersions in each light class.

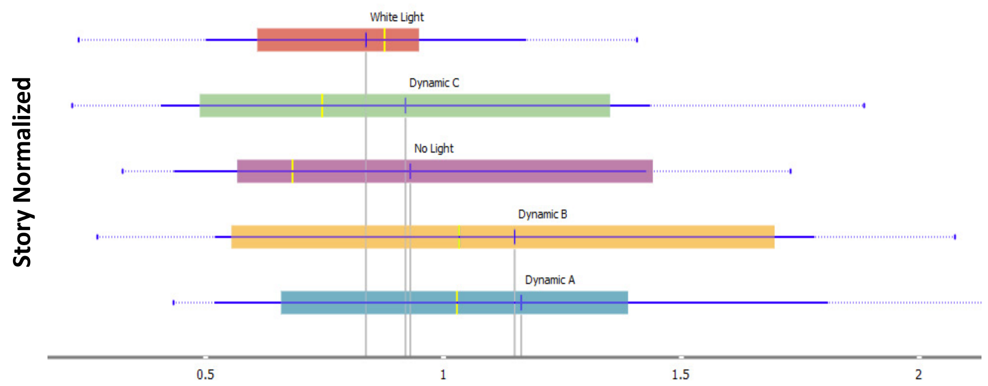

Figure 24.2. Story-normalized values of HR dispersions in each light class.

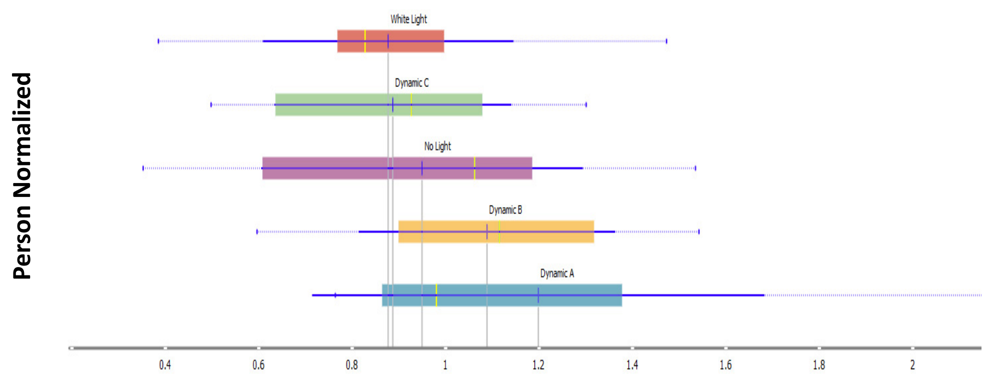

Figure 24.3. Person-normalized values of HR dispersions in each light class.

When analysing the figures, it is found that in all cases, Dynamic A light class achieves the highest dispersion in heart-rate, followed by Dynamic B, when comparing the means. The remaining light classes vary more depending on the normalization. Again it should be noted that these are not significant differences [p = 0.20- 0.65], and have fairly high variance, but the results do indicate that the two motivated light classes might affect heart-rate more effectively. Whether this is due to increased concentration, imagery, emotional affection or a result of chance is unknown. However, the White and Dynamic C light classes result in relatively low heart-rate changes, which could indicate that imagery and focus is part of the reason (see chapter 4.3.6). No patterns were found in individual story assessment of HR.

A manual comparison of heart-rate changes in each story (see Appendix for comparison document), reveals no significant patterns. It was expected that light transitions in Dynamic A, B and C light classes would be visible on HR-visualizations, but the HR-changes within each light class seem to be based on the story and the individual person. This implies that the gradient transitions between light qualities didn't affect subjects enough to affect their heart rate, and is considered positive due to lowered risk of stealing attention from the stories.

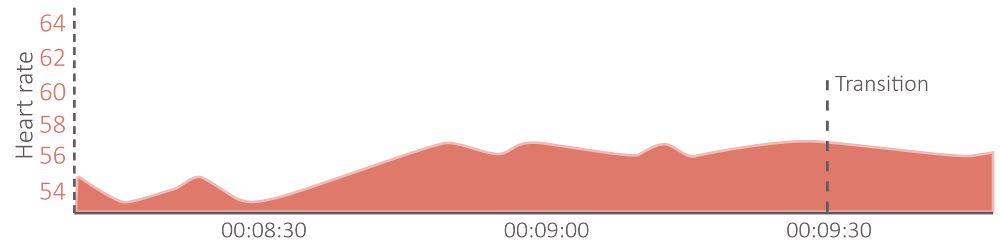

Figure 25. Example showing how no obvious HR changes are seen when the light transitions, but are rather based on the story and the individual subject.

4.3.5 Quantitative & Quantitative Assessment: Imagery levels

Fig. 26 shows the results of reported imagery levels in each light class. Dynamic B [mean = 4.3] achieves the highest levels, while White Light [mean = 4.0] has the second highest. Dynamic C [mean = 3.8], No Light [mean = 3.7] and Dynamic A [mean = 3.6] have the lowest levels. These results are surprising since the differences in color and brightness between Dynamic B and White Light light classes are quite significant. Hence, this may indicate that both darkness and light increase imagery, or that the results are partly biased or based on chance due to the little imagery-level differences and high variance [p = 0.312].

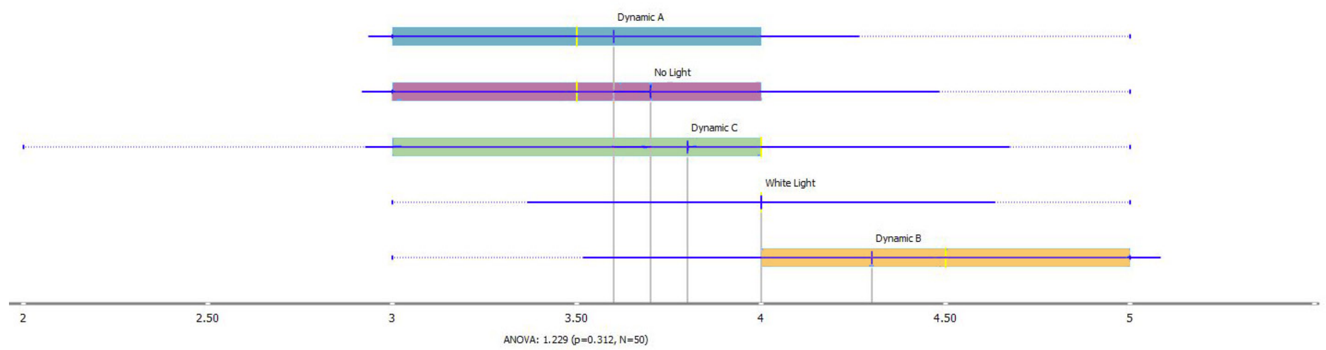

Figure 26. Results of self-assessed imagery levels, ordered by the means.

As seen from the imagery levels in table 9, there are indications stating that increased imagery occurs over time. This further questions the validity of the findings in fig. 26, which may be influenced by this increment over time. The increment theory is important to consider when developing experiments that evaluate imagery. It may generate different results based on the time or duration when subjects hear stories. Furthermore, it may suggest that the story experience becomes better over time, why lighting should potentially aim for extending reading/listening sessions.

Story	Imagery Level
1 (happy)	3.70 (± 0.60)
2 (sleepy)	3.80 (± 0.70)
3 (sad)	3.90 (± 0.70)
4 (scared)	3.90 (± 0.90)
5 (excited)	4.10 (± 0.80)
P Value (N = 50)	0.859

Table 9. The mean results of imagery levels of each story. Standard deviations are shown in parentheses. P-values between story results, using all values (thus, not the means), are given in the final row.

Three subjects reported that they didn't put much attention to the light, while one reported that there was no attention at all. These subjects had the lowest VVIQ levels, which could indicate that higher levels of imagery give room for light influence. This supports the claims of Keogh & Pearson (2011), stating that people with low imagery are less affected by sensory input.

4.3.6 Qualitative Assessment

Comparison of questionnaire answers in each story (see appendix- in Danish) reveals no obvious patterns or light class influences when subjects were to explain how visualizations appeared in their minds. On a few occasions, indications of light influence were found, e.g. a subject reported imagining green light when the story mentioned "a scary light" while being physically surrounded by a green light, while other subjects, who were influenced by other light classes, reported the light to be red. However, since these occurrences were rare, and stand alone as single occurrences, it could be based on subjective imagery rather than light influence. In most cases, the feedback of imaginated visuals seem to be based on the story text and individual associations.

The end-questions, concerning short-term memory, show no patterns besides the subjects remembering and liking the same two stories the best (story one and five). When reporting how the areas appeared in the subject's mind, the recall of the visuals were similar to what was first reported, why no differences were seen in memory.

Feedback on the different light classes indicates that reactive light was fun and helped subjects get into the story [n = 5], and could possibly even motivate for more reading. Reactive light classes were reported to have little to no influence on the remaining half of the subjects. Three subjects reported that they felt frustrated when surrounded by a color contradicting the story text (Dynamic C light class). Two of these reports came from subjects reporting little influence of reactive light classes, which may indicate that "incorrect" light will potentially do more harm than "correct" light might enhance.

Six subjects reported that imagery was easiest in darkness, herein one mentioning to feel as if the story stopped when white light appeared. These reports support the claims of Sherwood & Pearson (2010), stating that complete darkness is best for imagery. Three subjects reported preferring white light over darkness, herein one mentioning that this was due association with sunlight. One subject felt the light classes to make no difference (despite feeling frustrated under "wrong" lighting).

4.3.7 Light Class Discussion (partial conclusion)

In this chapter, the findings of each light class are summed up, combined and discussed, resulting in an overall purpose of the light classes.

- Dynamic A. Based on both self-assessment and heart rate dispersions, this light class best enhances the effect of stories on emotional state. The change of light in itself didn't affect heart rate, which is considered good, since the transition doesn't attract attention. Qualitative findings indicate that it is not the best light type for imagery, but it increases motivation, potentially nudging people to start reading.
- Dynamic B. Heart rate dispersions for this light class came close to Dynamic A. The combination of these two light classes may indicate that "correct" motivated lighting does have a high influence. However, since self-assessment results show something different, people may not actively realize the subtle changes, due to the low brightness levels. This implies that the brightness changes are needed for a more significant effect.
- Dynamic C. Self-assessment results show that this light class generated the lowest pleasure levels. This is backed up by qualitative reports, wherein subjects mentioned a frustration and confusion of "incorrect" lighting. This could potentially be used purposely to generate unpleasant feelings, but comes with the risk of stealing attention from the story- which may be why heart-rate dispersions are lower for Dynamic C. Surprisingly, the arousal levels didn't increase, whereas a direct link to annoyance (based on Russel's Circumplex) can not be found.
- White Light. From the qualitative results, white light is not beneficial for imagery. However, it was prefered by a few subjects when choosing between No Light and White Light. Like Dynamic C, this light class achieved low heart rate dispersions, which again could be linked to low concentration.
- No Light. Supporting the literature, darkness was reported to increase imagery. However, the preference for darkness was low compared to having light (whether White or Dynamic).

4.3.8 Data & Experiment Evaluation

The evaluation of the stories confirms that they were useful for the experiment, as they were achieving the targeted emotional states. A few parts of the stories were reported to be thought of as unrealistic (e.g. being guided by a butterfly or finding a flashlight with a little knife attached) by two subjects, why a genre should have been mentioned, along with an introduction preparing the subjects for a storyworld that exceeded real-world expectations, yet still being based on real-world association. Additionally, one user reported feeling negative about a happening that was intended to be positive (picking up a gold coin), caused by personal associations. Due to differences in individual associations, it is unlikely to create stories that completely fulfill the purpose for every individual, but the degree of association diversion is important to consider in such experiments. In this experiment, based on feedback, these issues didn't appear to cause significant implications.

The script was written with the purpose of containing different light conditions, which aimed to emphasize the mood of the stories. Hence, the results of the experiment may be found only in ideal circumstances. This will require more investigation on existing stories that do not take lighting conditions into account.

One possible implication that is important to note is the validity of subject reports. Despite being informed that it was okay to answer "I don't remember", it appeared as it was difficult for a couple of subjects to concentrate, thus some qualitative answers seemed to be based on directly recalling what the text said instead of what was imagined. Additionally, some answers could be made up *after* hearing the story (and not while hearing it), and again not be based on imagined visuals (at least not in the intended way). However, these assumptions are subjectively based on the author of the paper, and eliminating such response bias could prove difficult, and is expected in experiments (Nederhof, 1985). Due to the little impact of these qualitative findings, along with the fact that these are subjective (hereby, possibly false) assumptions, the answers weren't excluded.

The questions concerning how story-spaces appeared in the mind of subjects could possibly have been based more directly on light, color and weather, instead of being rather open questions, since subjects didn't report such factors before getting additional direct questions. Furthermore, in future experiments, it is suggested to investigate more moods, while using more time in each mood, with more light colors used. This could deepen the experiment, yet it would require more time and participants.

As mentioned in the introduction, the experiment was designed to give an overall understanding of light's effect of emotional state and imagery when listening to stories. Due to the relatively low subject number [n = 10], all findings are only indicational. Naturally, more subjects could give data for more significant findings, while also more measuring tools should be used in future investigations to deepen the understanding of light effects. For the purpose of achieving an indicational understanding and providing data to generate more questions (see chapter 7), the experiment succeeded.

4.4 Conclusion

The experiment was aimed at generating data that help understand how light can enhance story experiences. Due to the circumstances, the subject sample was small and measuring tools were limited. However, the indicative results are useful.

The findings indicate that reactive motivated lighting, with no brightness limits, *does* enhance the story experiences according to emotional state, while light-setting transitions don't create implications. Reactive light isn't necessarily beneficial for imagery, where complete darkness was reported to be better, but it saw a better effect in emotional state, and was reported to be interesting and motivating- as long as the qualities of light were correct replications of the light settings in the stories. "Incorrect" colors resulted in lower pleasure levels and reports of annoyance, yet the self-assessed arousal levels didn't imply annoyance. Thus, "incorrect" light may be more harmful than "correct" light may enhance.

Hypotheses Evaluations

The hypotheses are accepted/rejected based on indicative findings, and should not necessarily be considered solid.

1. Light influences emotional state when listening to stories. ✓
2. Light influences visual imagery when listening to stories. ✓
3. Light influences short-term memory when listening to stories. ✗
4. People can visualize better in complete darkness when listening to stories. ✓
5. People prefer reactive light when listening to stories. ✓
6. Incorrect lighting creates annoyance and confusion. ✓

The findings of the experiment imply that light may not be the best tool for directly increasing levels of visual imagery, but reactive light may be better for motivation and affection of emotions, when used correctly. These findings are indicational, but will be taken into consideration in Part III of the report.

PART III

Chapter 5
Discussion

This chapter combines the literature, framework and experiment findings. The main points are discussed in order to develop partial conclusions, which are used in the problem statement solving.

5.1 Motivation, Emotions and Imagery

From the literature chapter, It was expected that light would, to some extent, alter the mental images of story receivers. However, the findings of Part II reject this theory, only indicating that darkness is best for increasing imagery levels, but not that light directly influences the visualization. Considering that much research likewise fails to achieve imagery-influenced results, while some also support the improvement of imagery in darkness, it is not recommended to focus on improved imagery by using light. Thus, enhanced imagery should not be the main driver that makes people spend more time reading/listening.

From Part II, it was found that reactive light feels more motivating and fun than static white light and no light. Additionally, it was implied that motivated reactive light enhances emotional response according to the story intent. Hence, motivation and emotional response may be the best focus points if light should be utilized. The benefits that potentially come from increased imagery, such as increased comprehension and memory, may not be as significant in reactive light, compared to no light, but if it can motivate readers/listeners who struggle to find time or motivation, the results are better than not reading at all. To set things in perspective: maybe cycling is not an as efficient type of exercise as running, but if a person struggles to put on their shoes and go out running, but finds motivation in cycling, it is better to get out and burn some calories by cycling, rather than staying home due to the lack of running motivation. Some of these aspects are further discussed to assess target groups in chapter 5.4.

5.2 Design

From Part II, it was found that incorrect colors of light caused lower pleasure levels, as well as reports of annoyance and confusion. Thus, it is highly important that correct light qualities are generated. In Part I, it was suggested to use NLP for text analysis, but due to the significant damage that incorrect lighting may cause, an automated analysis system is not proposed as of now. Text analysis software may still struggle to make sense of advanced sentences (e.g. understanding if a sentence is based on irony), creating a high risk for incorrect lighting. Therefore, it is currently proposed to manually analyze and select light qualities, based on the framework presented in chapter 3, which uses guidelines from stage lighting. It can be done either by the story author, a lighting designer, or a collaboration between the two, where the story may be inspired by light settings in order to create a specific story+light based experience. Manual designing will also ensure successful continuation, where specific areas within the storyworlds will keep the same light qualities, for readers/listeners to create associations (Block, 2007). Eventually, machine learning can be utilized, learning from the manual lighting designs, and an advanced AI or NLP analysis system, with low error-rate, may be realistic.

The presented framework takes base in stage lighting, but has more limitations than e.g. a theater lighting design. Elements such as light- positioning, shape, patterns, shadows, illumination and space can not be controlled if people are to use such a light system in their homes. Thus, experiences may vary depending on the room settings. A specific research has to be conducted on what is the best room settings, whereas guidelines can be given to users, and customization can be done as well (e.g. brightness limitations). Costumization is elaborated in chapter 5.3.

The stage lighting guidelines used, generate light qualities based on the light sources, weather conditions etc. The effect of emphasizing object colors instead of light conditions is unknown and should be investigated. If a blue chair is the main driver of a story, how will people react to the light becoming blue whenever the chair is present? Additionally, the presented framework is simplified to use only one light color at a given time. Moving away from monochromatic-perceived light, and having multiple light colors present at once, will allow for better emotional affect, if used correctly. Color theories by J. Goethe & J. Ittens are proposed to help create aesthetic color combinations or to achieve specific emotional responses. Using multiple colors of light does, however, require more data and analysis examples before an automated system learns enough to see a low risk of selecting incorrect colors. Additionally, the use of multiple colors requires more advanced experiments in order to elaborate on the understanding of how light and stories collaborate to create immersive or motivating experiences, since color combinations can be many.

Based on possible implications from the statements above, it is suggested to use only one color of light at a time, except if a specific experience is designed, where a story+light setup is designed and installed for viewers/listeners to enjoy, and where the light combinations are carefully selected.

5.3 Implications

In Part I, it was stated how light is subjectively understood. Thus, customization is ideal to allow for a more personalized experience that embraces the preferences of text-receivers. Initially, it could be simple alterations, like changing saturation based on age or selecting CCT based on location. Eventually, when an automated system is realistic, choices of light qualities could be based on personalities to allow more precise visual associations. This would, naturally, require a lot of research and experimentation to solve, but could be used in other fields.

In the design framework and experiment, after-images weren't taken into account when transitioning from one light quality to another. When a person is presented with a color, the color will be "imprinted" in the mind for a while, why the after-image will be affected by the complementary color (Goethe & Matthaei, 1997). This may give the viewer a slightly incorrect understanding of a new color, when a transition is completed, if the mind is influenced by such an after-image. Thus, it is proposed to further experiment on after-image suppression. The result may be a slow gradient post-transition, after the main transition is completed, meaning that the new color is first altered by the previous and then gradually corrects itself as the eye and mind adapts.

The experiment in Part ll was based on audio-stories, where a task light wasn't necessary. The effects of motivated lighting when *reading* books, and having a reading task light, are therefore still unknown. Potentially, reactive light may not have an effect when the eye is focused on the task light, with reactive light only perceived in the peripheral vision. It may be that only audio-stories benefit from reactive lighting. Additionally, colored smart-lamps may struggle to provide enough illumination if a bright reading light is used, depending on the room size and lamp-setup. Alternatively, the reading light should be part of the reactive system, yet it may cause eye strains if the task-light fails to be sufficient due to being dynamic.

5.4 Target groups

From Part l & ll, it was indicated that people with low imagery levels are less influenced by visual input, yet it was hoped that the added input would help create mental images. If such were the case, light for digital books could potentially help people who suffer from aphantasia - the complete lack of mental imagery. The effects of reactive lighting, however, would still be interesting to investigate on this group.

With the focus on motivation and emotional response, it is implied that the target group are people who struggle to find motivation in reading. The reactive lighting takes a step towards modern media such as TV, which many people find comfort in watching, and this group of people might find motivation in the added layer of visual input. Readers/listeners who already find motivation and comfort in word-based experiences may not benefit much from reactive lighting, since their motivation levels are already high. Only if they struggle to feel emotional affect from the stories, reactive lighting is suggested. If motivation and emotional affect are already high, darkness is suggested to allow for better imagery.

An important group to consider are children. It is essential that people learn to read, and comprehend text and stories, at a young age, as well as finding the joy in word-based experiences (Neuman, 2001; Wager, 2016). The effect of reactive lighting may be different due to the limited amount of visual associations that children have (depending on age and person), while it may even help develop new light associations. The question may arise if the added input layer risks that children find trouble reading without reactive light, if they learn reading with it. If the alternative consists of watching TV or playing video games, which sees negative effects (Takeuchi et al, 2015), reading with reactive lighting is preferred. The negative and positive effects of reactive light on children is suggested to be investigated and evaluated carefully, since this group could potentially benefit the most.

Chapter 6
Conclusion

The presented paper attempted to answer the problem statement by combining knowledge from literature and experiment findings. This chapter sums up the most important aspects, which collectively fulfill the aims of the project:

Problem Statement

"How can reactive lighting enhance book- reading & listening, and make people spend more time on text-based experiences?"

From the literature, it was found that visual perception and visual imagery take use of numerous mutual processes in the brain. However, reactive lighting is not suitable for improving imagery, where darkness is suggested instead. Motivation and emotional response are suggested to be the main focus points to make people read/listen, as these aspects saw influential results in the experiment. Hence, it is implied that reactive lighting should be aimed at people who struggle to find motivation, whereas trained readers may benefit more from darkness. Additionally, due to the high importance that early development of text-based experiences has, children are an important target group, who might benefit the most from reactive lighting.

A Design framework was developed, based on guidelines from stage lighting. It consists of a script/ book analysis, breaking down stories to extract direct and indirect visual information of light conditions. Light qualities, of motivated light, are generated based on visual associations or direct word cues- or if possible, of mood cues. The aim of the system is to be automated, but due to the critical implications caused by incorrect light settings, as well as limited NLP text comprehension, the entry-point is manual designing by either the author, a lighting designer- or a collaboration between the two. This makes for two types of designs:

- Home experience: a reading or audio setup, controlled by a smart-lighting system. This version has no control over light setup, besides providing guidelines for the user.
- Social experience: an audio-only setup, in which listeners gather to experience a custom made story+light experience. Everything can be controlled for optimal conditions.

The thesis provides information on the importance of reading, while opening up topics to get a brief understanding of the interconnections between visual perception and visual imagery. Evidence was presented, stating that motivated reactive lighting could potentially enhance motivation and emotional responses when listening to audio-books. Thus it is implied that reactive lighting could potentially make more people listen to audiobooks due to increased motivation, and make people listen for longer due to increased emotional connection. These findings may possibly transfer to reading experiences, but further testing is required.

Chapter 7
Future work

Naturally, the findings of this paper led to new questions. The question-topics consist of implication solving, as well as further investigation to ensure improvements. Below are briefly listed topics for further work, starting off with questions based on implications.

- Reading light. It is recommended to investigate how motivated reactive light will affect readers who have a task light aimed at their book while reading. Due to the light only being reactive in the peripheral vision, the results may be less significant, or different, compared to audiobook listening. This investigation is needed in order to conclude whether the presented framework will only apply for audiobooks.
- Automation. Manual lighting designs were proposed as being the entry solution. Eventually, as more designs are developed, it should be investigated how an artificial intelligence may learn and understand text better, and apply lighting according to framework guidelines. The end-goal of this should be full automation.
- Customization. Due to the fact that visual associations differ from different groups and personalities, it is suggested to investigate personalization of light settings. Assessing visual associations from many different groups (age, location, education etc.) could give an overall idea of differences between groups. Such an investigation is of course significant, but the results may see use in many areas of lighting design.
- Space, settings and stories. The findings of this paper are based on experiment outcomes, why it is unknown if similar results will be achieved when reactive light is utilized in the "real world". Furthermore, different room setups should be tested, providing more information on where and how to implement such a lighting system. Finally, the framework should be tested on existing books, in order to evaluate the likelihood of implementing reactive lighting for existing books, or if story and light should mainly be developed together.
- Colors. It was concluded that motivated light is suitable when providing light for digital books. The framework is based on replicating light and weather conditions- and only *one* color at any given time. It should be interesting to see the effect of embracing object colors, if e.g. the text has focus on a blue chair. More importantly, the use of multiple colors, or even projections (including shape, and possibly motion), should be tested to see if such could further enhance the experience.
- Children. The importance of developing early associations with story-based experiences was stated to be high. Hence, considering children as being an important target group, reactive lighting should be tested on this group in order to evaluate differences compared to adults. Added to this, for the children, is the possibility to develop new associations, whether such is negative or positive.

As implied by the amount of future work topics, the connection between light and stories is an advanced topic. This investigation opened up questions that require more research in order to improve a reactive light system. More importantly, the presented topics may help scientists and designers to get a deeper understanding of the relationship between light and the human mind.

Acknowledgement

An enormous thanks to Georgios Triantafyllidis for excellent supervision, and for the small discussions that were incredibly motivating. Thank you to my friends and family who supported me along the way, and to those who participated in the experiment. Finally, the remaining gratitude goes to my better half who kept me going through a lockdown, making the work feel incredible despite being 'locked up', working in the same room, most hours of the day. Thank you.

Chapter 8
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Chapter 9

Appendices

Links for downloads and results

Master Thesis Video
Watch Link

Master Thesis Poster
Watch Link

Story audio-files (Danish)
Download Link

Processing Script for Experiment Control (incl. audio-files)
Download Link

Questionnaire Results Sheet (Danish)
Download Link

Heart Rate Comparison Document
Download Link

Heart Rate Sheet
Download Link

Experiment questionnaire after stories

(In Danish - the experiment was in Danish)

Navn: Dato: Eksperimentets start tid:	VVIQ gennemsnit: Tildelt Gruppe:

Historie 1 (happy) Glæde: Energi: Tydelighed: Hvordan så skoven ud? Hvordan så marken ud? Hvordan så hytten ud?	Historie 2 (sleepy) Glæde: Energi: Tydelighed: Beskriv ilden i pejsen? Beskriv himlen i drømmen? Hvordan så nattehimlen ud efter drømmen?
Historie 3 (sad) Glæde: Energi: Tydelighed: Hvordan var stemningen i hytten? Beskriv tøjet som hang på knagen? Hvordan så græsmarken ud?	Historie 4 (scared) Glæde: Energi: Tydelighed: Hvordan så grotten ud? Hvilke farver lys var der i grotten? Hvad tror du levede i grotten?
Historie 5 (excited) Glæde: Energi: Tydelighed: Hvordan så skoven ud? Hvilke farve lys kom der fra de magiske lanterner? Hvordan så festpladsen ud?	Slut Spørgsmål Hvad husker du bedst fra historierne og hvordan så stederne ud? Hvilken historie kunne du bedst lide? Var det farvede lys en god eller dårlig ting?

Experiment Sequences

Sequence of light classes in each group.

One bad and one good imager in each group (or two intermediate).

	Group 1	Group 2	Group 3	Group 4	Group 5
1. Happy	noLight	DynB	DynA	whiteLight	dynC
2. Sleepy	dynC	noLight	DynB	DynA	whiteLight
3. Sad	whiteLight	dynC	noLight	DynB	DynA
4. Afraid	DynA	whiteLight	dynC	noLight	DynB
5. Excited	DynB	DynA	whiteLight	dynC	noLight

Light Setting Sheets

Philip Hue Settings for each part in each story.

Dynamic A

	Part 1	Part 2	Part 3
Story 1	Hue: 21460 Sat: 212 Bri: 124 Name: Nature Green	Hue: 5400 Sat: 161 Bri: 254 Name: Warm White	Hue: 57500 Sat: 238 Bri: 254 Name: Party Magenta
Story 2	Hue: 1800 Sat: 254 Bri: 107 Name: Fireplace	Hue: 47180 Sat: 254 Bri: 116 Name: Heaven blue	Hue: 47180 Sat: 158 Bri: 11 Name: Starlight
Story 3	Hue: 49310 Sat: 254 Bri: 80 Name: Sad Purple	Hue: 47180 Sat: 167 Bri: 43 Name: Sad White	Hue: 4910 Sat: 123 Bri: 39 Name: Sad Sunlight
Story 4	Hue: 3110 Sat: 176 Bri: 13 Name: Rock Brown	Hue: 0 Sat: 245 Bri: 80 Name: Arousal Red	Hue: 15070 Sat: 80 Bri: 38 Name: Sick Green
Story 5	Hue: 9330 Sat: 208 Bri: 254 Name: Yellow Sunlight	Hue: 39650 Sat: 65 Bri: 254 Name: Magical White	Hue: 63240 Sat: 186 Bri: 254 Name: Party Pink

Dynamic B

-Same hue and saturation as Dynamic A
-Minimum Brightness

Dynamic C

-Complimentary (opposite) Hue
-Minimum Saturation: 200
-Minimum Brightness: 100

Introduction script to experiment

(In Danish - the experiment was in Danish)

1. Først forklarer jeg hvad der kommer til at ske.
2. Du skal høre fem forskellige historier med fem forskellige typer lys.
3. Før hver historie får du en nedtællings-opgave, som vi lige prøver:
4. Tæl ned fra 30 med tre mellemrum. Så 30, 27, 24, 21 osv...
5. Efter hver historie bliver du stillet nogle spørgsmål, som jeg lige gennemgår.
6. Først bliver du spurgt, fra en skala fra 1-5, hvor glad du var da du hørte historien, hvor 1 er trist og 5 er meget glad.
7. Derefter bliver du spurgt hvor energisk du følte dig, da du hørte historien. 1 er sløv og 5 er meget frisk.
8. Spørgsmål 3, omhandler hvor tydeligt det var at forestille dig historien. 1 er ikke så tydeligt , 5 er meget tydeligt.
9. Til sidst får du lidt ekstra spørgsmål omkring historien.
10. Spørgsmål? Jeg stiller spørgsmålene efter hver historie.
11. Før vi går i gang, skal vi lige gennem en test.
12. Du skal egentlig bare gøre hvad jeg siger.
13. Først tæl ned fra 40 med 4 mellem mellem hvert tal.
14. Træk vejret ind i 4 sekunder. Hold vejret i 6 sekunder. Pust ud i 7 sekunder. Bliv ved indtil jeg siger stop.
15. Sidste opgave inden vi går i gang:
16. <VVIQ>

VVIQ Questions

(Original by David F. Marks. Translated from English to Danish - with customizations.)

Intro. Vi gennemgår 4 emner, hvor jeg beder dig om at forestille dig forskellige ting. I hvert emne er der 4 fokuspunkter, som jeg vil bede dig om at fokuserer på, når du forestiller dig hvordan tingene ser ud. Når du har forestillet dig hvordan tingene i hvert fokusområde ser ud, skal du, på en skala fra 1-5 sige hvor tydeligt billedet var i dit hoved. Så hvis billedet var meget tydeligt, siger du "en" og hvis billedet var meget tydeligt, siger du "fem" osv.

Emne 1. Tænk på et familiemedlem eller en ven, som du ser ofte, og læg mærke til det eller de billeder af hvordan personen ser ud, der opstår i dit hoved.

Forestil dig...

1. Det præcise form af hovedet, ansigtet, skuldrene og kroppen.	Klarhed:
2. Ansigtsmimikken, kropsbevægelser osv.	Klarhed:
3. Personens kropsholdning og skridtlængde når personen går.	Klarhed:
4. De forskellige farver tøj som personen har på.	Klarhed:

Emne 2. Forestil dig en solopgang. Læg mærke til det eller de billeder der opstår i dit hoved.

Forestil dig...

5. At solen stiger op over horisonten og ind i en tåget himmel.	Klarhed:
6. At himlen bliver klar og omringer solen med en blå farve.	Klarhed:
7. Skyer. En storm kommer, med blinkende lyn.	Klarhed:
8. At en regnbue frembringes.	Klarhed:

Emne 3. Tænk på en butiksfacade, på en butik du ofte handler i. Læg mærke til det billede der opstår i dit hoved.

Forestil dig...

9. Hvordan butikken ser ud fra den anden side af vejen eller gågaden.	Klarhed:
10. Vinduesudstillingen, inklusiv farver, former og detaljer fra de forskellige varer der er til salg.	Klarhed:
11. At du er tæt på indgangen. Tænk på farverne, formen og detaljerne på døren.	Klarhed:
12. At du går ind i butikken og op til disken. Butiksassistenten servicerer dig og I udveksler penge.	Klarhed:

Emne 4. Forestil dig et landskab som har træer, bjerge og en sø. Læg mærke til det billede der opstår i dit hoved.

Forestil dig...

13. Formerne i landskabet.	Klarhed:
14. Farver og formerne på træerne.	Klarhed:
15. Farven og formen på søen.	Klarhed:
16. At en stærk vind blæser i træerne og laver bølger på søen.	Klarhed:

Gennemsnit: __________