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Eyes in the Dark: Using Eye-Tracking Technology to Investigate the Effects of Darkness on Human Cognition and Implications for Cave Archaeology

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By

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Abstract

The ethnographic and archaeological evidence indicates a cross-cultural association of dark zones of caves with supernatural phenomena. In various geographic locations and time periods, human beings have frequented dark zones for ritual purposes. Regarding the unsuitable living conditions of dark zones, the following question arises: what drives humans to choose such places for practicing rituals? The answer to this question lies in the way human beings interact with dark cave environments. In this paper, I suggest that experiencing sensory deprivation, in particular lack of vision in dark zones, precipitates the enhancement of abstract and magical thinking. To verify this hypothesis, I employed the methods of cognitive sciences—namely, experimental research. I conducted an experiment using eye-tracking glasses to record participants' eye-movement trajectories in darkness. The results indicated that eye-movement patterns during darkness resemble those during activities involving abstract and divergent thinking. Consequently, darkness seems to provoke and facilitate creativity. I thus suggest that in addition to social and cultural incentives, darkness, as an environmental cue, sets the stage for human beings to associate dark zones of caves with supernatural powers and therefore choose to practice rituals in such locations.

Keywords: Embodied cognition, Cave archaeology, Effects of Darkness, Eye-tracking technology.

Introduction

The present paper employs an interdisciplinary approach to address a long-standing question encountered by cave archaeologists: what reasons underlie the universal association of dark zones of caves with supernatural phenomena? In order to answer this question, my paper is structured in six sections. I begin by describing cave morphologies and in particular specific features of dark zones of caves. I then proceed to provide archaeological and ethnographic evidence to show that supernatural and ritual use of dark zones is a universal and cross-cultural concept. In section two, I review the hypotheses suggested by scholars across disciplines to justify the use of dark zones. My main focus will be on the sensory deprivation hypothesis according to which the environment of dark zones hinders and/or heavily attenuates one's perception of the external stimuli and therefore gives rise to a unique experience which in turn leads to the association of dark zones with supernatural phenomena. Section two is also concerned with shortcomings of the above-mentioned hypothesis and the reasons for which the study of sensory deprivation ceased to be of interest for scholars. One of the major drawbacks is that sensory deprivation is too general a term it includes so many different variables that it is almost impossible for scholars to specify the effects of each variable. In section three, I propose a solution to this problem; instead of referring to sensory deprivation as a whole, I narrow down the scope of the study and attempt to isolate the effects caused by the lack of individual senses (primarily vision). Hence, to realize what attracts individuals to dark zones of caves despite the unsuitable living conditions, I concentrate on darkness and its physical and perceptual as well as psychological and cognitive effects on humans. In the same section, I argue that, among numerous effects of darkness, the enhancement of abstract and divergent thinking may play a key role in associating darkness with supernatural powers. This can be tested using replicable experimentation with human subjects by investigating eye-tracking in dark environments. Eye-tracking technology enables researchers to examine how environmental information is acquired and dynamically processed. In section four I describe the study that involves the use of eye-tracking glasses to record eye-movement trajectories in a dark environment. Section five presents results and discusses of the implications of the experiment. The results confirm that darkness may in fact enhance creativity. Finally, section six enumerates the broader impacts of the present paper as well as the significance and necessity of an interdisciplinary research approach.

1 Evidence of Practicing Rituals in Dark Zones of Caves.

What types of activities were (and in many places still are) performed in dark zones of caves and why do most scholars argue that these activities were ritual and associated with supernatural powers? The primary objective of the following section is to address these questions.

Caves have long been used by human beings for various purposes. There is evidence suggesting that human species such as *neanderthal* and even *Homo erectus* may have used caves for ritual purposes (e.g. see Beaumont, 2011 and Cueto et al., 2016). The ritual use of dark zones of caves, however, is more evident regarding the Upper Paleolithic and the species of *Homo sapiens*. Archaeological evidence indicates that our species has frequented dark zones of caves in order to connect with supernatural agents and practice rituals; a function that has been continued up to this date (Brady & Prufer, 2005; Clottes, 2012; Dowd & Robert, 2016; Moyes et al., in press).

Concepts such as ritual and supernatural do not easily lend themselves to definition; scholars have looked at these terms from different perspectives and have described them in various ways (see Durkheim, 1912; Evans-Pritchard, 1965; Geertz, 1973; Turner, 1969; Bell, 1997; Hodder, 1983). Nonetheless, in this paper, the term ritual will take a Durkheimian perspective

referring to the "sacred" as opposed to the "profane"—in other words, to activities that are different from domestic and everyday activities that do not involve supernatural agents or separate realities. By the term supernatural, I simply mean what is not explainable by science and what can be contrary to the rules of physics and the natural world, or what Moyes et al. 2017 refer to as "transcendental or imaginary" thinking.

To understand the supernatural associations of caves, it is important to distinguish between caves and rock shelters. Rock shelters have been mostly used for habitation; they are not deep and therefore are usually well-lit. Deep caves, on the other hand, can be extremely long, getting darker as one moves away from the entrance. The cave space is divided in three parts: the entrance which is light, the dark zone which is characterized by total darkness, and the twilight zone which is located in between the other two (Faulkner, 1988). Among these three locations, the dark zone is the least appropriate for habitation; it is cold, its dampness can cause rheumatism, and it is inhabited by bats and filled with insects that carry deadly diseases such as histoplasmosis, rabies, and chagas. Moreover, living in dark zone requires perpetual artificial light (Moyes, 2012; Moyes et al., in press; Tomkins, 2012). Consequently, these dark zones are not used for habitation except during extreme situations such as war or excessively cold climate. The undesirable conditions of the dark zone make it almost certain that humans have inhabited such locations only temporarily. Therefore, human presence in dark zones, attested by archaeological record, must be due to a reason other than habitation (Moyes, 2012).

Geographically and temporally disparate evidence suggest that dark zones have been frequenting by humans for ritual purposes, specifically for communicating with supernatural powers (Moyes et al., in press; Bednarik 2016; Brady & Prufer, 2005; Clottes & Lewis-Williams, 1998). Evidence of the association of dark zones with supernatural powers include ethnographic information gleaned from modern indigenous people as well as archaeological findings such as certain ritual potteries, hand-made structures, purposeful burials and most significantly cave paintings. As might be expected, the majority of English sources are dedicated to European, South and Central American caves and less work has been done on deep caves in other places (Bednarik, 2016). However, below I attempt to draw on concrete examples from various regions of the world to show that the supernatural function of dark zones exhibits some uniformities across human societies.

In Europe, cave art started at least around 40.000 years ago and continued throughout Upper Paleolithic. For example, in Chauvet Cave, Late Upper Paleolithic people produced elaborate cave art in the form of paintings and sculptures; many of which were performed on hard and inaccessible wall surfaces (Morales, 1997; Pettitt, 2016). According to Paul Bahn (1997), in Western Europe half of what is known to be Pleistocene cave art is performed in dark zones. Examples of caves that include either engravings or paintings in dark and inaccessible zones are: Chauvet, Lascaux, Le Cheval, Gabillou, Gargas, Niaux, Montespan, Rouffignace, Massat, Pergouest, Le Tuc-d'Audoubert, Combarelles, Les Trois-Frères in France; Altamira in Spain; Fontanet and Longu Fresu cave in Italy (Sieveking, 1997, p. 29; Clottes & Lewis-Williams, 1998, pp. 83-85; Skeates, 2012, p. 42). Moreover, Bahn mentions a cave in Australia where engravings have been found in total darkness and in a very narrow location where only one person can attend at a time. He suggests that this place must have been a sanctuary built at the back of the cave for ritual purposes (1997, p. 36). Another example is Kapova cave in Russia, featured by four galleries at the very back of the cave. Kapova galleries include paintings of herbivore animals as well as geometric shapes (Dolukhanov, 1997, p. 12).

The presence of cave art in the dark zone is of importance due to the fact that it is thought by many to signal ritual and supernatural function of these places. For instance, some suggest that they functioned as "hunting magic" and were supposed to help the painters and their tribe to hunt more animals. Some posit that paintings served as a type of "magic" that could eliminate harmful animals and increase useful ones (Clottes & Lewis-Williams, 1998, pp. 70-72; Blakeslee, 2012, p. 356). Others attribute dark zone paintings to shamanic vison quests and claim that they were created as a result of an altered state of consciousness and by shamans (Eliade, 1972; La Barre, 1972; Lewis-Williams & Dowson, 1993; Lewis-Williams, 2004). This point of view draws on various signs; one line of evidence is hand stencils with less than five fingers which are argued to be remnants of a shamanic ritual in which they amputated a finger to strengthen their relationship with the spirit world. This claim is based on the ethnographic works conducted in southern Africa among KhoeKhoe people (Clottes & Lewis-Williams, 1998, p. 96). This point of view also draws on painted geometric shapes –dots, zigzags, grids, sets of parallel lines, nested curves, and meandering lines—and states that these shapes are identical to the ones that individuals see during ASC. Since shamanism is characterized by the attempts of shamans to induce ASC and enter the state of trance, it is inferred that cave paintings are parts of a shamanic ritual (Clottes & Lewis-Williams, 1998; Lewis-Williams & Dowson, 1993; Whitley, 2008, p. 18).

In addition, some archaeologists argue that choosing hidden corners and hard to access walls to perform the paintings as well as paying specific attention to cave topography in relation to patterns of darkness and light are indicative of the ritual purpose of cave paintings (Pettitt, 2016, p. 13; Sieveking, 1997, p. 25; Bahn, 1997, p. 36).[1] According to them, painters could have easily chosen to perform their art in the entrance or at least on more accessible surfaces; the fact that they did not do so indicates that dark zone paintings are not just decorations. It seems that the painters were fully aware of the presence of darkness and took advantage of it; they turned darkness into an active element of their art, as the paintings either emerge from or turn towards darkness. This interactive use of darkness is particularly clear in Lascaux cave located in France (Pettitt, 2016, p. 18).

In addition to cave paintings, the discovery of intentional burials in dark zones is more evidence that supports the supernatural association of these locations. Such burials have been found in many different regions. A few examples are the Neolithic caves, Grotta di Porto Badisco and Longu Fresu in Italy (Whitehouse, 2016, p. 25; Skeates, 2012, p. 42); the Robber's Den cave in Ireland (Dowd, 2016, p. 64); the Chalcolithic cave, Nahal Qanah in Levant, which includes at least 22 burials (Gopher & Tsuk, 1997, pp. 172-174); and Actun Tunichil Muknal (ATM) cave located in Belize, Central America. Interestingly enough, in Fiji Islands after a chief died, at night his bones would be brought to and buried in an inaccessible cave in the mountains (Dowd, 2016, p. 68). Recent evidence suggests that cave burials may even date back to the Middle Paleolithic. According to Marcel Otte (1997), Spy cave in Belgium contains Neanderthal burials (see Rouzaud, Soulier, & Lignereux, 1995).

The material culture excavated from dark zones of caves is more proof indicating that such locations have always been associated with powers beyond everyday life. Objects made from various materials including bone, antler, shell, stone, pottery, ivory and animal teeth are prevalent

[1] Several point out a relation between acoustic features of caves and depicted animals. According to Waller, in Fonte-de-Gaume and Lascaux, bison, bulls, horses and deers are painted on areas with high sound reflections, while felines were depicted on areas with low sound reflection (see Waller, 1993, p. 501; Sieveking, 1997, p. 9; Bahn, 1997, p. 37).

in dark zones. These findings are piled in an organized way, signaling that they have been carried to the dark zone intentionally; therefore, many categorize them as votive and ritual offerings (Whitehouse, 2016; Tomkins, 2012, p. 140). Moreover, these findings are usually distinct from what is found near the entrance or in the twilight zone (Pettitt, 2016; Hensey, 2016; Sieveking, 1997). For example, the dark zone of Brother's cave in Ireland was filled with "disarticulated human bones (with a preference for clavicles); newborn calves, lambs and piglets; joints of meat; shreds of Late Bronze Age pottery; animal teeth, perforated shells and bone beads" (Dowd, 2016, p. 69). In France, bones have been found inside wall cracks of Les Trois-Frères and Enlene caves (Clottes & Lewis-Williams, 1998, pp. 83-85). In Latvia, symbols of Yumis, an ancient deity of fertility in the form of a twin ear of corn, have been discovered in dark zones (Urtäns, 1997, p. 97). That is why Urtäns argues that caves in Latvia were used for 'cult' purposes. He also mentions these caves are labeled with names that connote supernatural concepts such as devil, deity, offering, and the sacred (Urtäns, 1997, p. 93). In southern Aegean caves such as Ayio Gala and Tsoungiza, assemblages include human bones, metal objects and whole and fragmented ceramic vessels. Lambert suggested that ceramics were intentionally fragmented for the sake of a ritual. He inferred intentionality from the stone rings that elaborately encircled the ceramic fragments (Tomkins, 2012). The same story goes for dark zones in Italy; in addition to offerings and votive objects (Skeates, 2012, p. 42), these caves contain man-made water related structures in the form of water pools. To show that dark zones were used for rituals surrounding the importance of water, Whitehouse (2016) grounds her argument on the presence of artificial pools and ceramic vessels placed in the dark to collect drips of water. Grotta Scaloria, Grotta di Occhiopinto and Pozzi della Piana are examples of such caves in Italy which were mostly frequented during Neolithic (Whitehouse, 2016, pp. 25-31). This phenomenon is not restricted to Europe, in Caucus, a huge pile of animal skulls were discovered at the back of Digory-zed cave (Lubin, 1997, p. 147). Nahal Qanah cave in southern Levant contained potteries organized in a specific order and also burial offerings including gold rings (Gopher & Tsuk, 1997, pp. 172-174). Many Maya and Inka caves are also characterized by material culture found from their dark zones. Maya caves, such as Actun Tunichil Muknal, El Duende and Cueva de Sangre, are good examples of caves rife with remnants of ceramic vessels as well as human and animal bones (Stone, 2012, p. 202; Brady & Prufer, 2005; Moyes & Brady, 2012; Moyes & Gibbs, 2000; Moyes, 2005). Prufer (2005) reports the discovery of ritual assemblages in dark zones of Maya caves including Xmuqlebal Xheton. He attributes this material culture to shamanic activities (209-211).

Along with archaeological record, ethnography reveals the ritual importance of caves and particularly dark zones. Ethnographic analogies help archeologists to categorize and interpret the material culture excavated from caves and also open a window into what past people might have thought of caves and what they might have practiced in dark zones. More importantly, ethnographic works show that frequenting dark zones is not limited to the ancient world. Quite the contrary, up until this day, dark zones are being frequented for ritual purposes in various geographic locations. Certainly, there are places where dark zones are not frequented by people; however, it is worth mentioning that in many cases the reason behind avoiding dark zones is that people are terrified of these places due to the common belief that dark zones are inhabited with evil powers and demons and therefore not everyone is qualified to enter darkness (Bednarik, 2016).

Caves are a vital element of Mesoamerican cosmology; they are considered supernatural places connecting the human world to the 'underworld,' where all the deities, demons, spirits and ancestors live (Brady & Prufer, 2005; Stone, 2012; Moyes & Brady, 2012; Pettitt, 2016). Caves are often regarded as the origin of life, human races and gods (Heyden, 2005). The importance of

caves in Maya cosmology is evident from the massive sacred architecture built upon and around caves. Such architecture can be seen in Dos Pilas and Las Pacayas, both located in Guatemala, and at Las Cuevas in Belize (Moyes et al, 2015a). The Pyramid of the Sun at Teotihuacan, in central Mexico, is also founded on top of a cave (Brady, 1997; Brady & Prufer, 2005). Mayans believed that the more remote a place is, the closer it is to the supernatural beings and thus reserved for special purposes. According to post-contact sources, Maya cave rituals mostly regarded "rain and other agricultural interests, hunting, ancestor worship, renewal/ New Year rites and other calendrically timed ceremonies, and petitions for various personal needs (e.g. health problems)" (Stone, 2012, p. 203). Surprisingly enough, according to Stone (2012), smashing pottery after a ceremony was one of the rituals practiced by Maya people. This practice can explain the reason for which archaeologists find an abundance of fragmented ceramic vessels in dark zones and accordingly why they categorize them as ritual items (Stone, 2012), although Moyes has found evidence for massive sherd scatters that indicated that large numbers of single sherds were brought into the cave as ritual offerings in and off themselves (Moyes et al., 2015b).

Inkas had somewhat similar beliefs about caves, according to which the founders of their royal lineage came to this world through a cave called Pacariqtampu, or "house of origin" (Dransart, 1997, p. 207). Moreover, it is mentioned in Spanish sources that young Inka boys went through an initiation ceremony held in caves (Dransart, 1997). Even today, some Andeans use caves to perform initiation ceremonies for their herds (Dransart, 1997, p. 215).

It has been long argued that caves present individuals with perfect settings for rites of passage which are characterized with three stages: *segregation* (pre-liminal rites)*, margin* (liminal rites), and *aggregation* (post-liminal rites). During the first stage, participants symbolically lose the state or social role that they possessed; in the second stage, they struggle with ambiguity and invisibility; and finally during the third stage, participants are symbolically conferred with a new state or social role (Bell, 1997; Heyden 1975; Turner, 1969; Whitehouse, 2016). In other words, the ternary topography of deep caves could work as a metaphor for three stages of initiation ceremonies. A successful rite of passage would make participants truly feel transformed into a new person. Hence, such rites were designed to provide participants with an unusual and intense emotional experience. Nothing contributed to that goal more than the dark, disorienting and frightening environment of a deep cave (Whitehouse, 2016, p. 35). Lastly, as in regard with rites of passage and initiation ceremonies, it is relevant to note that in Mexico's Pre-Hispanic mythology, caves are compared to a womb— a dark place that can give rise to life (Heyden, 2005).

Ethnographic evidence also confirms the contemporary practice of shamanic rituals in caves. Clottes and Lewis-Williams (1998) mention shamanic traditions in both Chile and North America where shamans go to the darkness of caves in order to enter trance and connect with their spirit-helper. Every *curandero*[2] in Tzinacapan, Mexico, has their own cave where they contemplates problems of various sorts and tries to find remedies for mental and spiritual illnesses. A *curandero* gets notified about when to visit their cave through spiritual dreams (Dowd, 2016, p. 67; Heyden, 2005, pp. 26-27). Retreating in darkness is a practice common among different beliefs and religions. Dark zones of caves are of great importance in Buddhist traditions and have been used as meditation sites at least since 15th century (Aldenderfer, 2012; Dowd & Hensey, 2016, p. 5). In the Tibetan plateau, dark zones are regarded as places of origin and spiritual power (Aldenderfer, Caves as Sacred Spaces on the Tibetan Plateau, 2012). Mithraism, a religion that started from Persia and during first century found its way to the Roman Empire, designated caves

[2] Curandero refers to a native healer or shaman usually found in Latin American cultures.

for practicing rituals. Discovered sanctuaries and temples belonging to this religion are also featured with excessive darkness (Clauss, 2001, p. 74). Christianity[3] and Islam also include stories about saints and ascetics spending time in isolation and in dark caves in order to achieve certain spiritual goals (Dowd, 2016; Kazemi, Vahdat Ghasemi, & Alizadeh, 2012; Eliade & Trask, 1972; Bednarik, 2016).

All these examples indicate that regardless of time and geography, dark zones of caves cross-culturally, have been associated with counterintuitive beings and supernatural powers; therefore, in many cases, they have been used as sites for practicing rituals (Faulkner 1988; Arias, 2009; Moyes 2012). However, as mentioned before, dark zones are unpleasant locations that are hard to access and with poor air quality. It goes without saying that the deepest part of the cave is in total darkness and even when carrying a source of light, it is still so dark and dim that human eyes cannot see anything beyond their immediate surroundings. Studying the dark zone is not easy and poses complex problems. One problem is that scholars cannot be sure that all human beings experience dark zones the same way (see Tilley, 1994; Brück, 2005). Hence, we do not yet know how darkness affects cognition in the laboratory, much less across cultural groups. Nevertheless, one can postulate that since humans share basic perceptual and cognitive abilities (see Bloch, 2012), their interaction with a given environment must not be significantly different from one another. Another problem is that speaking of darkness can be confusing at times due to the fact that there is no exact scale to measure the degree of darkness. More importantly, archaeologists are not certain that past individuals experienced total darkness at the back of the caves. In fact, both logic and evidence suggest that they carried simple torches and lamps with them to the dark zone.[4] One might argue that if this is the case, it is futile to talk about dark zones of caves as places that feature a lack of light. However, the attempts of several experimental archaeologists to replicate light sources used in caves showed that such sources approximately emitted 10 watts of light which is equivalent to a small candle (Stone, 2012; de Beaune, 1987). Artificial light sources only result in a dim environment and do not illuminate the space well. On the other hand, studies of the human retina suggest that during both dark and dim conditions the same photoreceptors are activated which means that, with some degree of indulgence, dark and dim environments have similar effects on human perception and cognition (Steidle, Werth, & Hanke, 2011).

2 Underlying Reasons for Supernatural Associations of Dark Zones.

As argued above, copious evidence associates dark zones with supernatural powers and their use as ritual venues. This section reviews some of the hypotheses suggested in order to explain what motivates humans to choose dark zones for ritual performances.

As Aldenderfer (1993) has suggested, emerging leadership in simple societies may gain prestige and ultimately power by claiming to be closer to the deities and sacred powers. Lewis-Williams and Thomas Dowson (1993) propose that the ritual use of caves is implicated in socio-political circumstances. They maintain that leaders were chosen by the deities as medians who could communicate with supernatural powers in perilous locations such as the deepest and darkest

[3] Confession box in catholic churches is an example showing that darkness facilitates communication with supernatural powers (Dowd, 2016).

[4] In some caves, evidence of hearths is discovered; nevertheless, this immobile source of light has not been discovered in dark zones.

corners of a cave (places where normal individuals did not dare to frequent).[5] In fact, the topography of dark zones supports Lewis-Williams and Dowson's hypothesis: the difficult access, narrow paths and dangerous environment of dark zones suggests that only a few people could attend these locations at once (for detailed descriptions of dark zones by cavers see Dowd & Hensey, 2016; Montello and Moyes, 2012). Hence it is reasonable to assume that rock shelters and the entrance of caves were allocated to public rituals while dark zones were exclusive to the practitioners with the highest rank (Clottes & Lewis-Williams, 1998, p. 103). The content of this hypothesis is sensible, and the socio-political changes within certain societies may have motivated the shift from a public entrance to a more special and private place; nevertheless, this hypothesis does not directly address why among all alternatives, dark zones of caves were chosen for a more private practice of rituals.

Although one's culture, beliefs and preconceptions influence the way one experiences the cave, the very unique environment of deep caves seems to play a more significant role in shaping the interactions of visitors. Consequently, scholars such as Daniel Montello and Holley Moyes (2012), Jean Clottes and David Lewis-Williams (1998, p. 29) have hypothesized that the way human beings interact with the cave environment is the underlying reason for the ritual function of dark zones. Entering the dark zone impairs and may even deprive individuals of their senses, particularly vision, which affects their perception and cognition of the immediate environment (Steidle, Werth, & Hanke, 2011). The term 'sensory deprivation' usually refers to deliberate attempts to diminish the intensity, or meaningfulness of sensory stimuli that one can receive through senses (Rossi, Furhman, & Solomon, 1964, p. 447; Kubzansky, 1961).[6] The state of sensory deprivation is induced for various reasons and through different practices. Psychologists simulate sensory deprivation for experimental purposes using two primary methods. The first method consists of a chamber that provides subjects with an environment with the minimum amount of visual and acoustic stimuli. The second method consists of a flotation tank filled with water, which restricts tactile stimuli as well (Vaitl, et al., 2005, p. 105). In a number of experiments, subjects were even confined to a chair, on a bed, or in a tank-type respirator (Zuckerman & Cohen, 1964, p. 3). Such methods are also referred to as REST or Restricted Environmental Stimulation Techniques. Moreover, various practices such as shamanic drumming, trance and meditation simulate the state of sensory deprivation (see Castillo, 1990; Dietrich, 2003; Lutz, et al., 2008; Gingras, et al., 2014; Dahl, et al., 2015; and Hove, et al., 2016). Regardless of its induction method, sensory deprivation is known to have a number of physical as well as perceptual, psychological and cognitive effects on human subjects. However, it is worth mentioning that the intensity of these effects may vary according to both the induction method and the duration of the experience. In order to verify whether sensory deprivation is the reason behind supernatural associations of dark zones of caves, this section presents a through study of various effects of sensory deprivation on human perception, cognition and behavior.

[5] Whether this shift from the entrance to the dark zone was intentional or due to social and political situations of given societies is out of the scope of this research.

[6] In research, perceptual deprivation is methodologically differentiated from sensory deprivation. Sensory deprivation involves reduced sensory stimulation such as wearing masks to cover the eyes or ears, whereas perceptual deprivation involves an attempt to reduce the patterning and meaningful organization of sensory input such as placing ping pong balls over the eyes to admit diffused light that do not allow for clear imagery (Rossi 1969, 18-19; Schultz 1965,6-10).

The physical effects of sensory deprivation include reduced plasma levels of epinephrine, norepinephrine, and stress hormones (Vaitl, et al., 2005, p. 105) (see Hamad, Fine, & Turner, 1966; Lilly, 1956; Schulz & Kaspar, 1994; Turner & Fine, 1983). Studies also indicate that sensory deprivation results in enhanced creative thinking (Vaitl, et al., 2005, p. 105; Forgays & Forgays, 1992; Kjellgren & Eriksson, 2010, pp. 7-9; Takahashi, et al., 2005). Creativity itself is a complex concept and has so many aspects to it that makes it difficult to reach consensus on a single definition (Suler, 1980; Sessa, 2008; Balzac, 2006; Heilman, Nadeau, & Beversdorf, 2003).[7] The word creativity is derived from the Latin root *creates* which means 'to have have grown' and describes the mental ability to generate new ideas and associations out of what already exists (Sessa, 2008, p. 821). In fact, divergent thinking—the ability to produce distinctive ideas and to think of multiple solutions to a single problem—is thought to be one of the few characteristics of creative thinking that scholars agree on (Sessa, 2008; Balzac, 2006). Scholars have also tried to explain the neural mechanisms behind creative thinking. For instance, Heilman et al. (2003) suggest that the communication among brain regions that are not normally connected to one another gives rise to creativity.

In addition to creativity, sensory deprivation facilitates primary process thinking. This mode of thinking is metaphoric and has an associative nature; it tends to ignore the differences and emphasizes even the slightest similarities among various ideas and matters. Primary process thinking is egocentric and subjective, and may even stand in contrast to what is considered real or logical (Russ & Grossman-McKee, Affective expression in children's fantasy play, primary process thinking on the Rorschach, and divergent thinking, 1990; Suler, 1980, pp. 144-145).[8] Freud believed that primary process thinking was a primitive mode of thinking (see Freud, 1958). This tradition according to which primary process thinking was thought to be the sheer opposite of secondary process thinking—characterized as practical, realistic and logical rather than instinctive and impulsive— continued for some time (Suler, 1980; Russ & Grossman-McKee, Affective expression in children's fantasy play, primary process thinking on the Rorschach, and divergent thinking, 1990). However, today, it is agreed upon that in a normal situation they both are combined and interact with each other in order to maintain self-identity and its relations to the external world, although one mode of thinking focuses more on the external world. the other revolves primarily around the concept of self. As Suler suggests (1980), it is better to see these modes of thought as a continuum rather than two absolutely separate modes of thinking.

Primary process thinking and creativity are closely related to one another. Primary process thinking increases the scope of attention and therefore individuals find it easier to see connections between remote ideas and are more open to new, unusual and distinct views. That being said, studies indicate that merely having the ability to access primary process material does not lead to creativity; creative individuals are able to cognitively control and integrate such material into the more rational secondary process thinking (Russ, 2001, p. 28; Russ & Grossman-McKee, 1990, p.

[7] Holt devised a system to assess the extent to which primary process thinking is manifested and also the extent to which it is integrated into 'an adaptive and stable context' by secondary process thinking. (Holt, 1966). Most of the research investigating primary-process thinking and creativity has utilized Holt's Scoring System for Primary Process Responses on the Rorschach (Holt, 1956).

[8] In archaeological context, primary process thinking is referred to as supernatural or magical thinking and is defined as a type of thinking in which physical laws of nature are violated. For example, imagining that solid objects come into life and become animate, or imagining that magic and spells can transform objects in the real life (Subbotsky, 2004).

757; Suler, 1980, p. 154). The underlying neural and attentional mechanism of primary process thinking has been studied by scholars such as Martindale (1981) who suggests that primary process thinking is most likely to occur during the state of defocused attention throughout which many neurons are activated at the same time. He also claims that creative individuals become more engaged in a state of defocused attention[9] which is known to enhance primary process thinking (Russ, 2001, p. 32)(see Martindale, 1981).

Activities involving sensory deprivation can, to varying degrees, give rise to altered states of consciousness (ASC). ASC is defined as a short, dramatic, and temporary change in the way one thinks, feels and perceives the world (Krippner, Altered states of consciousness, 1972; Kjellgren, Lyden, & Norlander, 2008; Kjellgren A. , 2003). Experiencing ASC is often characterized by "perceptual changes, body image changes, disturbed time sense, alterations in cognitive functions, but also experiences best described as mystical or ineffable" (Kjellgren & Eriksson, 2010, p. 1). ASC can be induced by physiological methods such as long distance running and hyperventilation, or by consuming psychedelic drugs. In any case, all techniques involving ASC are heavily influenced by a person's sensitivity, set (expectancies) and the setting (environment and circumstances) in which the induction is being performed (Vaitl, et al., 2005, p. 107). To determine whether ASC is induced and to measure its intensity, psychologists employ EDN tests (Experienced Deviation from Normal state) (Kjellgren & Eriksson, 2010; Kjellgren A. , 2003).

More often than not, individuals experiencing sensory deprivation have reported having hallucinations. Hallucination can be defined as feeling, seeing, hearing or even smelling things that do not really exist in the immediate surrounding of an individual. Different theories have been suggested to explain the reason behind hallucinating caused by sensory deprivation, among which the faulty source monitoring hypothesis is the most supported (Mason & Brady, 2009, p. 783)(see Morrison & Haddock, 1997; Bentall, 1990). According to this hypothesis, hallucinations happen due to individuals' failure to distinguish between internal and external cues. When external sensory stimuli are absent or significantly attenuated, the brain attempts to classify random internal noise from the retina or inner ear into "previously acquired cognitive schemata" (Zuckerman & Cohen, 1964, p. 18). In other words, the brain tries to generate familiar patterns even when the pattern cannot be found in the external world. It goes without saying that the frequency and intensity of such hallucinations are influenced by various factors including the duration of the sensory deprivation and the extent to which individuals are prone to psychosis (Mason & Brady, 2009, p. 783; Fletcher & Frith, 2009).

Further effects of REST (sensory deprivation) include enhanced memory functions, social cognition and flexibility to change attitude and behavior. Vaitl et al. (2005, p.105) denote that sensory deprivation facilitates the retrieval of autobiographical memory (see Suedfeld & Eich, 1995; Suedfeld, 1980). Moreover, examining brain waves during sensory deprivation shows that in the majority of cases, theta and slow alpha band frequencies augment due to the attenuated external stimuli (Gendreau, Freedman, Wilde, & Scott, 1972, pp. 54-57; Hayashi, Morikawa, & Hori, 1992, p. 403; Kjellgren & Eriksson, 2010; Iwata, Nakao, Yamamoto, & Kimura, 2001). It was stated earlier that the above-mentioned effects are witnessed during various practices involving sensory deprivation. The remainder of this section attempts to specify some of these practices including floating, meditation, shamanic drumming and trance.

[9] By defocused, he means defocused from the external environment.

2.1 Flotation

Flotation is one of the methods employed for simulating sensory deprivation. In this method, participants enter a tank filled with a solution of water and Epsom salt which facilitates the flotation process. While in the tank, sensory experiences are at their lowest level especially if participants choose to turn off the light and keep the ear muffs on without listening to the music. In an experiment conducted by Forgays and Forgays (1992), half of the participants spent an hour in a flotation tank while the other half spent that time sitting in a dimly-lit room. Before and after the experiment, they took the Guilford creativity measure test. The results indicated while both conditions increased creativity levels, floating subjects scored higher on post-experiment creativity tests (Forgays & Forgays, 1992). The relation between floating and creative and primary process thinking is verified by other scholars as well (Kjellgren, Sundequist, Sundholm, Norlander, & Archer, 2004; Vaitl, et al., 2005). The transition of beta or alpha brainwaves to theta is thought to be one of the reasons for the augmentation of creativity and problem solving abilities during and after floating (Jonsson & Kjellgren, 2014).[10] Further studies show that floating subjects experience a decrease in their level of anxiety, depression, hostility, and fatigue, while their memory function and level of vigor increases and their level of curiosity remains the same (Forgays & Forgays, 1992; Kjellgren, Lyden, & Norlander, 2008; Vaitl, et al., 2005).

Floating can give rise to either moderate or strong ASC (measured through EDN test or Experienced Deviation from Normal test) . The former case resembles meditative daydreaming, while the latter involves more intense cognitive and perceptual experiences (Kjellgren, Lyden, & Norlander, Sensory isolation in flotation tanks: altered states of consciousness and effects on well-being, 2008). Due to an altered state of consciousness caused by flotation, individuals may lose their sense of time and space. Some experienced visual and acoustic changes such as hearing internal voices,[11] seeing light phenomena and different patterns of color. Some had out-of-body experiences; they could see themselves from above and felt like they were flying or soaring. Transpersonal and spiritual experiences, like feeling connected and unified with the universe, was another reported consequence of ASC during a floating session (Kjellgren, Lyden, & Norlander, Sensory isolation in flotation tanks: altered states of consciousness and effects on well-being, 2008). Finally, the floating experience made some participants feel uneasy, vulnerable and alone in the world—they had frightening thoughts associated with evil and adversity (Kjellgren, Lyden, & Norlander, Sensory isolation in flotation tanks: altered states of consciousness and effects on well-being, 2008, pp. 644,650). Most of the participants, however, felt calm and protected especially after their first experience in the flotation tank.

2.2 Meditation

Another activity involving sensory deprivation is meditation which may be defined as "a restful yet fully alert physical and mental state practiced by many as a self-regulatory approach to emotion management" (Takahashi, et al., 2005, p. 199). Meditation is practiced through various techniques; some require practitioners to move, walk, sing and dance, while others comprise of sitting immobile. These techniques also require varying degrees of concentration on either external objects or internal images. One of the best-known meditation methods is mantra recitation in which

[10] Brainwaves change according to one's activities, feelings and thoughts. Theta brainwave is usually indicative of a state of deep meditation and when the attention is internally focused.

[11] Participants claimed that it was the voice of their thoughts and not anything frightening.

practitioners repeat a given syllable in a passive and effortless manner (Vaitl, et al., 2005, p. 108). Meditation practices are often categorized in three families: attentional, deconstructive and constructive; all of which are characterized by highly increased internalized attention and mindfulness[12] (Takahashi, et al., 2005, p. 205). However, the first category is the most relevant to our argument about sensory deprivation. The attentional family enables practitioners to self-regulate attentional processes by disengaging from distractors and intentionally focusing on a certain target (Dahl, Lutz, & Davidson, 2015).[13] Monitored electroencephalogram (EEG) during meditation signifies an increase in fast theta and slow alpha power in frontal area. Increased slow alpha power points to enhanced internalized attention and correlates with enhanced creativity levels, while increased fast theta power points to enhanced mindfulness and correlates with the tendency to avoid harmful situations (Takahashi et al., 2005, p. 199). Moreover, meditation causes sympathetic[14] activities to decrease and parasympathetic[15] activities to augment. Finally, meditation is marked by a decoupling process during which the external stream of attention changes into an intensified internal stream of attention (Takahashi, et al., 2005, pp. 204-208).

2.3 Trance

Trance is another experience involving sensory deprivation (Gingras et al., 2014; Hove et al., 2016). It is usually defined as an absorptive state of consciousness that is featured by heightened internal focus and narrow awareness of the external surroundings (Hove, et al., 2016, p. 3116). Methods as various as hypnosis, chanting, dancing and taking psychedelic drugs are used by shamans to induce a trance; however, a very common method of entering trance is listening to repetitive drumming while lying down with the eyes closed. This method reduces the sensory input and limits it to predictable auditory stimuli which in turn make it easier for the individuals to disengage from the outside world. Consequently, shamans enter a world characterized by imagery, spirits and symbols (Hove, et al., 2016; Vaitl, et al., 2005; Kjellgren & Eriksson, 2010).

As it is indicated by Vaitl et al. (2005), trance gives rise to several effects in practitioners including deep immersion and loss of reflective thinking. Loss of sense of time, unusual bodily sensations (e.g. feeling light, warm, energized), vivid imagery, strong positive emotions (e.g. Joy, happiness, ecstasy), and feeling united with the rhythm are other effects cited for shamanic drumming (Vaitl, et al., 2005, p. 107). Moreover, examining the EEG during shamanic drumming

[12] Here, mindfulness refers to heightened awareness of the process of consciousness including thinking, feeling and perceiving (see Dahl, Lutz, & Davidson, 2015).

[13] The deconstructive family of meditation is featured by using self-inquiry to promote insight into the conscious experience of perception, emotion and cognition. This type of meditation is shown to enhance creativity and problem-solving skills. Constructive meditation intends to increase well-being by promoting healthy interpersonal dynamics, commitment to ethical values, and habits of perception (Dahl, Lutz, & Davidson, 2015).

[14] The sympathetic nervous system (SNS) is part of the autonomic nervous system (ANS) that activates what is often termed the fight or flight response.

[15] The parasympathetic nervous system (PNS) is part of the autonomic nervous system (ANS) and is sometimes called the rest and digest system. It conserves energy as it slows the heart rate, increases intestinal and gland activity, and relaxes sphincter muscles in the gastrointestinal tract.

indicated that listening to monotonous rhythmic sound results in increased theta activity (Vaitl, et al., 2005, p. 107)(see Neher, 1961 & 1962). Oohashi et al. (2002, p.435) employed a portable EEG suitable for vigorously moving subjects to measure the EEGs of Balinese subjects who claimed to have gotten possessed and entered trance during a ritual performance consisting of ritual drama and music playing. The results confirmed augmentation of theta band frequency while in the state of trance.

In another experiment conducted by Hove et al. (2016), the brain-network reconfiguration during trance (induced by shamanic drumming) was examined using fMRI. The results show that during trance, stronger hubs are formed in three regions of the brain: posterior cingulate cortex (PCC), dorsal anterior cingulate cortex (dACC), and left insula/operculum. PCC is related to internally oriented cognitive states; it is a default mode network (DNM) region where many interconnected subsystems converge. PCC is active when the subject is not engaged with the external environment. The other two (dACC and left insula/operculum) are control networks that identify both salient and relevant external and internal events maintaining those neural streams that are relevant to task goals (Hove, et al., 2016). When coupled together, DNM and control networks cause an internally-directed cognitive state to endure (Hove, et al., 2016). Sustaining an internal stream of thoughts requires a perceptual decoupling that disengages and suppresses irrelevant sensory streams. This perceptual decoupling during trance causes a decrease in auditory pathway connectivity which in turn suppresses the repetitive drumming sound and prevents it from reaching cortex as quickly as it normally would (Hove, et al., 2016).

These examples suggest that these activities involving what could be argued as sensory deprivation share common underlying neural mechanisms. For instance, flotation, meditation (particularly mantra-recitation) and trance (induced by different methods such as shamanic drumming) are all featured by highly focused attention that leads to a perceptual decoupling (Kjellgren & Eriksson, 2010; Dahl, Lutz, & Davidson, 2015). During these practices, the mind starts wandering and accordingly the external attention stream directed towards the physical environment turns into an internal stream of attention wherein the practitioners' engagement with sensory stimuli is highly attenuated (Schooler, Smallwood, Christoff, Handy, Reichle, & Sayette, 2011; Smallwood & Schooler, 2006; Smallwood, et al., 2011; Smallwood, McSpadden, & Schooler, 2007; Hasenkamp, Wilson-Mendenhall, Duncan, & Barsalou, 2012; Vaitl, et al., 2005). The same thing happens during relaxation and upon the consumption of given hallucinogens (Krippner, 1999, p. 67). Various techniques including EEG and fMRI of the brain during such practices reveal that internal attention is characterized by the activation of default mode network (DMN) (Takahashi, et al., 2005; Hove, et al., 2016; Oohashi, et al., 2002; Guldenmund, Vanhaudenhuyse, Boly, Laureys, & Soddu, 2012, p. 109). DMN is activated "when individuals are engaged in internally focused tasks including autobiographical memory retrieval, envisioning the future, and conceiving the perspectives of others" (Buckner, Andrews-Hanna, & Schacter, 2008, p. 1). Consequently, sensory deprivation results in perceptual decoupling which leads to somewhat similar psychological and cognitive effects including hallucinations, out of body experiences, enhanced divergent thinking, etc. (see Mason & Brady, 2009, p. 783; Suedfeld, 1980; Suedfeld & Eich, 1995; Forgays & Forgays, 1992; Zuckerman & Cohen, 1964; Hayashi, Morikawa, & Hori, 1992; Kjellgren, Sundequist, Sundholm, Norlander, & Archer, 2004).

The evidence discussed above suggest that sensory deprivation can indeed give rise and promote abstract and primary process thinking. Nevertheless, the study of sensory deprivation suffers from several caveats that reduce its utility in answering the central question of this paper. Thus, I end this section by examining some of the obstacles of studying sensory deprivation.

Sensory deprivation was of great interest during the 50s and 60s, however, as the time passed the topic lost its allure for scholars. The main reason for this lack of interest is that sensory deprivation involves numerous variables, making it very difficult to accurately attribute the results to any specific variable (Mason & Brady, 2009, p. 783). Additionally, conditions, subjects and procedures used by experimenters are so diverse that in many cases they cannot be replicated. Other elements influencing the process of sensory deprivation, such as differences in prior knowledge, expectations, and personality characteristics of participants, make it even harder to study this phenomenon. The intricacy of studying sensory deprivation and its controversial nature is evident from the fact that scholars working on this topic have used a variety of terms to address the same phenomenon. For example, decreased sensory variation, sensory isolation, sensory alteration, reduced sensory input, physical isolation, perceptual deprivation, and perceptual isolation are only a few terms used to describe the same incident (Zuckerman & Cohen, 1964, pp. 1-12). To find out why humans conceive dark zones of caves as places endowed with supernatural powers, it is imperative to employ more accurate approaches.

3 Effects of Darkness as a Subset of Sensory Deprivation.

One way to avoid controversies surrounding the topic of sensory deprivation is to narrow the topic of the study. Instead of discussing 'sensory deprivation' as a whole, it is more efficient to isolate the effects caused by the lack of individual senses; for instance, exclusively depriving vison, smell, or touch. Thus, this section focuses on ambient as well as primed darkness and seeks to reveal the physical, psychological and cognitive effects of this phenomenon.

3.1 Physical effects

Ambient darkness deprives individuals of their sense of vision. The human retina has two types of photoreceptors: cones and rods. During the day and in a lit environment, both rods and cones are activated. Cones are located in the center of fovea, enabling individuals to receive colors and details of a scene with high quality. In darkness or in a dimly lit environment, however, cones do not function; instead, rod photoreceptors are activated. Rods are situated in the outer edges of the retina and are more light sensitive than cones. Rods' inability to recognize colors and details thus provides viewers with a full but blurry vision of the dark environment. Subsequently, human vision in the dark is more holistic and allows the recognition of simple structures such as contours (Steidle, Werth, & Hanke, 2011). As a result, human perception of its surroundings in a light condition is different from a dark condition. This perceptual difference influences human cognition as well, and gives rise to a cross-cultural symbolic association between darkness and certain feelings and concepts (Schaller, Park, & Mueller, 2003).

3.2 Psychological effects

Psychological effects of darkness have been a topic of interest for scholars across disciplines. For instance, during her field work in southern Africa, anthropologist, Polly Wiessner (2014) observed that when gathering around the nightly campfire, Bushmen of Ju/'hoan (!kung) did not talk about daily subsistence related activities; rather they entered a mode in which they preferred to listen to stories and set their imagination free (Wiessner, 2014). During night time indigenous people were more inclined to think in supernatural terms. Additionally, they felt more vulnerable to spirits and predators, although this fearfulness and vulnerability was compensated for by a sense of security resulted from intergroup trust and cooperation. As Wiessner puts it:

> Night activities steer away from tensions of the day to singing, dancing, religious ceremonies, and enthralling stories, often about known people. . . night time plays an important role in evoking higher orders of theory of mind via the imagination, conveying attributes of people in broad networks, and transmitting the 'big picture' of cultural institutions that generate regularity of behavior, cooperation, and trust the regional level. Body language is dimmed by firelight and awareness of self and others is reduced. Facial expressions—flickering with the flames—are either softened, or in the case of fear or anguish, accentuated. (2014, p. 14027)

The mood changes described by Wiessner may have been caused by multiple factors, among which ambient darkness is of high explanatory value. In a well-lit environment, people directly experience the proximal space, time, and social entities; thus, they receive detailed information about here, now and the self. In a dark or dim environment, however, individuals' do not have access to such detailed information and their experience of people and objects is limited (Steidle, Werth, & Hanke, 2011). In other words, they experience their surroundings from a distance and have to mentally construe the space, time, self, other and hypothetical alternatives to the reality. This phenomenon is known as psychological distance (Steidle, Werth, & Hanke, 2011; Trope & Liberman, 2010). Psychological distance induced by darkness causes the emotional influence of stimuli to decrease, giving rise to negative and aggressive behaviors (Steidle, Werth, & Hanke, 2011; Schaller, Park, & Mueller, 2003). This hypothesis has been verified by different experiments, for instance, in one experiment, participants applied more intensified shocks to a victim while in a dimly lit environment, and also when the victim was in another room (Steidle, Werth, & Hanke, 2011). Increased isolation, anonymity and self-interested behavior also result from psychological distance (Werth, Steidle, & Hanke, 2012; Zhong, Bohns, & Gino, 2010). As Steidle et al. (2011) showed playing a dictator game in a dark room increases the rate of cheating and self-interested behavior among players.

Moreover, psychological distance induced by darkness gives rise to fear. Feeling fearful is an evolutionary mechanism that causes human beings to avoid situations that may threaten their survival. Darkness is an environmental cue for isolation and potential vulnerability to danger, therefore, it increases emotions associated with danger and fear (Wennekers, Holland, Wigboldus, & Van Knippenberg, 2012; De Gelder, Snyder, Greve, Gerard, & Hadjikhani, 2004; Schaller, Park, & Mueller, 2003). For instance, darkness facilitates negative associations with a feared out-group. In an experiment conducted by Wennekers et al. (2012), it was examined whether darkness would trigger and intensify negative feelings (fear for females and anger for males) towards Moroccan males considered to be a feared out-group. The results demonstrated that the participants in a dark condition felt more fearful and had more negative emotions regarding Moroccans (Wennekers, Holland, Wigboldus, & Van Knippenberg, 2012). A somewhat similar experiment run by Schaller et al. (2003) points to the joint effects of darkness and ethnic stereotypes. During this experiment, participants were presented with pictures of black males in a dimly lit or dark room. Subsequently, they rated to what extent specific traits were used stereotypically to describe black people. Participants then performed reaction-time tasks in either a well-lit or a dark room making associations between black people and evaluative attributes. The results attested that darkness facilitates the activation of ethnic stereotypes (Schaller, Park, & Mueller, 2003).

Aggression, negative behavior and fear, however, are not the only effects brought about by darkness. Contrary to expectations, under certain circumstances, increased cooperation and social

closeness can be triggered by darkness. It was mentioned before that darkness signals social isolation, which is threatening for human survival and security. In order to maximize their power against this threat, human beings tend to seek cooperation and closeness in the dark (Werth, Steidle, & Hanke, 2012; Steidle, Werth, & Hanke, 2011). The fact that darkness augments cooperation has been verified by various experiments. In one experiment, participants gave higher scores to a fictitious employee while in the dark. They also were more willing to donate while in a dimly light environment (Steidle, Werth, & Hanke, 2011). In another experiment, darkness was primed by asking participants to write about either a dark or a bright location. Later on, participants were asked to read a conflict scenario about a joint seminar and decide to what extent they were likely to cooperate with the seminar. As was expected, participants primed with darkness showed a higher tendency for cooperation (Werth, Steidle, & Hanke, 2012). The influence of darkness on collaboration was also examined in an experiment where illumination was physically manipulated. Participants took part in five trials of a computerized social dilemma task requiring them to sacrifice their own profit for a greater good. Again, the individuals who performed the tasks in a dim condition made more cooperative decisions (Werth, Steidle, & Hanke, 2012). To offer more support for the relation between darkness and an enhanced social inclination, Werth et al. (2012) designed an experiment during which participants played a computer version of the so-called "prisoner's dilemma" in either a dim or a lit room. All participants had a fictive fellow player that always cooperated. The results demonstrated that individuals in the dim room more often chose a win-win cooperative strategy and also felt closer to their fictive partner.

One shortcoming of the above experiments is that all of them present participants with either no partner, or an always cooperative one; none of them examine a condition wherein the partner is not willing to cooperate. To compensate for this shortcoming, Werth et al. (2012) conducted an experiment in which the interaction partner was either cooperative or uncooperative. Contrary to their expectations, the results showed that even though the environment was dimly lit, cooperation and the feeling of social closeness did not increase when the partner was reluctant to collaborate. In other words, darkness leads to higher cooperation rate only if other parties involved are willing to cooperate. Furthermore, other elements such as personality traits play a part in the degree of cooperation induced by darkness (Werth, Steidle, & Hanke, 2012).[16]

3.3 Perceptual and Cognitive effects

Both dark and dimly lit conditions cause visual perception to be based on less concrete, less focused and less detailed information which leads to global processing or the act of processing visual stimuli holistically. As stated by Steidle et al. (2011): "Global perception broadens the conceptual scope of attention and facilitates the activation of distant associates or atypical representations" (2011, 175). Global perception is followed by high-level construal or abstract thinking (Steidle, Werth, & Hanke, 2011).

Four experiments conducted by Steidle et al. support the effects of darkness discussed above. One of the experiments examines the relation between ambient darkness and processing style. During this experiment, participants performed a verbal analogy problem-solving task while sitting in either a well-lit or a dark room. The results demonstrated that participants in the dark room solved more analogies which supports the idea that darkness triggers a global processing style (Steidle, Werth, & Hanke, 2011). In another experiment, participants recalled a situation in

[16] According to Werth, et al. (2012), egoistic individuals are more sensitive to situational variable of darkness, meaning that darkness has more influence on egoistic individuals than it does on people who are naturally willing to cooperate and make social bonds (Werth, Steidle, & Hanke, 2012).

either a dark or a light environment; they were asked to rate the similarity between one target figure and two other figures. The results indicated that individuals primed with darkness were more likely to match the figures based on the overall shape of the target. According to the results, even primed darkness affects perception by evoking global processing (Steidle, Werth, & Hanke, 2011).

Conceptual processing style is also influenced by primed darkness. In a third experiment, participants were presented with 16 five-word sentences, eight of which were either about darkness or brightness. Participants were instructed to unscramble the sentences by removing one extraneous word from each. Afterwards, they completed a categorization task in which they had to rate words on a 10-point scale. The results demonstrated that individuals primed with darkness had more inclusive categorizations of atypical exemplars (Steidle, Werth, & Hanke, 2011). A fourth experiment, designed by Steidle et al. (2011), sought to illustrate the implicit association between darkness and construal level[17] which is directly linked to lack of concrete information in situations such as darkness and hypotheticality (Steidle, Werth, & Hanke, 2011). This complex experiment involved 4 categories: darkness, brightness, high-level and low-level construals. Participants were instructed to do a congruent pairing (darkness + high-level construal) and an incongruent one (darkness + low-level construal). The reaction time to associate categories to each other then was measured and the result demonstrated that participants performed faster when associating darkness with high-level construal (abstract categories) (Steidle, Werth, & Hanke, 2011). The fact that darkness triggers global thinking and increases the construal level extrapolates the direct relation between darkness and both abstract and divergent mode of thinking.

In line with experiments proposing that darkness causes a more inclusive categorization of stimuli, Moyes et al. (in press) hypothesized that spending time in a dark environment specifically enhances one's ability to think about supernatural concepts. To support this hypothesis, Moyes et al. (2012) conducted an experiment during which participants filled out a questionnaire in either a well-lit or an almost totally dark room. The questionnaire consisted of two parts; the first part required participants to rank a statement about supernatural phenomena on a scale of one (strongly disagree) to ten (strongly agree). The second part presented the participants with various scenarios of counter intuitive events and asked them to choose one of the four possible explanation for each event. Two of the explanations included supernatural causes (divinity, ghosts, etc.), and two of them included scientific statements. The results show that participants who filled out the questionnaire in darkness were more inclined to relate counter intuitive events of everyday life to supernatural causes.

Studies also indicate that darkness as a subset of sensory deprivation can give rise to various types of hallucinations. In an experiment conducted by Mason and Brady (2009), participants were instructed to spend 15 minutes in total darkness in an anechoic chamber.[18] The results demonstrated that the majority of participants had hallucinations in different forms. For example, some saw shapes and faces that did not exist, some felt that their sense of smell had become strangely strong, and some felt an evil presence even though they could not see it. This experiment consisted of two groups of participants; one group involved individuals that were more

[17] Construal level theory (CLT) is a theory in social psychology that describes the relation between psychological distance and the extent to which people's thinking (e.g., about objects and events) is abstract or concrete.

[18] Anechoic chamber is a room designed to completely absorb reflections of either sound or electromagnetic waves.

prone to psychosis, while the control group included individuals less prone to the condition.[19] It is significant to mention that both groups experienced hallucinations during the experiment; however, participants prone to psychosis experienced more intense hallucinations. Mason and Brady suggest that this phenomenon happens due to participants' failure in attributing the internal stimuli to an internal source and instead substituting an external but imaginary source (a phenomenon known as faulty source monitoring hypothesis).

The above-mentioned experiments propose that visual isolation promotes abstract and divergent thinking—concepts that with some degree of indulgence are equal or closely related to such terms as creativity, primary process thinking, and magical or supernatural mode of thought (see a more detailed discussion on section two). Looking back at the central question of this paper, proving the correlation between darkness and abstract thinking helps us understand why choosing dark zones of caves for ritual purposes is a universal phenomenon. Nevertheless, it can still be argued that the results of these experiments may have been affected by participants' prior knowledge and cultural assumptions about darkness. Thus, I designed a replicable experiment that provides the experimenter with a set of data that is indicative of participants' pure physical reaction to darkness.

4 Experiment[20]

Today, it is a well known fact that eye movement patterns offer a window into human cognitive processes (Thomas & Lleras, 2007; Hayhoe & Ballard, 2005; Oh, Chun, Lee, & Kim, 2014). For instance, specific patterns of eye movements can be revealing of one's engagement with creative and abstract thinking (Knoblich, Ohlsson, & Raney, 2001; Muldner & Burleson, 2015). Although there are not many experiments focusing on eye movements in a dark environment, various experiments have been designed to observe eye movements during activities that involve abstract thinking. As was mentioned earlier in this paper, abstract and divergent thinking are of various types and categories; experiencing altered states of consciousness, creating a work of art, and trying to come up with a solution to a math problem all to varying degrees involve abstract thinking (Russ, 2001; Knoblich, Ohlsson, & Raney, 2001; Muldner & Burleson, 2015). Here, I discuss a number of experiments that have examined eye movements during such occasions as intoxication and solving a geometry question. Subsequently, in section 4.2, I will propose my own experiment which is designed to record eye movements in a dark environment and will discuss whether the results of my experiment are comparable to other studies measuring the effects of abstract thinking on eye movements.

4.1 Background

In an experiment, Griffiths et al. (1984) examined the effects of certain drugs on eye movements. The participants were injected with given drugs and then were instructed to sit in front of a 26" TV screen and follow a target with their eye. The experimenters employed the Cardiff Saccade Generation and Analysis System (CSGAAS) and monitored the eye movements using an electro-oculogram with electrodes placed on the outer canthi of each eye (Griffiths et al., 1984, p.

[19] Proneness to hallucinations was measured based on The Revised Hallucination Scale (RHS).

[20] The experiment that is included in my thesis is a pilot version. However, I have started collecting data for an actual experiment. The actual experiment is slightly different from the pilot version since it includes more participants. Moreover, during the actual experiment, dark and light conditions were randomly assigned to participants in order to keep the results reliable.

75). Each session took 1 minute and 55 seconds during which the following variables were measured: saccade velocity, saccade acceleration, saccade amplitude, peak velocity, peak deceleration, peak acceleration, saccade duration, the delay between target movement and the start of the eye movement, the accuracy (under or overshooting the target). Results revealed that the injection of drugs such as diazepam, ethanol, opium and its compounds causes decreased peak saccade velocity, increased saccade duration, and also decreased accuracy (Griffiths et al., 1984).

In another experiment, Muldner and Burleson (2015) first measured the creativity level of students based on *Gough Personality Scale* self-assessment creativity instrument. Subsequently, they chose two groups of participants; one consisted of individuals with lower creativity levels and the other consisted of individuals with higher creativity levels. The experimenters then employed various sensory devices including eye trackers, EEG, and a skin conductance bracelet to model students' creativity during a geometry proof generation activity (Muldner and Burleson, 2015). For the sake of this paper, I will only explain the results that they gathered from their eye tracking device. Participants had up to 75 minutes to solve the geometry problem. During this time span, their eye movements were being recorded via a free standing Tobii eye tracker that could record 16 samples per millisecond. The features that they chose to perform the analysis on included: total number of fixations, mean fixation duration, total saccade distance, mean saccade length, average saccade speed, number of sit forward events (times that students leaned towards the monitor), mean pupil size and total number of pupil peaks. The results indicated that the group with lower creativity levels had marginally fewer total fixations, significantly shorter total saccade path length and lower average saccade speed. The low creativity group were less focused which could have affected their potential creativity. Moreover, they had shorter saccade length compared to the other group, this indicates that the low creativity group were more locally focused and failed to form a holistic picture and exhaust all the opportunities to solve the problem. In contrast, the high creativity group had longer saccade length and therefore had a more global view of the problem (Muldner and Burleson, 2015, p. 135).

These experiments suggest that there is a direct correlation between creativity and the mean saccade duration (see Hebbard & Fischer, 1966; Holdstock & Wit, 1999). Hence, if we realize that the same eye-movement pattern happens in a dark environment, then we can use that as a new piece of evidence supporting the idea that darkness enhances abstract and divergent thinking. Having this hypothesis in mind, I designed and conducted a pilot experiment in an attempt to examine physical as well as cognitive effects of darkness on eye movement trajectories. The experiment involves the use of a pair of eye-tracking glasses and attempts to examine physical as well as cognitive effects of darkness. The proposed experiment seeks to address three main questions:

1- Does an individual's eye movement trajectory change in a light environment versus in a dark environment?

2- If the answer to the former question is yes, in what ways do eye movement trajectories differ from one another in either of those conditions?

3- Finally, regarding eye movement trajectories in darkness, can we claim that ambient darkness enhances abstract and divergent thinking?

4.2 Methods

Participants: Four individuals (3 males and one female) volunteered to participate in this pilot experiment. Three of the individuals were students of the University of California, Merced (two graduate and one undergraduate student), respectively they were 26, 29 and 57 years old. The forth participant was an attorney of the age 31. None of the participants wore glasses nor any of them claimed suffering from visual deficiencies such as glaucoma or cataract.

Apparatus: To record participants' eye movements, a pair of SMI Eye Tracking Glasses (version iViewETG 2.0) was employed. The eye tracker is video-based; it employs dark pupil technique and is designed to track eye movements with the same quality in both light and dark conditions. The device is binocular and has a temporal resolution of 60Hz. Three major events were recorded for the sake of this experiment, including saccades (total number, duration, amplitude, peak speed and average speed), fixations (total number and duration) and blinks (total number). The collected data was analyzed using SMI BeGaze software version 3.1.

Procedure: The experiment consisted of two conditions. All sessions were conducted individually and took approximately 15 minutes. During the first condition, each participant in his/ her turn was guided to a small room (270cmx350cm) and was asked to sit on a chair that was fixed on the floor. Participants were not informed about the actual purpose of the experiment; they were told that professor Rick Dale had bought a new high-tech eye tracker for his lab and that he wanted to examine whether the device had the same rate of accuracy in both dark and light environments. Prior to the start of the experiment, participants were asked not to carry their cellphones or any other distractive device with them during the experiment. Then they were guided to the experiment room and were instructed how to wear the eye-tracking glasses. Participants were afterwards informed about the procedure which consisted of a free viewing session during which they were required to look at a completely white wall in a distance of 150 cm. Participants were also instructed to remain still and not to turn their head. Subsequently, the experimenter calibrated the device, turned the lights off and left the room. Participants stayed in darkness alone for five minutes while their eye movements were being recorded. When five minutes passed, the experimenter entered the room and stopped the recording process. The participants were asked to leave the room for a couple of minutes so that they could refresh their mind set. Upon their return, the second condition started. This condition was different from the first one only in that during this second free viewing session, the room was well-lit.

When the second condition was done and the recording stopped, the experimenter asked participants to write down whether they noticed any difference between their eye movements in each condition, and whether the content of their thought was different in the two conditions. There was a consensus among participants that while in darkness, their eyes were constantly searching for light and form. However, they could not focus on one area and therefore they felt that their eyes were "drifting." On the other hand, in the light condition, they had spatial awareness and their eyes could find focus. Consequently, their eyes did not have to search and move as much or as fast as it did in darkness. Two of the participants further explained their feelings during each condition and stated that during the darkness session they experienced an "increased mind wandering," they were "encouraged to meditate" and felt a higher level of "self-awareness." One participant reported that he felt very sleepy in the dark room and had a struggle not to close his eyes; he also reported that he got very bored in the light room and started to keep track of time. These comments are of significance for the experimenter on the ground that they are considered potential supportive evidence for the final results.

4.3 Results

In this pilot experiment, specific features of human eye movements were measured in both light and dark environments with the aim of specifying different patterns of eye movements in each condition. The following features were measured for each condition: total number of fixations, saccades and blinks; the duration of fixations and saccades (microseconds); saccade amplitude (degrees); saccade peak speed (degrees per second); and finally saccade average speed (degrees per second).

Total numbers: the number of fixations, saccades and blinks increased during the dark condition. Total numbers of fixations, saccades and blinks in light condition were respectively: 1785, 1490, 286. Total numbers of the same variables in dark condition were 2414, 1897, 388. Based on t-test results, however, none of the variables showed a significant increase (total number of fixations: $t(4.85) = -1.41$, p= 0.21; total number of saccades: $t(5.35) = -1.43$, $p= 0.20$; total number of blinks: $t(5.94) = 0.55$, $p= 0.59$) (see Figures 1-3).

Fixation duration: the fixation duration was measured based on microseconds and increased statistically significant in the light condition compared to the dark. The p-value showed a number as small as <2.2e-16 ($t(2340.7) = 10.15$, $p < 2.2e-16$) (see Figure 4 and Table 1).

Saccade duration: the saccade duration was measured based on microseconds. The duration of saccades was significantly different between the two conditions. In fact, the duration increased noticeably in the dark. Here again, the p-value was as small as <2.2e-16 ($t(2966.9) = -9.25$, $p <$ 2.2e-16) (see Figure 5 and Table 1)

Saccade amplitude: saccade amplitude was measured based on degrees. The value of the amplitude did not differ significantly in either of the light or dark conditions ($t(3383.9) = -0.70$, $p = 0.47$) (see Figure 6 and Table 1).

Peak saccade: peak saccade speed was measured by degree per seconds and no significant difference was observed in peak saccade between the two conditions ($t(2130.5) = -0.34$, $p = 0.72$) (see Figure 7 and Table 1).

Average saccade speed: the average speed of saccades was also measured by degree per second and was not significantly different between the light and dark condition ($t(2120.3) = -0.16$, $p = 0.87$) (see Figure 8 and Table 1).

4.4 Discussion

The results of this pilot study suggest that human eyes behave differently in light and dark environments. The most significant difference is witnessed in the duration of fixations and saccades. In the light condition, the duration of fixations augmented while the saccade duration decreased. However, the opposite happened during the dark condition; the saccade duration increased and the fixation duration decreased considerably. It is worth mentioning that conducting mean comparisons using the t-test for a sample size as small as five may not render a general conclusion. Nevertheless, the tests do give an initial statistical exploration of the obtained measures. In fact, even with this small sample size, there may be substantial differences along some of these measures under dark vs. light conditions. [21]

[21] One caveat of this pilot experiment is the small number of participants which may have affected the results. To compensate for this caveat, I have been conducting an actual version of this experiment with IRB approval and enough number of participants.

5 General Discussion

In consistence with my original hypothesis, the eye-movement patterns in darkness are similar and comparable to those of activities involving creative thinking. Both in darkness and during a creativity involved activity, the mean saccade durations augment significantly. Therefore, it can be extrapolated that darkness itself can increase individuals' creativity and abstract thinking. The significance of the proposed experiment and its merit over the sensory deprivation experiments lies in its simplicity and in that it tries to just measure the effects of light and dark on eye-movement trajectories. In other words, it does not include too many variables for which it cannot offer accurate explanations. moreover, this experiment is highly replicable and its results can be easily attributed to a single independent variable which is darkness.

As demonstrated throughout this paper, various types of evidence, from archaeology and ethnography to psychological and cognitive experiments, indicate that people in many different geographic localities tend to associate darkness with supernatural powers. This association is at least to some extent due to the perceptual and cognitive changes caused by deprived or impaired sense of vision. Darkness is an environmental cue that can to varying degrees trigger meta-awareness, hallucinations, altered states of consciousness, increased creativity and primary process or magical thinking. Above all, both conditions of darkness and dimness provoke global processing, abstract thinking and other effects such as increased psychological distance, fear, isolation, anonymity, vulnerability, negative interpersonal behaviors, aggression and—under certain conditions—cooperation and social bonding. In dark environments, individuals are more prone to imaginative thinking, at the same time they feel threatened and vulnerable which leads to seeking protection not only from other humans but also from whatever supernatural agents and deities that they believe in. Hence, it is possible that a combination of these features (imaginative thinking, vulnerability and looking for protection) give rise to the universal association between darkness and supernatural powers. Looking back at the central question of this paper, conceptualizing dark zones as the entrance of a magical underworld and choosing them as places to connect to supernatural agents by practicing rituals can be understood in the light of darkness itself and the way in which it influences human perception, cognition and behavior.

6 Conclusion

Tracking human eye movements in the dark is a new and unexplored area. Thus far, I have not come across any experiments on this subject within the eye tracking literature. Nonetheless, using eye tracking glasses can aid in investigating the effects of darkness on human perception and cognition. The result of this research, however, is in line with previous work done by scholars such as Moyes et al. (in press) reinforcing the idea that darkness can provoke creative thought. This can be vital when thinking about archaeological interpretations of cave data. The present paper is just a small piece of a bigger picture, supporting the idea that various disciplines can collaborate with one another in order to find answers to long-lasting questions; questions that single disciplines have failed to address. Here, I drew on different approaches used by the disciplines of archaeology, anthropology and cognitive science to answer an enduring archaeological question: why human beings have continued to choose dark zones of caves for ritual practices and supernatural purposes. While the nature of this question is multifaceted and demands a thorough investigation from different angles, this paper's focus is on the framework of embodied cognition according to which humans are not agents totally independent from their environment. Quite the contrary, human perception, cognition and even behavior is shaped through their interactions with the physical world. If scholars aspire to know more about underlying mechanisms of humans' decision-making processes, it is imperative to investigate environmental cues and how they may affect humans in

various different levels (i.e. perception, cognition, emotion, and behavior).

7 Figures

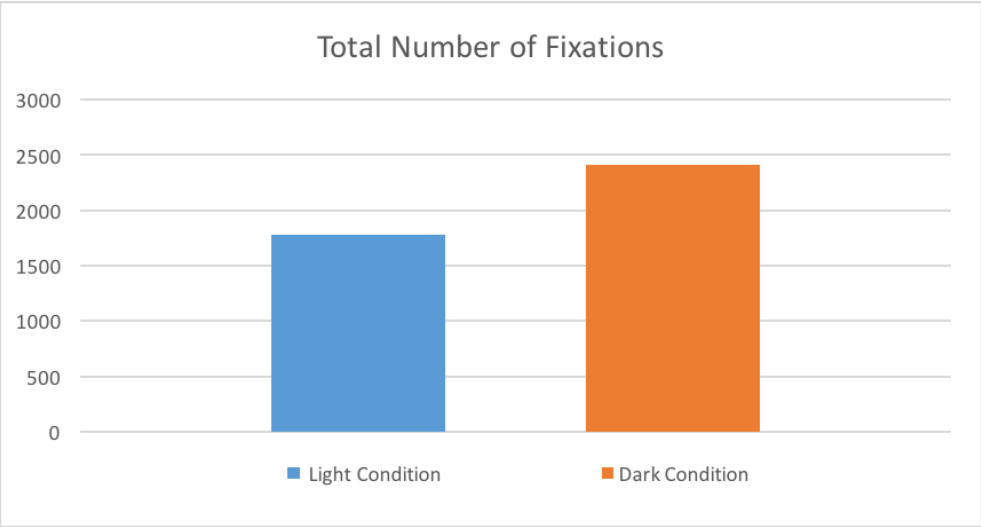

Figure 1. Total Number of Fixations. This bar graph indicates that total number of fixations increased during dark condition. However, this increase was not statistically significant.

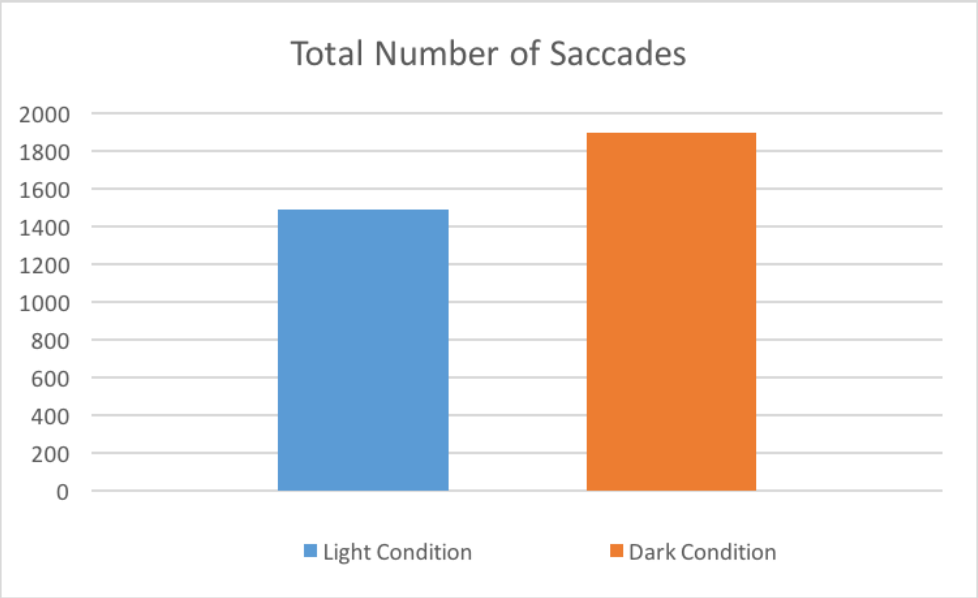

Figure 2. Total Number of Saccades. This bar graph indicates that total number of saccades increased during dark condition. However, this increase was not statistically significant.

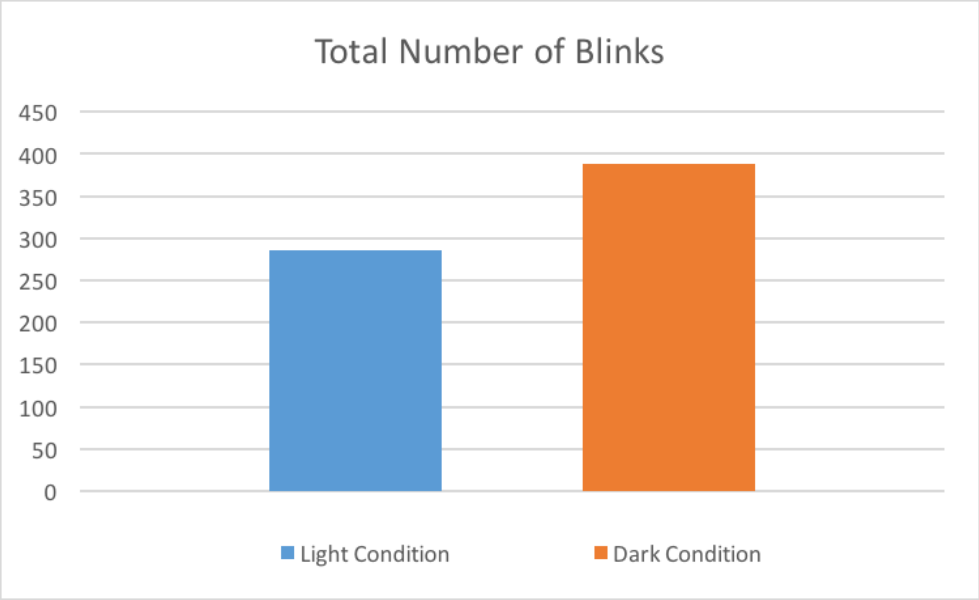

Figure 4. Total Number of Blinks. This bar graph indicates that total number of blinks increased during dark condition. However, this increase was not statistically significant.

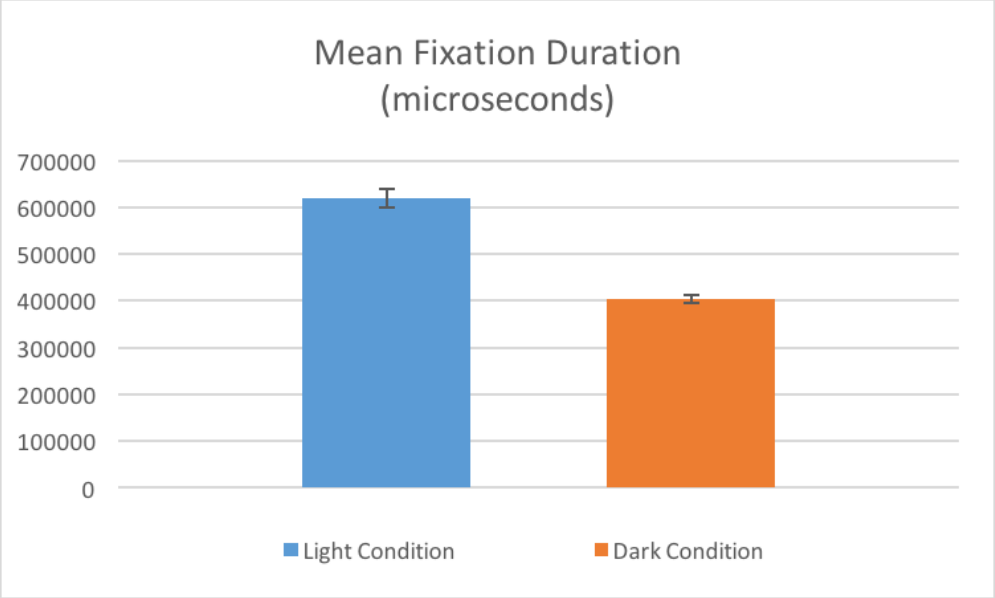

Figure 4. Mean Fixation Duration (microseconds). The mean fixation duration decreased significantly during dark condition. The unit of measurement for fixation duration was microseconds. Error bars represent 95% confidence intervals.

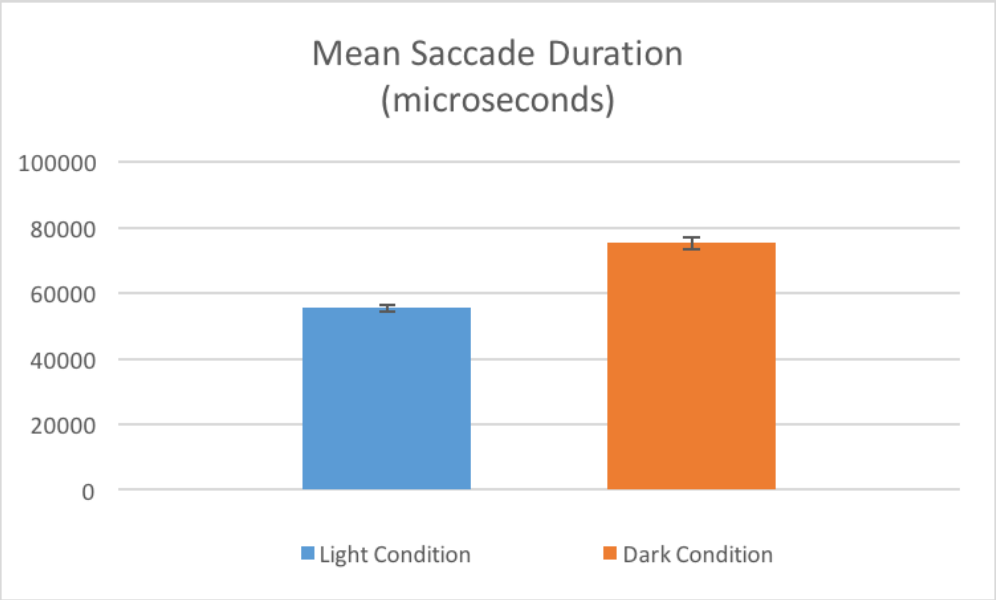

Figure 6. Mean Saccade Duration (microseconds). This bar graph indicates that the mean duration of saccades increased during dark condition, this increase was statistically significant. The unit of measurement for saccade duration was microseconds. Error bars represent 95% confidence intervals.

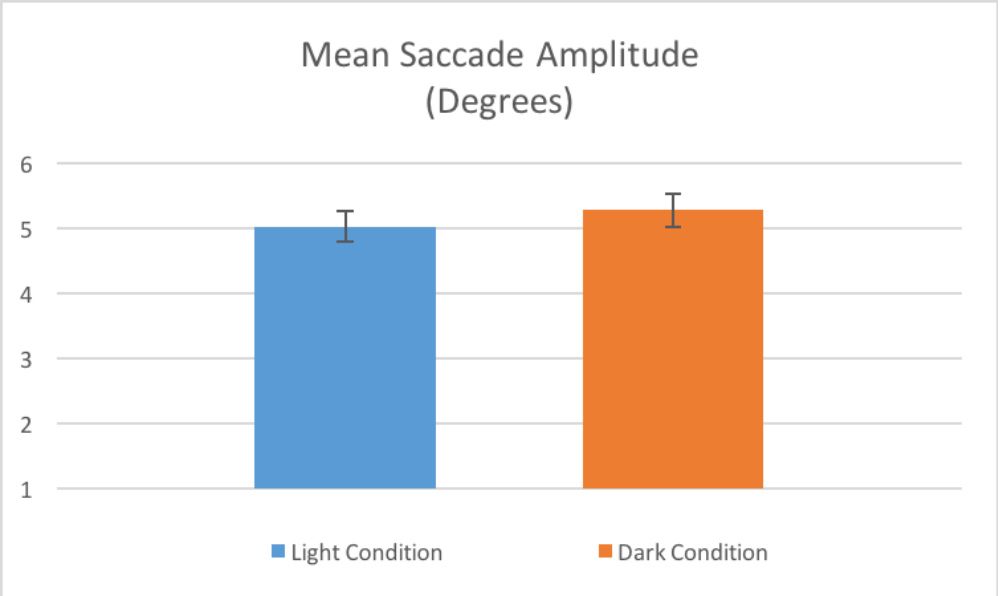

Figure 6. Mean Saccade Amplitude (Degrees). This bar graph shows that the mean saccade amplitude increased during dark condition. The increase, however, was not significant. The unit of measurement for saccade amplitude was degree. Error bars represent 95% confidence intervals.

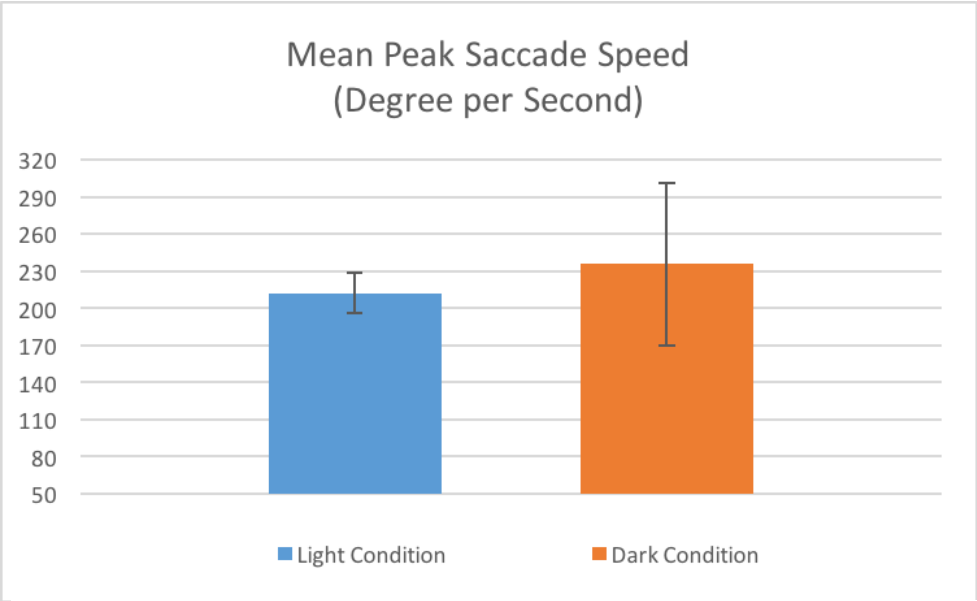

Figure 8. Mean Peak Saccade Speed (Degree per Seconds). This bar graph shows that the mean for peak saccade speed has increased during dark condition. However, this increase was not significant. The unit of measurement for peak saccade speed was degree per second. Error bars represent 95% confidence intervals.

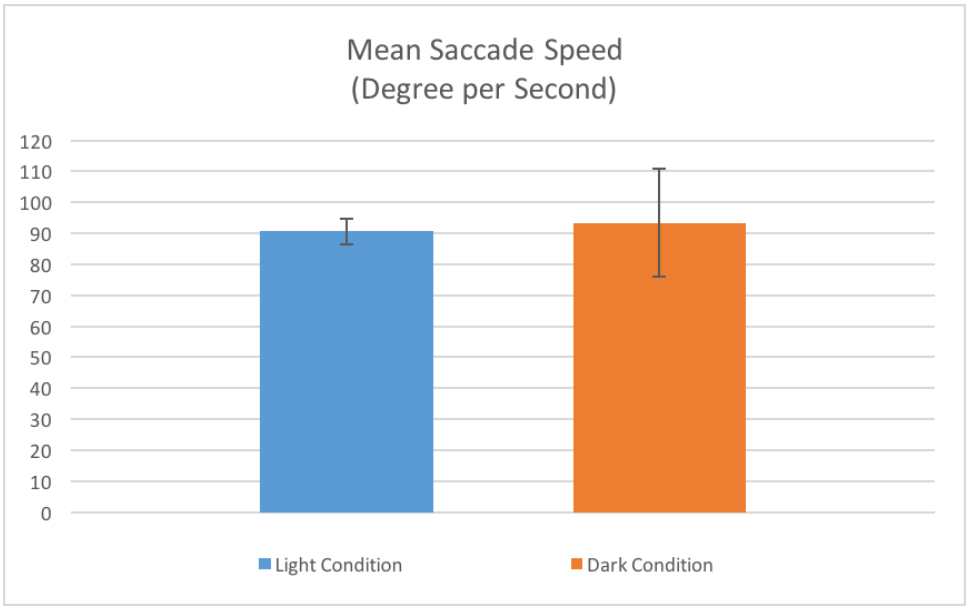

Figure 8. Mean Saccade Speed (Degree per Second). This bar graph indicates that the average saccade speed increased during dark condition. However, this increase was not significant. The unit of measurement for average saccade speed was degree per second. Error bars represent 95% confidence intervals.

8 Tables

Table 1. Table of means including means, standard deviations (SD) and p-values of variables in both dark and light conditions. Note that the values are rounded.

	Light Condition		**Dark Condition**		**P-Value**
	Mean	**SD**	**Mean**	**SD**	
Fixation Duration (microseconds)	618441	829306	404167	380620	< 2.2e-16
Saccade Duration (microseconds)	55411	41668	75268	80677	< 2.2e-16
Saccade Amplitude (degree per second)	5	9	5	11	0.47
Peak Saccade Speed (degree per second)	212	633	235	2855	0.72
Mean Saccade Speed (degree per second)	90	163	93	753	0.87

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