Differences in Object Perception: A comparison of Indian and British participants on Scene and Silhouetted Object Perception Tasks.

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Abstract

Background: The impact of contrasting societal structures on various neuropsychological test performances is well recognized within the clinical community. Much of the research to date has focused on showing that a difference in performance exists, and less so on understanding specifically which aspects of the societies' structure or "culture" are driving these differences. Many studies have explored conscious behavioral responses between individuals that are deemed "Western" and "Eastern-mainly Americans and Chinese-on visual perceptual tasks. Authors of these studies extrapolated their results to a theory suggesting that individuals who originated from Western/individualistic societies tend to implement an analytical cognitive style, attending to more focal/local information; and those who originate from Eastern/collectivist societies implement a holistic cognitive style, attending to the background/global information. With the rapid rise in technology starting from the turn of the century, one's ability to understand various physiological mechanisms related to visual perception increased, and with it came a rise in studies investigating the translation of the aforementioned theory as a kinetic behavioral response-eye movements and neural activity specifically. The results of the studies investigating this theory within object/scene perception have been mixed, some confirming this theory while others showing little to no evidence of it. However, it is also important to note that this theory is limited to mainly Americans and Chinese individuals, and is unclear as to whether it can be confidently expanded to other cultures that are historically considered as part of the "West" and "East", e.g. British and Indians, two cultural groups that have not been used in comparison with each other in cultural visual perceptual studies. This theory, along with the advances in technological techniques, has also not been explored as an explanation for performance differences seen in various neuropsychological visual perceptual tests. One example of observed performance differences in neuropsychological tests of perception is in the Visual Object Space Perception (VOSP) Battery. More specifically, on the Silhouettes subtest, a subtest that requires participants to identify objects from silhouettes of animals and man-made objects. Indians performed significantly worse than their Spanish, Greek, and

American counterparts; however the driving forces behind this difference remain unknown.

Given this information, the purpose of this thesis is to use eye tracking, the most commonly used technology in cultural object/scene perception studies, to see if differences in eye movement pattern exist between British and Indian individuals, whether these differences emulate the West/East theory in perceptual processing, and finally, whether these patterns of eye movements can help explain the performance differences seen between Indians and the British on the Silhouettes subtest.

Method: I first conducted a systematic review to establish in what way eye tracking, fMRI, and EEG are able to detect differences in perception between distinct cultural groups during scene or object perception. In addition to this, the systematic review also investigated how cultural concepts, e.g. East vs West, Individualism vs Collectivism, etc., are used to explain any differences seen, and the specific cultural groups used as exemplars of the cultural concepts, e.g. Chinese vs. American, Japanese vs. American, etc. to represent East vs West, Individualism vs Collectivism, etc.

My first experimental study utilized a scene perception recognition task, the most commonly used visual perceptual paradigm, to establish whether differences in eye movement are seen between Indians and the British, and whether these differences followed the West/East theory. In addition, participants were also given the Singelis Self-Construal Scale, a scaled used to measure degree of collectivist or individualist values an individual holds. I incorporated this scale in order to see if the conceptual link made between West/East and individualism/collectivism in previous studies could be demonstrated.

In the second experimental study, the findings of the first experimental study were used as a base to investigate whether comparable differences in eye movement patterns were also present when viewing the shadowed single objects from the Silhouettes subtest.

The question of familiarity to the objects depicted in the Silhouettes subtest as a driving cultural factor either oppose to or in addition to the West/East theory of perception held strong relevance. Thus, my third experimental study investigated whether the self-reported degree of familiarity with the objects represented in the Silhouettes subtest influenced their ability to accurately identify them. Participants were also asked to physically indicate which parts of the image they felt caught their attention when looking at the picture. This was to see if the features that Indians and British participants felt they were attending to differed from each other, and whether this explained their chances of accurately identifying the objects.

Findings: My systematic review suggested that the cultural concepts most commonly used to explain perceptual differences were East Asians vs. Westerners, and Object/Context Independent vs Context/Context Dependent. The most common participant groups compared were Chinese/Chinese Singaporeans/Han Chinese and Americans. In terms of differences in perception, all but two studies found a cultural difference in at least one measurement. EEG and eye-tracking studies showed conflicting results among studies, but fMRI studies consistently showed differences between groups in neural activation for the processing of objects in scenes.

British participants significantly out-performed the Indian participants in the memory recall portion of the first experimental study. A difference in eye movement was also present between Indians and the British only within the focal object; eye movement patterns in the background was not significantly different between the Indians and the British. When looking at the focal object, the British and Indians made a comparable number of shorter fixations and saccades, but made significantly fewer longer fixations and saccades than the Indians. The Singelis self-construal scale showed that Indians were slight more collectivist than the British but not significantly so. Singelis, regardless of which country participants were from, did not influence any of the eye movement patterns.

My second experimental study showed that no significant difference in performance alone existed between Indians and the British; however a significant difference in performance was seen when analyzed across difficulty levels. Performance/accuracy was negatively correlated to the difficulty level of the object, and the British showed a greater declined in performance than the Indians. This is expected since the difficulty level of the objects was determined by the accuracy rates of each objects from the original UK normative data that the Silhouettes subtest was based on. In terms of eye movement data, the British showed a significantly greater saccade amplitude and saccade velocity than the Indians. No differences were seen in any other eye movement data. Singelis was not an influential variable in predicting accuracy or in any of the eye movement data.

In third experimental study, I combined the performance data of the current study with the previous study and the integrated result re-enforced the findings of the second study. The British, overall, performed better than the Indians, but the difference did not reach significance. Performance/accuracy was, again, negatively correlated to the difficulty level of the object, for which, the British showed a greater declined in performance than the Indians. When examining the influence of familiarity on accuracy, results showed that the performance of the British were significantly influenced by how familiar they were with the object, however the performance of Indians remained unaffected. Furthermore, of all the incorrect answers given, participants claimed the correct answer to be a part of their thought process for only a small percentage (13% for the Indians and 3% for the British) of them. When asked about features that participants felt their attention was drawn towards, features indicated by Indians and the British largely overlapped.

Conclusions: Though there is a difference in perceptual strategy between Indians and the British when viewing scenes, as evidenced by their eye movements, the strategies don't follow the expected cognitive styles—analytic vs. holistic— of the West/East theory described in previous studies. This may be because the previously described cognitive styles have been examined mainly through studies of individuals who are American and Chinese, and thus the explanations developed may not fully encompass other types of cognitive styles that could possibly exist, or any variations of the analytical/holistic styles. None-the-less, the differences in eye movements seen between Indians and the British during scene perception were not evident during the viewing of the single, shadowed objects of the Silhouettes subtest suggesting that eye movement patterns used during scene perception and single object perception may not be directly interchangeable-how individuals go about looking at a scene may not be indicative of how individuals go about looking at a single object. Furthermore, though the overall difference in performance was not significant, a difference in performance was still seen between the Indians and the British on the Silhouettes Subtest which was driven by notable differences certain items. Self construal and familiarity were also not influential factors on overall performance which suggests that any performance difference may not be a result of any one factor but maybe be more specific to each item. Overall, I recommend that future research investigate the factors influencing the major performance differences seen on specific items of the Silhouettes subtest and to be cautious that factors may be unique to each case-what may be influential for one item may not be the same for a different item. This will allow for a clearer understanding of how to move forward in the test development of a Silhouettes subtest in the Indian context.

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Abbreviations

AIC = Akaike information criterion

ANOVA = Analysis of variance

av_fix_dur = Average fixation duration

av_sacc_dur = Average saccade duration

back_av_fix_dur = Average fixation duration of fixations made in the background

back_fix_count = Total number of fixations made in the background

back_sacc_count =Total number of saccades made in the background

country = Country of origin of participant

fix_loc = Fixation location

focal_av_fix_dur = Average fixation duration of fixations made in the focal object

focal_fix_count = Total fixation number of fixations made in the focal object

focal_sacc_count = Total number of saccades made in the focal

GLMs = General linear models

GLMMs = Generalized linear mixed models

MMSE = Mini-Mental State Examination

NIMHANS = National Institute of Mental Health and Neurosciences

sacc_locc = Saccade location: focal or background

sqrt = Square root

tot_fix_count = total fixation count

tot_sacc_count = total saccade count

VOSP = Visual object space perception battery

yoe = years of education

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Author's Declaration

I, Sumita Chatterjee, declare that, except where explicit reference is made to the contribution of others, this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

1. General Introduction

Perception can be understood to be the organization, interpretation, and conscious experience of sensory information (Schacter, Gilbert, & Wegner, 2011). It is what informs us about our surroundings, and our personal relationship with those surroundings which, in turn, allows us to make judgements on how we maneuver ourselves and interact with our environment. This creates a continuous relational cycle between ourselves and our surroundings; in other words, perception is an essential part of human ecology. In particular, our visual input accounts for a large portion of what informs our conscious and unconscious experience (Van Essen, 2003; Jerath, Crawford, & Barnes, 2015), and is what directs our attention towards information deemed relevant to the task, goals, or desires at hand. When our faculties of visual perception are impaired, so is our ability to understand and experience our environment. The degree and type of impairment can be evaluated in a clinical setting using a range of neuropsychological assessments which compare conscious behavioral responses on the individual in question with those of a representative normative sample of a population to determine whether the individual's performance is within normal range or substantially below (i.e. is impaired). Though these tests are designed to target the different facets of perception, they have typically been made to mimic stimuli from a specific environment, and therefore the "expected" normative performance against which individuals' responses are compared is based on the responses from people who are from that specific environment. For example, if an individual was shown a picture of a blueberry and asked to name it in order to test for their object identification and verbal recall abilities, this question would have been based on the presumption that the individual is familiar with such an object. This presumption is particularly unfair if the individual being tested spent a life time in a place where this fruit would not typically exist. If we are to then extend this example to the whole assessment, where the individual is asked to identify many objects that are unfamiliar, the ultimate performance of the individual on the test will suffer and not be representative of the individual's true abilities. To the clinician, if the performance on the test below the "normal range", the individual would appear to have cognitive impairments, but the clinician may not know how much to attribute this apparent impairment to the individual or to the inherent bias of the test. Many of the commonly used neuropsychological assessment have been developed in the United States or the United Kingdom and are, therefore, designed for English speaking populations. Therefore, when presenting these assessments to individuals who belong to societal structures that are less similar to that of the assessments' point of origin, responses to them begin to vary, from the normative expectations rendering these tests less effectual in detecting cognitive impairment (e.g., Bonello, Rapport, & Millis, 1997; Agranovich & Puente, 2007; Salinas, Salinas, & Arango-Lasprilla, 2018).

In response to this, many countries have started to adapt these assessments to better suit their populations (Albonico, Malaspina, Daini, 2017; Fernández & Fulbright, 2015). This movement in increasing awareness towards creating more culturally compatible tests came with greater vigor starting from the end of the 20th century (Puente & Agranovich, 2003) and with it came the necessity to take a broader look at what factors are influencing performance on cognitive tests. In doing so, it increases the possibility of appropriately developing/adapting tests to be used in a new context.

India, starting from around the mid 1970's, has taken an active stride in adapting many neuropsychological assessments that were developed in the USA and Europe for the Indian population, one example being the creation of the National Institute of Mental Health and Neurosciences (NIMHANS) Neuropsychological Battery (Kumar & Sadasivan, 2016). Though this battery steps towards the improvement of neuropsychological testing in India, it still does not cover all aspects of cognition and as a result, unadapted assessments are still being used to fill in the gaps. One such example is the Visual Object Space Perception Battery (VOSP), a visual perceptual battery developed in the UK (Warrington & James, 1991) that has been shown to have varying results across cultures (Bonello et al., 1997; Herrera-Guzmán et al. 2004) including India (Dutt et al., 2016). However, in order to understand how to best proceed in adapting the VOSP, it is important to begin isolating the factor(s) responsible for this difference in performance.

This thesis will mainly focus on visual perception, examining evidence for the impact of culture on visual perception as a potential impetus for the discrepancy described above. I will first examine whether the object perceptual differences observed between two cultural groups—principally Chinese and American—in previous studies involving object perception tasks are also present between Indian and British people, two cultures that are thought to have considerably different societal structures. I will then examine whether any differences in the perceptual processing involved in eye movement seen in the first study can be used to explain any performance differences between Indians and the British on the Silhouettes Subtest, a visual perceptual assessment developed in the UK that has begun to be used in India. Lastly, I will examine familiarity as a potential additional or alternative factor driving performance difference. All together, my studies will allow an understanding of how to better evaluate a path towards the adaptation of the Silhouettes Subtest within the Indian context. In order to understand the nuances of culture's influence on visual perception, I will begin with a brief review of what is known about the human visual system.

1.1 Anatomy of the Visual System

Our eyes have evolved to capture information about the external world via the medium of light; this information in light is carried in the form of photons (Palmer, 1999). After light enters the eye, the photons strike millions of photoreceptors that cover the retina and fovea located at the back of the eye (Palmer, 1999). These photoreceptors then translate the photonic information to a chemical and electrical form that can then be passed on to the next stages of the visual system (Palmer, 1999, Kolb & Whishaw, 2009). This chemical and electrical form can be called neural activity.

There are two types of these photoreceptors: rods and cons. Rods span much of the retina with the exception of the center. They are extremely sensitive to light, and they are what allows our vision to adjust to low light situations-scotopic conditions-such as a dimly lit room or twilight. At the center of the retina exists a small pit called the fovea that is densely packed with cones. Though the fovea is where cones are most abundant, some cones are found scattered along the periphery of the retina. Cones are less sensitive to light compared to rods but are essential for our perception of color, and for vision in normal light-photopic conditions. The fovea is where we are able to see the most amount of detail about the objects and events we are viewing (Palmer, 1999). Though the eye is an incredible piece of evolution, it is not perfect. Depth resolution is reduced converting a 3D image into a 2D image (Webb & Hughes, 1981). In other words, information is lost, which the human visual system must then reconstruct using other cues, e.g. shadowing. Therefore, human visual perception is partly a construction of the brain, which is a central point in understanding how culture/experience shapes vision (Hermann Helmholtz, 1867/1910, as described by Hatfield, 2002).

When photoreceptors translate photons into neural activity, it travels along the optic nerves that leave each of the eyes. These optic nerves cross over at a point called the optic chiasm and it is from there that two pathways branch out into the brain on both sides (Palmer, 1999; Kolb & Whishaw, 2009). The smaller of the two pathways leads to the superior colliculus, which is thought to be involved in the processing of preliminary spatial information and in directing eye movement. The larger of the two paths leads first to the lateral geniculate nucleus in the thalamus before continuing on to the occipital lobe (Palmer, 1999; Kolb & Whishaw, 2009).

The first place where cortical processing of this visual information takes place is in the striate cortex, or area V1, which is the outermost layer of the occipital lobe. From here, information is conveyed to area V2 where further processing takes place (Kolb & Whishaw, 2009). No one specific type of information is analyzed in V1 or V2 but rather all information is processed and segregated into color, form and motion to then be sent to other cortical areas that specialize in more specific information processing (Kolb & Whishaw, 2009). For example, area V4 is thought to be crucial for color perception, V5 is thought to be specialized in detecting motion, and V3 is thought to be involved in perception of object shapes when in motion (Kolb & Whishaw, 2009). It is important to note here that these cortical areas are not exclusive in what they process. Though they mainly process specific types of information, these regions are highly interconnected and therefore influence each other in what and how information is analyzed.

From the V1 and V2 cortical areas, two main pathways, or streams of information flow to regions of the brain that make differing contributions to perception. Early on, it was thought that these two pathways were distinctly separate from each other: the temporal pathway, or the ventral stream, was thought to be more involved in object identification, where as the parietal pathway, or the dorsal stream, was thought to carry information regarding spatial location of objects (Ungerleider & Mishkin, 1982; Mishkin, Ungerleider, & Macko, 1983); Ungerleider and Mishkin called them the "what" vs. "where" streams. Melvyn Goodale and David Milner then expanded this theory to include the purpose for which the information was being processed. They theorized that the dorsal stream is involved in processing information about an object—vision for perception—and the ventral stream is involved in processing information that can guide movement—vision for action (Goodale & Milner, 1992, Goodale et al., 1994). Thus they expanded the "what" vs "where" streams to the ""what" vs "where/how" streams. However, this distinction between the functionality of the dorsal and ventral stream is not absolute. It is simply a description of the degree to which different regions play a part in specific information processing. The two streams have been shown to anatomically interact with each other (for review, see Cloutman, 2013) and therefore cross-over in information processing would be expected. An overlap in information processing is evident when looking into clinical cases of cortical blindness (Goodale et al., 1994). These patients typically have lesions in the ventral stream leaving them "blind", however despite their lack of visual experience, they are able to identify the location of objects and are able to interact with the objects appropriately (referred to as 'blindsight'). This indicates that along with having an intact spatial awareness, they are able to "understand" the shape of the object such that they are then able to direct specific movements towards the object in a manner that would be considered correct for the most part (Goodale et al., 1994) with some limitations when changes to the orientation of an object are made (Carey, Harvey, & Milner, 1996). Though these patients with cortical blindness are able to direct movement and grasp objects with sufficient proficiency, knowledge of how to use the object does not occur until tactile explorations are made upon holding the object itself (Carey, Harvey, & Milner, 1996). For this knowledge to have existed prior to physical interactions, object perception is critical.

1.2 Object Perception

An early model for object perception and identification followed Biederman's theory which claimed that all objects can be reduced to basic features, and our ability to process the interaction of these individual structural elements is what allows for object identification (Biederman, 1987). Though this recognition-by-components theory is rooted in decomposing objects into geometric shapes, more recent research has shown that features can be extended beyond concrete structural parts to include contours (Loffler, 2008), colors or textures (Bramão et al., 2011a), or minimal elements of contrast, such as Gabor patches (Dong & Ren, 2015). Some theories suggest these specific visual components, or diagnostic features, facilitate object identification within a specific context by enabling efficient and effective decision making between probable alternatives (Baruch, Kimchi, Goldsmith, 2014). However, what is considered to be a "diagnostic feature" can vary dramatically depending on the situation in which the viewing is occurring, and other cognitive factors such selective attention (Baruch, Kimchi, Goldsmith, 2014; Schlangen & Barenholtz, 2015; Ballesteros & Mayas, 2015). For example, when viewing a zebra amongst brown horses, the stripes of the zebra will undoubtedly be the most salient visual information to guide identification; saliency being the degree to which a feature stands out or is attention-grabbing. However, this would not be the case to the same degree if the zebra were amongst white Bengal tigers. Furthermore, when considering object identification across all view points, it is argued that for relatively consistent recognition, the most distinct diagnostic features must be available to the viewer (Hayward & Tarr, 1998). For example, if asked to identify a hammer from an angle that mostly obscured the hammerhead, it is likely that the viewer would find it more difficult (and so be slower) to identify the object based on a portion of the wooden handle than if the angle were reversed and the hammerhead was more clearly seen (see spreading activation theory of memory; Anderson, 1983). Once the distinguishing features of an object are identified, it can then be compared across multiple exemplars of the same object or category (Karimi-Rouzbahani, Bagheri, & Ebrahimpour, 2017) (e.g. double headed hammers, single headed hammers, other tools similar to a hammer, etc.), and the similarities/dissimilarities found can then be used to fine tune which diagnostic features are essential for accurate identification. Though strides have been made, the link between discrete diagnostic features and more holistic or complex cognitive representations still remains unclear. It is therefore important to understand the relationship between object perception and recognition so as to move towards improving the theories and methods that can accommodate all the processes involved in object perception. However, this becomes further complicated when what is considered diagnostic varies between individuals (Karimi_Rouzbahani, Bagheri, & Ebrahimpour, 2017), or when the influence of "culture" is considered — what would generally be considered to be a "diagnostic feature" becomes even more abstract if different cultures vary in terms of which features are essential for perception and identification (Kuwabara & Smith, 2017). Furthermore, when many objects are viewed simultaneously with a single space, e.g. a scene, how an individual approaches the perception and understanding of the relationship between objects or themselves and the objects in space can be heavily influenced by that individual's culture/past experiences.

1.3 Scene Perception

Multiple objects can be placed together to form a scene. However, a real-world scene contains a spatial layout that organizes a large variety of objects into foregrounded objects and background elements in a meaningful manner. Henderson & Hollingworth (1999) have defined a scene as:

> "a semantically coherent (and often namable) view of a real world environment comprising background elements and multiple discrete objects arranged in a spatially licensed manner." - p. 244

This definition allows us to understand how scene perception differs from object perception in that:

"objects are spatially compact entities that one acts upon, scenes are spatially distributed entities that one acts within" (Epstein 2005)

The visual system is finely tuned towards rapidly recognizing scenes as it allows us to quickly locate ourselves within a space. An example of this was seen in research by Potter and colleagues which showed that when exposed to pictures of scenes at a rate of 8/sec, individuals were able to detect the target scene that was mixed in with a number of distractor scenes with 75% accuracy (Potter, 1975; Potter, 1976; Potter & Levy, 1969). This ability to quickly recognize the scene as a category rather than a specific unique place with unique objects is beneficial because, though spatial identity can be deduced by individual objects, understanding a scene as a whole provides a much more cohesive constellation of place related cues. Furthermore, scenes inform us of objects likely to be found in that space, and therefore the kinds of actions that can be executed (Bar, 2004). For example, if I am able to identify a space as a kitchen, I can therefore deduce that I will most likely find food and utensils to cook the food in that space. Understanding scenes as a whole as opposed to separate single objects can also allow us to evaluate the quality of a space—does this place look sanitary or not—or make judgements on the level of safety a space provides. Previous behavioral work has also shown that humans are strongly evolved to recognize logically organized real-world scenes that are very briefly presented. For example, Biederman (1972) reported that individuals were able to more accurately recognize target single objects if the scene briefly shown to them was coherent rather than if the image of the scene was jumbled up. Antes, Penland, & Metzger (1981) found very similar results when participants were shown images of scenes and were asked to identify the object in the image from a selection of options. Participants were more accurate in identifying the object if it "made sense" that the object would be found in that kind of scene vs. if the scene was nonsensical for the object to be in (for review, see Wu, Wick, & Pomplun, 2014). Another study showed that the co-occurrence of objects that would be expected to coexist within a space facilitate scene identification. For example, a sink and an oven together, are highly predictive that the scene is a kitchen (Gagne & MacEvoy, 2014). These studies indicate that the human visual system can extract meaning from a complex visual scene in a very short amount of time, and can use it to advance various types of decision-making. Subsequent work in scene perception also provided evidence that scenes can be identified based on more global characteristics. For example, Schyns and Oliva (1994) demonstrated that participants were able to correctly categorize scenic images that were briefly flashed (30 ms), even though the images were filtered to remove all high-spatial-frequency information— any objects looked more like coarse blobs. Similarly, Greene and Oliva (2009) were able to demonstrate a 75% accuracy rate for the target image when images of nature were presented between 19-67 ms (performance peaking at 100 ms). Furthermore, subjects were able to categorize certain global features, e.g. how expansive or navigable the scene is, at even lower presentation times, when the images were masked to reduce high level features. This ability to quickly and accurately identify complex scenes has also been demonstrated in other properties of low-level features beside spectral features including contour junctions (Walther & Shen, 2014; Wilder, Dickinson, Jepson, & Walther, 2018), and color (Oliva & Schyns, 2000; Goffaux et al., 2005, Castelhano and Henderson, 2008). Our ability to rapidly recognize different types of environments based on very little information implies that a relatively conservative amount of brain power is used for this process. However as we start to gather greater detail about said environment, greater cognitive processing is required. To streamline the demanding nature of this, we start to selectively attend to certain aspects of the surroundings more than others depending on our goals or desires.

1.4 Selective Attention and Eye Movements

The environment in which we exist carries much more information than the finite computing power of our brains (Palmer, 1999). As a result, we selectively attend to certain information more than others depending on what our needs, aspirations, desires, etc. are. This doesn’t mean that we are physically receiving less information, simply that not all the visual information that we are sensing is brought to conscious awareness. The classic example of this is demonstrated in the Invisible Gorilla experiment in which individuals are asked to watch a video of a group of people running around passing a basketball between them, and to count the number of passes made. However when asked if they noticed the person in the gorilla suit walk through the group, only about half of them had said “yes” (Simons & Chabris, 1999). This phenomenon is referred to as change-blindness.

What is available to our brains for visual processing is dependent upon a range of factors, including eye movements such as eye fixations and saccadic eye movements, the latter referring to rapid, ballistic movements of the eyes that occur between fixations and influence the direction/location of the next fixation point (Palmer, 1999). Whether it is for detailed recognition, search, or something else, eye movements are essential. Different parts of the eye are evolved to pick up different levels of information: the fovea, the central ~2° of the visual field, is able to gather information in high resolution-it can “see” the greatest level of detail. The level of acuity drops in the surrounding parafoveal (~4.5° into the periphery) and peripheral regions, though these regions are very sensitive to other types of information such as motion (McKee and Nakayama, 1982; see Finlay, 1982 for review), and scene-gist categorisation (Loschky et al., 2019). Our eye movements are strongly biased towards fixating objects instead of backgrounds (Malcolm and Shomstein, 2015; Xu et al., 2014), typically landing the fixation itself within the object (Foulsham & Kindstone, 2013; Pajak & Nuthmann, 2013). When there is no specific goal, certain properties can predict where people will fixate, e.g. edge density, visual clutter, and homogenous segments, while other features like luminance and contrast are more minor influencers (Nuthmann & Einhauser, 2015). When there is a more specific goal, the visual system can utilize various scene properties depending on how diagnostic they are for that particular goal.

If one were to attempt to view a scene with all its details, the process would take a long time as we would have to systematically fixate at different consecutive points in order to take in all the details of the scene. So to make this more efficient, the visual system directs eye movements by integrating low-resolution peripheral information and high-resolution foveal information, with our goals, past experiences, and knowledge of the environment (Nuthmann, 2014; Castelhano et al., 2009). This might be done by matching low-level features, such as color (Nathmann &Malcolm, 2016) or shape (Reeder and Peelen, 2013) that fall within our peripheral view to the target's properties, along with high-level factors like the semantic relationship between scene gist and object (Eckstein et al., 2006; Pereira & Castelhano, 2014), co-occurrence of objects (Mack & Eckstein, 2011; Hwang et al., 2011; Coco et al., 2014), spatial dependency between objects (Wu et al., 2014), or spatial layout (Castelhano & Heaven, 2011). These various factors are integrated to direct attention to the most likely location of our target (Spotorno et al., 2014). To give an example, when searching for our keys, we first identify the space where they would most likely be found, given our personal habits, past experiences, etc. Once we are in that space, instead of scanning the whole space in consecutive segments until the keys are found, our eyes are initially directed to specific locations within that environment where we believe the keys would most likely exist. In other words, we first selectively attend to specific areas that are chosen based on expectation and passed experiences. When attending to these areas, information falling within the foveal or parafoveal regions allows for detailed visual processing therefore leading to a more confident identification of the keys or identification of other objects, like a wallet, that might bring greater confidence as to the location of the keys-perhaps you are highly likely to keep your keys and wallet together. Information in our periphery can influence our saccadic movements, informing us on where to potentially fixate next, e.g. detecting the general shape or color of the keys (or wallet) in our periphery would influence the direction of the saccade and therefore the location of the next fixation; this, in turn, increases the efficiency of saccadic distribution so that our eyes are not haphazardly moving about between fixations (Nuthmann, 2014).

Where we gaze is thus the result of a feedback loop between scene properties-low level features and high level semantics-and the viewer's goal and past experiences. However, the diagnostic value of a particular property is also dependent on availability. Searching for an object in a space initially relies on semantic knowledge: the keys are typically on the key holder by the door. However, if the semantic cues are not fulfilled: the keys are not on the key holder, our eyes are then guided by episodic memory (Vo and Wolfe, 2013): when did I last have the keys? As we interact with an environment more and continue to build memories in it, we continue to develop more detailed scene representations (Malcolm et al.,

2014) and our eye movements continue to become more fine-tuned. These concepts can be easily related to when the task at hand is a simple search task, however, these concepts can also be applicable to larger concepts of “environment” like societal structure and other factors that belong under the umbrella of culture.

1.5 Culture and Visual Perception

Culture is a term that comes with much controversy. Etymologically the word is derived from the Latin term cultura, meaning cultivating, and was primarily used in the context of agriculture (Williams, 1976). However, it came to be used figuratively to mean caring for or honoring somebody or something (Williams, 1976). The origins of the word can also be traced to cultus or colo, coming from the Latin stem word colere which means to tend, guard, till, inhabit, cultivate, foster (Williams, 1976). The word was used by Cicero, a Roman orator, in the 1st Century B.C. as *cultura anima*, meaning cultivation of the soul however, its usage was not very popular outside of the works of Cicero (Williams, 1976). In the 15th century, *cultura* was mainly linked to land and the preparation of the earth for crops (Williams, 1976). It wasn’t until around the 16th century that it took on a more figurative sense of cultivation through education and a systematic refinement of the mind. By 1867, *culture* started to be related to the collective customs, achievements, and intellectual development of a people. Strong commentary on this definition was made by Mathew Arnold in his 1869 collection of essays, *Culture and Anarchy*, in which he brings to light the classist nature with which “culture” was used to distinguish a certain sub-sect of society from the other “less civilized” sect. Though meant as criticism of the society within which he belonged, his work was used to bring forward the Victorian cultural agenda, which remained dominant until the 1950’s. Since then, many have defined culture in an attempt to break away from such an oppressive ideation and towards a more encompassing definition of its meanings and connotations.

Kroeber and Kluckhohn (1952) suggested that:

"Culture consists of patterns, explicit and implicit, of and for behavior acquired and transmitted by symbols, constituting the distinctive achievement of human groups, including their embodiments in artifacts; the essential core of culture consists of traditional (i.e. historically derived and selected) ideas and especially their attached values; culture systems may, on the one hand, be considered as products of action, on the other as conditioning elements of further action." – p. 181

This definition relates *culture* with a group of people as opposed to a single individual. At the same time, it conveys the idea that the acquired behavior can be transmitted forward. Raymond Williams, a major figure within the British New Left, in *Culture and Society* (1958) argued that the meaning of culture changes with time. For him culture was a:

"description of a particular way of life which expresses certain meanings and values not only in art and learning but also in institutions and ordinary behavior."

Culture from this perspective aimed to clarify the meaning and values that are implicit as well as explicit in our particular ways of living. Raymond Williams intended to popularize the notion that culture is ubiquitous, emphasizing the ordinary, everydayness of culture. Moving towards the end of the 20th century, definitions of culture continued to emphasize the aspect of a transmittable shared nature:

"Culture consists of the derivatives of experience which are more or less organized, learned or created by the individuals of a population including those images or encodement and their interpretations (meanings) transmitted from past generations, from contemporaries, or formed by individuals themselves" -T. Schwartz (1992, p. 324)

The same idea continued into the 21st century by Spencer and Oatey (2008) who suggest that:

“Culture is a fuzzy set of basic assumptions and values, orientations to life, beliefs, policies, procedures and behavioral conventions that are shared by a group of people, and that influence but do not determine each member's behavior and his or her interpretations of the meaning of other people's behavior.” - p. 3

The influences of culture on cognition have intrigued cognitive scientists for many years. Segall et al. (1968) demonstrated this in a study in which geometrical illusions, specifically the Müller-Lyer and the Sander parallelogram illusions, were presented to over 1000 individuals from 14 non-European countries and the United States. Their results showed that susceptibility to these illusions was different across cultural groups because of different ways in which these groups of people were taught to infer the information provided. Similarly, Deregowski (1972) was able to demonstrate that individuals belonging to various African tribes showed difficulty in depth perception when shown 2D pictorial drawings of 3D images. These differences in perceptual abilities have been attributed to thinking styles that are thought to be encouraged by the ideology, politics, language, and other characteristics of a social structure within which individuals live. A popular characterization of the influence of culture on cognition is the analytical style of the individualistic West, and the holistic style of the collectivist East. Varnum et al. (2010) explain analytic and holistic thinking as:

“Analytic cognition is characterized by taxonomic and rule-based categorization of objects, a narrow focus in visual attention, dispositional bias in causal attribution, and the use of formal logic in reasoning. In contrast, holistic cognition is characterized by thematic and family-resemblance-based categorization of objects, a focus on contextual information and relationships in visual attention, an emphasis on situational causes in attribution, and dialecticism” - p 9

Richard Nisbett, in his book *Geography of Thought,* consolidates his many years of research in which he claims that the dichotomous holistic-analytic cognitive styles of the East and West are a byproduct of the geography from which these styles originate. Rooting the “East” to China, he describes that the vast nature of the land and the little communication between villages encouraged individuals to turn inwards and form a societal structure that valued harmonious living. Thus came Confucianism, a legal system that emphasized the context within which the offense was created, and scientific discoveries that revolved around relational interactions, e.g. the push and pull relationship between the moon and water. Attributing the "West" to Greece, Nisbett argues that the location of Greece by water lent itself to the exposure of different cultures through trade. As a result, Greek-and therefore Western-thought was propelled outwards towards questioning contradictions, encouraging an Aristotelian style of thinking involving categorizations and logic, and scientific discoveries that were more extra terrestrial in nature, e.g. Pythagoreans and their strive to create geometric models that could imitate celestial motion. In relating this to cognition, Nisbett links these styles of thinking to causal attribution, where individuals categorized as Easterners are more likely to attribute the cause of a situation to something in the environment, as opposed to individuals categorized as Westerners who are more likely to attribute the cause to something integral to the perpetrator (Choi & Nisbett, 1998; Hong, Chiu, & Kung, 1996; Kitayama & Masuda, 1997; Lee, Hallahan, & Herzog, 1996; Miller, 1984; Morris & Peng, 1994, for review see Choi, Nisbett, & Norenzayan, 1999). Emulations of this dichotomy have been shown in studies involving logical vs. dialectical tasks where individuals from East Asia were more susceptible to contradictions and propositions than Americans (Norenzayan et al., 2002; Peng and Nisbett, 1999). Similar, on categorization tasks, East Asians were more likely to classify objects and events on the basis of relationships and family resemblance, whereas Americans were more likely to classify objects on the basis of rule-based category membership (Chiu, 1972; Norenzayan et al., 2002); and in terms of attention, "Easterners" are thought to attend more to background or contextual information and "Westerners" are thought to attend more to focal information (Masuda & Nisbett, 2001; Masuda and Nisbett, 2006; Boduroglu, Shah, & Nisbett, 2009, Ji et al., 2000; Kitayama et al., 2003). With the developments in eye tracking and brain imaging (e.g. EEG, fMRI) technologies, there has been a new found interest in using them to understand these behavioral differences at a kinematic and neurological level (Chua, Boland, & Nisbett, 2005, Gutchess et al. 2006; Lewis et al., 2008; Masuda et al., 2016; Paige et al. 2017). These studies clain that attention to the contextual information by "Easterners" manifests in greater eye movements to the background of a scene

(Chua, Boland, & Nisbett, 2005), greater neural activation in cortical areas that are more involved in scene/background processing-not in areas more involved in processing individual objects present in the scene (Goh, Chee, & Tan, 2007; Jenkins, Yang, Goh, 2010)-and greater activation in attentional networks when presented with a task that would require more analytical thinking (Heden et al., 2008; Liddell et al., 2015). Similarly, attention to focal information in "Westerners" manifests in greater eye movements to the focal object (Chua, Boland, & Nisbett, 2005), greater neural activation in cortical areas involved in object processing, as opposed to scene/background processing (Goh, Chee, & Tan, 2007; Jenkins, Yang, Goh, 2010), and greater activation in attentional networks when given tasks that would require more holistic thinking (Heden et al., 2008; Liddell et al., 2015). The use of these technologies to investigate cultural differences in scene/object perception has mainly been reported in the 21st century and have shown some inconsistencies in their results (Rayner, Li, &Williams, 2007; Evans, Rotello, Li, Rayner, 2009; Kitayama & Murata, 2013). This begs the question of where in the entire perceptual processing process do we begin to see a divergence in perceptual strategy because of the influence of certain cultural factors, and are these technologies truly sensitive to this differences.

Another point of contention is that the association of collectivism/interdependence to the "East" and individualism/independence to the "West" have been linked to analytical and holistic cognitive style respectively; however, most of these studies have used America and China or Japan as the according exemplars of the "West" and "East". Some studies have shown that they are not confined to just North America and East Asia. This framework has been shown between Russians and Americans, Russians being more interdependent than Americans (Grossmann, 2009; Matsumoto, Takeuchi, Andayani, Kouznetsova, & Krupp, 1998). In other words, the Russians approached categorization, attribution, visual attention, and reasoning about change more holistically that the Americans (Grossmann, 2009). Similarly, Varnum et al. (2008) demonstrated that individuals from Eastern Europe had a more holistic cognitive approach to categorization and visual attention than those from Western Europe. Even within cultures, Kitayama et al., (2006) found that individuals living on the smaller island of Hokkaido, Japan were more independent than those from the main islands of Japan. Similar intracultural bi-variation in social orientations and their coinciding cognitive styles have been found in northern and southern Italians (Knight & Nisbett, 2008) and between farming and fishing communities of Turkey (Uskul, Kitayama, & Nisbett, 2008). What has been explored much less is whether these differences within cultures, and between cultures that are globally thought to be a part of the "East" or "West", are also seen in other historically "Eastern" and "Westerner" countries that are not North America, or China or Japan. For example, India, a country that is chronicled as being part of the "East" (Chakkarath, 2010) but is culturally distinctly different from China has been featured very infrequently in comparative studies of cultural visual perceptual studies. Furthermore, though India has been perceived as collectivist (Country Comparison - Hofstede Insights, 2018), many studies have shown this to be a mischaracterization of India, arguing that India, being a very diverse land within itself, is a spread between collectivism and individualism with certain area tending more towards collectivism, others more toward individualism, and some places in which both individualistic and collectivistic characteristics exist symbiotically (Jha & Singh, 2011; Khare, 2010; Sinha, Sinha, Verma, & Sinha, 2004).

In essence, "culture" carries with it a great complexity and it can not be denied that it plays an influential role on visual perception. This could have a very important practical implication in the field of Clinical Neuropsychology, particularly for neuropsychological assessments of cognitive functions in the context of neurological conditions. However, it is just an important to start teasing apart the many layers of "culture" to begin understanding which aspects of "culture" are driving differences on these assessments. In this way, we can better guide ourselves towards the improvement/expansion of a health service.

1.6 Culture and Neuropsychology

Alexander Romanivich Luria was well noted for developing many neuropsychological assessments during his clinical work with victims of World War II, and is thought to be one of the founders of Cultural-Historical Psychology (Luria, 1962). Luria had taken on a particular interest in cultural factors that influence the development of human cognition. In 1931 and 1932, Luria had conducted studies in Uzbekistan investigating cultural factors, particularly education, as a determinant of cognition. Luria's work was replicated by Gilbert (1986) in Kwa Zulu, South Africa with results that closely reflected those of Luria. More recently, a study by Sisco et al. (2015) demonstrated the importance of quality of early education and literacy on cognition, using it to explain race-related disparities of cognitive functioning later in life. Performance disparities on neuropsychological assessments are hardly a new discovery however the subject gained momentum towards the end of the 20th century and into the 21st. Major efforts have been made to address this issue in the United States, considering the growing diversity of minority groups (Manly, 2008); however, most of the effort has focused on the Hispanic community. This is not surprising considering that the Hispanic community currently makes up about 18% of the American population, and is the largest ethnic minority group in the U.S.A.

In India, Neuropsychology as a separate field was not introduced until 1975 when Professor C.R. Mukundan took the initiative to develop the NIMHANS Neuropsychological battery (Mukundan & Murthy, 1979), which consisted of a collection of neuropsychological assessments that had been adapted to better suit the population. Since then, the field has continued to grow to include more batteries such as the NIMHANS Neuropsychological Battery for the Elderly (Tripathi, Kumar, Bharath, Marimuthu, & Varghese, 2013), The NIMHANS Neuropsychological Battery for Adults (Rao, Subbakrishna, & Gopukumar, 2004), and The NIMHANS Neuropsychological Battery for Children (Kar, Rao, Chandramouli, & Thennarasu, 2004). These batteries have also been used in Sri Lanka as a tool to create their own normative data set (Srinivasan & Jaleel, 2015). It should be noted that these batteries provide a brief assessment of all cognitive domains. If further assessment is required in any one domain, clinical neuropsychologists in India are then compelled to use the already existing, unadapted assessments that have come from America or Europe. For example, though the NIMHANS batteries have a visual spatial construction component to them, in order for a more detailed examination of visual and spacial perception, other batteries, like the VOSP, that have not been created or adapted to the Indian context are then used.

The VOSP battery was created in 1991 by Warrington and James to evaluate visual perception. The battery consists of eight subtests: shape detection, incomplete letters, silhouettes, object decision, dot counting, progressive silhouettes, position discrimination, number allocation, and cube analysis; all created to assess specific aspects of visual perceptual abilities. Recently, a study by Dutt et al. (2016) examined healthy Indians' performance on the VOSP by comparing a sample of 200 Indians residing in India, and comparing them with the performance of individuals from the UK (in relation to the test norms) as well as participant samples from Greece, Spain, and the United States. Their results showed that a substantial proportion of Indians performed below the original cut-off for impairment on all object perception subtests, including the Silhouettes Subtest. The study had controlled for education and had also tested for object familiarity, both of which proved to not be contributing factors for the difference in performance. Thus, the study revealed a cultural incompatibility of the assessments, implying the necessity of further exploration of more specific cultural factors, and for the potential need to adapt the battery.

According the Comprehensive Handbook of Psychological Assessments and the International Handbook of Cross-Cultural Neuropsychology, when modifying measures, we must

> "take into account the purpose of the assessment as well as the various test factors, test-taking abilities, and other characteristics of the person being assessed, such as situational, personal, linguistic, and *cultural differences* [emphasis added], that might affect psychologists' judgments or reduce the accuracy of their interpretations." — International Handbook of Cross-Cultural Neuropsychology, p. 55

To do this, we must be aware of varying equivalences when recording variables. For example, the number of years of education to receive a high school diploma may vary between different countries. We must be aware of the, "value and significance of specific cultural concepts, model of knowledge, and model of communication," of the individual being interviewed (Puente & Agranovich, 2003). Importantly, "when selecting assessment methods, researcher should address the variables that needs to be measured, and then select the test that measures those variables; select measures that have been accurately translated according to cognitive rather than linguistic equivalence; when possible, use tests that have appropriate norms accompanied with specific instructions and protocols; select tests that reflect the language ability and culture of the patient; and if available, use ecologically valid tests of function." —Puente & Agranovich, 2003, p. 328

Keeping this in mind, when adapting the VOSP, it is important to understand how culture—and which aspects of culture specifically—are the driving forces for the differences in perceptual abilities at its root. If we can understand this at a fundamental level, clarity can be brought upon the path towards creating a battery that can fulfill the needs of a population and better the practice of clinical neuropsychology compassionately.

1.7 Rationale for Thesis

The primary focus of the thesis is to explore whether what is understood about culture and object/scene perception in the "East" and "West" is emulated in the Indian and British cultures—two countries that are considered to be part of the "East" and "West" respectively but have not been compared in perceptual studies before. These studies were done for the purpose of stepping towards understanding how to approach the development/adaptation of a suitable version of the Silhouettes subtest of the VOSP for the Indian population.

Firstly, Chapter 2 reports a systematic review investigating whether there are consistent patterns of differences in eye-movements and brain processing (measured using fMRI and EEG technologies) between cultures on visual object and scene perception tasks. In addition, the cultural frameworks used in the cross-cultural comparisons were identified, e.g. Easterners vs. Westerners, Collectivism vs. Individualism, etc., within each study, and the cultural groups used to exemplify the cultural frameworks. This was undertaken to understand specifically which cultures were showing differences in perceptual strategies, given the cultural framework lens through which each study was described. The systematic review provided information on which paradigm has been most commonly used to demonstrate cultural differences in perception in order to investigate whether the same paradigm would also reveal cultural differences between Indians and the British.

Thus, in Chapter 3, the scene perception task first used by Chua, Boland, and Nisbett, (2005), was used with Indian and British samples in order to investigate whether a behavioral performance difference existed, whether there were differences in eye movements, and whether or not these related to the types of visual information that was processed. A key question was whether findings from this scene perception task would also be relevant in explaining performance differences previously reported on the Silhouettes Subtest of the VOSP.

In Chapter 4, a study is presented in which participant samples from the UK and India were presented with the Silhouettes subtest of the VOSP while tracking their eye movements. This study added to the previously mentioned findings of Dutt et al., (2016)'s study, while also investigating whether differences in eye movements between the British and the Indians during scene perception related to potential eye movements when presented with single objects with significantly reduced diagnostic information—the shadowed objects of the Silhouettes subtest—with the aim of investigating whether or not performance differences could be explained by differences in eye movements.

One reason why one group of participants may be poorer at identifying objects is differences in familiarity with the objects. In Dutt et al., (2016)'s study it was found that Indian participants were familiar with the objects included in the VOSP Silhouettes task and hence familiarity with the objects was not considered to explain performance differences. However, in Chapter 5, a detailed investigation of familiarity is reported in which participants were asked to rate their familiarity with the Silhouettes objects but also with objects that had incorrectly been given as answers in the study reported in Chapter 4. The aim of this study was to investigate whether differences between cultures in relative familiarity of objects might explain performance differences.

Chapter 6 presents an overview and general discussion of the findings from all of the studies reported in the thesis. In particular, the implications of the findings from the studies for the development of culturally appropriate neuropsychological tests of perception in India are outlined.

2. Eyes, brains and culture: A systematic review of the use of eye-tracking, EEG, and fMRI in measuring cultural differences in object and scene perception

Abstract

Objective: There is substantial evidence that culture influences perceptual processing. However, which particular perceptual stimuli show differences and the mechanisms that underlie differences in perception between cultures remain uncertain. The aims of this systematic review were: (1) to locate, collate and synthesize the results of studies that have examined whether differences between cultures in the perception of scenes and objects are detectable using eye tracking and brain imaging (EEG/fMRI) technologies and (2) to identify the cultural frameworks used to characterize comparator groups.

Participants and Methods: Web of Science and EBSCOhost were searched using a set of key terms. Of 4718 potential articles, 38 met the *a priori* inclusion criteria. Studies were categorized according to the cultural framework examined and type of technology used.

Results: Cultural frameworks were most commonly used were East Asians vs. Westerners, and Object/Context Independent vs Context/Context Dependent. The most common participant groups compared were Chinese/Chinese Singaporeans/Han Chinese and Americans. All but two studies found a cultural difference in at least one measurement; however, EEG and eye-tracking studies showed conflicting results among studies. fMRI consistently showed differences between participants from different cultures in neural activation for the processing of objects in scenes.

Conclusions: Although some studies found quantifiable cultural differences between Americans and Chinese participants, little evidence exists to extrapolate these findings beyond these two groups. Most studies reported differences between

cultures in eye movements and in measures of brain function; however there was very little consistency between studies in the specific measures used. Thus the specific mechanisms that may underlie cultural differences in object/scene perception remain uncertain and require further investigation.

Introduction

The concept of "culture" has been debated for many decades. Initially, culture referred to the arts and so, it was mainly reserved for "high society". Matthew Arnold, in *Culture and Anarchy* (1869/1932), initially set forth to criticize this view that separated the elite from the mass, believing that culture was "the study and pursuit of perfection." Though meant as a social commentary of the Victorian society to which he belonged, "culture" came to be associated with aesthetics, bringing with it connotations of "civilized" and "high intellect". Those who were not a part of this niche were seen as potential sources of anarchy.

In reaction to Arnolds' definition of culture, a second usage of "culture" exemplified in E.B. Taylor's *Primitive Culture* (1870) came about. In it, he explains culture to be a set of characteristics held by all individuals residing in a particular place. He defined it as,

> "that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society".
> -p 1

This definition became the foundation for cultural anthropology, expanding culture to everyone who could claim membership to a group of people. These characteristics of culture were thought to be a by-product of a type of "social evolution" progressing from "savagery" to "barbarism" to "civilization". Though the idea of an inherent movement of entire groups of people through a social hierarchy was rejected by subsequent anthropologists, many could identify with the idea of integrated systems creating a "complex whole".

Though Taylor’s definition of culture was more inclusive, it oversimplified entire groups of people. Thus, came the third main usage of culture, brought forward by Franz Boas and his students such as Margaret Mead and A.L. Kroeber. Boas completely rejected the idea that culture operated along an evolutionary, classist system. Rather, he believed in cultural relativism where individuals viewed and interacted with the world according to their own set of acquired knowledge and norms (Boas, 1920; for collection of works of Franz Boas and other cultural anthropologist, refer to Moore, 2009). His approach stepped away from the extreme categorization of a group of people based on geography and saw culture to have more autonomy to the individual. Though overlap could be seen between individuals’ sets of norms, they were not seen to be limited to these common cultural boundaries (Baos, 1887; Boas, 1920).

Boas’ usage of culture was carried forward by psychologists such as Lev Vygotsky, Alexander Luria, and B.F. Skinner in an attempt to bridge the gap between biology and social psychology. Culture was seen as a result of a feedback loop between one’s environment and one’s cognitive development. B.F. Skinner argued that,

“behavior evolved as a set of functions furthering the interchange between organism and environment.” - p 501

He believed that natural selection, when combined with operant conditioning, resulted in behaviors that indirectly affected survival. These behaviors are then further reinforced through the development of verbal behavior, lending itself to social environments. Over time, these behaviors are thought to then take on a less practical role and become something that is pervasive within a society, or culture in a larger sense (Skinner, 1981). This link between society and biology continued to be reinforced as research continued to investigate deeper into the influence of one’s environment on various aspects of cognition.

One line of investigation within the topic of culture and cognition relates to visual perception. Differences in patterns of perception have been demonstrated in multiple domains including color perception, face perception, and scene perception. Color perception has been linked to language in a well-known theory called the linguistic relativity hypothesis (Whorf, 1940/1956). This theory suggests that language guides how thought is shaped, and therefore influences how we perceive the world. Applying this theory through the lens of color perception, or color categorization, one can say that “seeing” a color is reliant upon how one’s language distinguishes the different hues of the light spectrum. This theory has been demonstrated by a South West African tribe who speak a language called Himba (Roberson et al., 2005) and a hunter-gatherer tribe in Papua New Guinea who speak Berinmo (Davidoff et al,1999). Both groups identified colors according to their own linguistic categorization as opposed to strictly adhering to the color categorizations that occur in English.

Similar sorts of cultural relativity beyond language have also been demonstrated in the categorization of facial expression. In other words, a person from one culture may emote an expression that is unrecognizable to a person from a different culture because the physical expression of that emotion is not the same. This was demonstrated in a study by Jack et al. (2012) in which Western Caucasian and East Asian participants were asked to categorize simulated facial expressions as one of the six basic human emotions: happy, sad, fear, surprise, disgust, and anger, and the intensity to which the expression was being displayed. The results showed that though the two groups categorized the emotions differently, they were in accordance with the culturally specific facial muscles used to express those emotions. It should also be noted that face learning and recognition have also been shown to be easier when the face presented is the same as one’s own race. This is known as the cross-race effect (Hourihan et al., 2012).

Scene perception studies, however, have been commonly used to demonstrate two main styles of cognition: Analytical vs Holistic. The study often referenced to exemplify this dichotomy is a study by Masuda and Nisbett (2001) in which participants were asked to view underwater video vignettes depicting various life forms. These videos consisted of a foregrounded, or focal, object, e.g. a fish, performing some kind of activity in a background scene, e.g. swimming across a water tank containing seaweed. This was followed by a recall task in which participants were asked to describe what they had seen in the short videos. Japanese participants were more likely to recall information regarding the background whereas the American participants recalled more detail about the 'focal' objects.

Other examples demonstrating cultural differences in attention are studies utilizing the change-blindness paradigm, in which parts of a picture are changed but due to an inability to attend to the entire picture, the change may go unnoticed or require some time before it is detected (Levin and Simons, 1997). Masuda and Nisbett (2006) used this change-blindness paradigm to selectively modify either a focal object, an aspect of the background, or both. The participants' task was to report any changes they detected. Consistent with Masuda and Nisbett's (2001) findings, East Asians were faster than Americans at detecting visual changes that occurred in the background scene, and Americans were more likely to detect changes occurring in the focal objects.

Similar patterns were also demonstrated in judgement studies. For example, in a study conducted by Kitayama et al. (2003), Japanese and American participants were asked to mentally judge the length of a line presented within a square frame of a fixed size. In the subsequent test phase, participants are presented with an empty square frame of a different size and were asked to draw a line that was either to the same length:frame ratio or the absolute length of the line seen during the previous phase. The results showed that Americans had greater accuracy in making absolute judgments and were less affected by the change in the contextual frame size, however the Japanese showed greater accuracy in making relative judgments. This study reinforced the finding of a previous study (Ji et al., 2000) in which East Asians were more dependent on the contextual frame when determining rod orientations compared to European Americans.

Though culture has been deeply discussed in the social sciences and psychology for over 100 years, it has become a more significant part of the rhetoric of the natural sciences starting from the turn of the 21^{st} century, particularly because of technological advancements. The first studies that used technology to directly investigate culture and cognition were published in the year 2000 using functional magnetic resonance imaging (fMRI) (Hart et al., 2000; Phelps et al.,2000) and since then, many studies have been conducted using eye-tracking, Electroencephalography (EEG), as well as fMRI to further our understanding of the influence of culture and cognition. Despite the rapid increase in these kinds of studies, they have also been heavily criticized for taking a more Taylorean approach. In other words, these studies tend to investigate universal mechanisms between "cultural groups" by categorizing wholes sets of people along dichotomous scales likes Easterners vs. Westerners, Asian vs. Caucasian, Blacks vs. Whites, etc.

Few researchers have highlighted these critical aspects of socio-biological research, mainly in studies done with fMRI (Mateo et al., 2012). Technology is also increasingly becoming an integral part of research, making it important to assess whether these technologies are truly sensitive to the measurements used to demonstrate cultural differences. A large body of research using technology to investigate cultural influences on perception has accumulated however, up to date, only one study has done a meta-analysis on culture and perception in fMRI studies (Han et al., 2014). This study took a broad perspective on perception which included object/scene perception, face/emotion perception, and self perception. It should be noted that neural pathways for these forms of perception, particularly between face and object perception, are distinctly different from each other (for reviews, refer to Leibo et al., 2011 and Kitayama and Park, 2010). Furthermore, cultural influences in perception have not been systematically investigated in studies utilizing eye-tracking or EEG. Thereby, this systematic review intended to review fMRI, eye-tracking, and EEG studies, specifically focusing on object/scene perception, and how these differences relate to the cultural frameworks and cultural groups used in these studies.

Methodology

This systematic review was conducted with reference to the PRISMA reporting protocol (Moher et al., 2009). The systematic literature search was conducted between August 6, 2019 - August 10, 2019 using the following databases; search filters are described with the parentheses: 1) Web of Science which includes BIOSIS Citation Index, BIOSIS Previews, CABI: CAB Abstracts, Current Contents Connect, DATA Citation Index, Derwent Innovations Index, KCI-Korean Journal Database, MEDLINE, Russian Science Index, SciELO, Web of Science-Core Collection, Web of Knowledge, and Zoological Record (Document Type: Article, Language: English, Time Span: all the years), 2) EBSCOhost which includes CINAHL, Medline, PsycARTICLES, Psychology and Behavioral Sciences Collection, PsycINFO, Russian Academy of Science Bibliographies (Source Type: Academic Journal, Journal, Language: English).

"Culture" related search terms included culture, cross culture, ethnicity, race, self construal, priming, interdependence, independence, analytic, and holistic; "perception" related search terms included cognitive style, visual perception, visual search, free search, search task, visual scanning, perception, perceptual processing, visual attention, selective attention, selective processing, global, local, scene perception, object perception, object processing, and categorical perception; "technology" related search terms included eye movement, eye tracking, fixation, fixation pattern, saccade, scan path, fMRI, EEG, neural, and event related potential. These search terms were entered in the aforementioned databases using Boolean rules. Some examples of these combinations include: Cultur* AND "visual percept*" AND "eye movement", "Self construal*" AND "visual atten*", and Cultur* AND "event related potential" AND percept*.

We screened the search results according to specific eligibility criteria established by the authors:

1. Be written in English.
2. Have participants who are 18 years and above
3. Have participants with no relevant health conditions
4. Be quantitative
5. Include more than one cultural environment
6. Pertain to scene and/or object perception only
7. Incorporate the use of technology (e.g. an eye-tracker, fMRI, EEG, etc.) in its experimental design.

8. Paper must be a published article and not a book, conference extract, dissertation, etc.

Based on the eligibility criteria, we selected and categorized the articles according to the experimental design used. This resulted in the following categories: 1) EEG; 2) Eye Tracking- Scene Viewing; 3) Eye Tracking-Change Blindness; 4) Eye-Tracking-Saccade; 5) Eye-Tracking- Narrative Construction with Motion Video; 6) Eye Tracking- Reading Directions; and 7) fMRI.

From all articles, we extracted the following data: name of first author, year of publication, experimental design, cultural framework, cultural groups used, cultural/self-construal survey results, and the presence/absence of a cultural difference in the main categories of measures taken within each category listed above.

In addition to these variables, we used an adapted version of the Crowe Critical Assessment Tool (CCAT) in order to provide an empirical assessment of study quality. Since the CCAT contained questions geared towards assessing the quality of clinical studies, the tool was adapted to better suit the non-clinical studies included in this review. This was done by removing questions that were not relevant for a non-clinical context if the question could not be rephrased. Values for this tool range from 0 to 99 with a higher score indicating greater quality. This adapted version of the CCAT was also given to a second rater along with seven articles chosen at random to ensure inter-rater reliability.

Cultural Framework Categorization

Mateo et al. (2012) critically analyzed the concepts of culture used in fMRI cultural studies by classifying papers as Differentialism or Universalism based on defined parameters drawn from previous work done in understanding culture. This was intended to present potential biases in the framework within which these studies were operating. Though we did not use the same classification system, we categorized papers based on the cultural frameworks described in the paper. We then compared this to the cultural sample groups taken in order to bring to light links being made between cultural concepts and actual cultural groups used to exemplify these concepts.

Results

Literature Selection Flow Chart

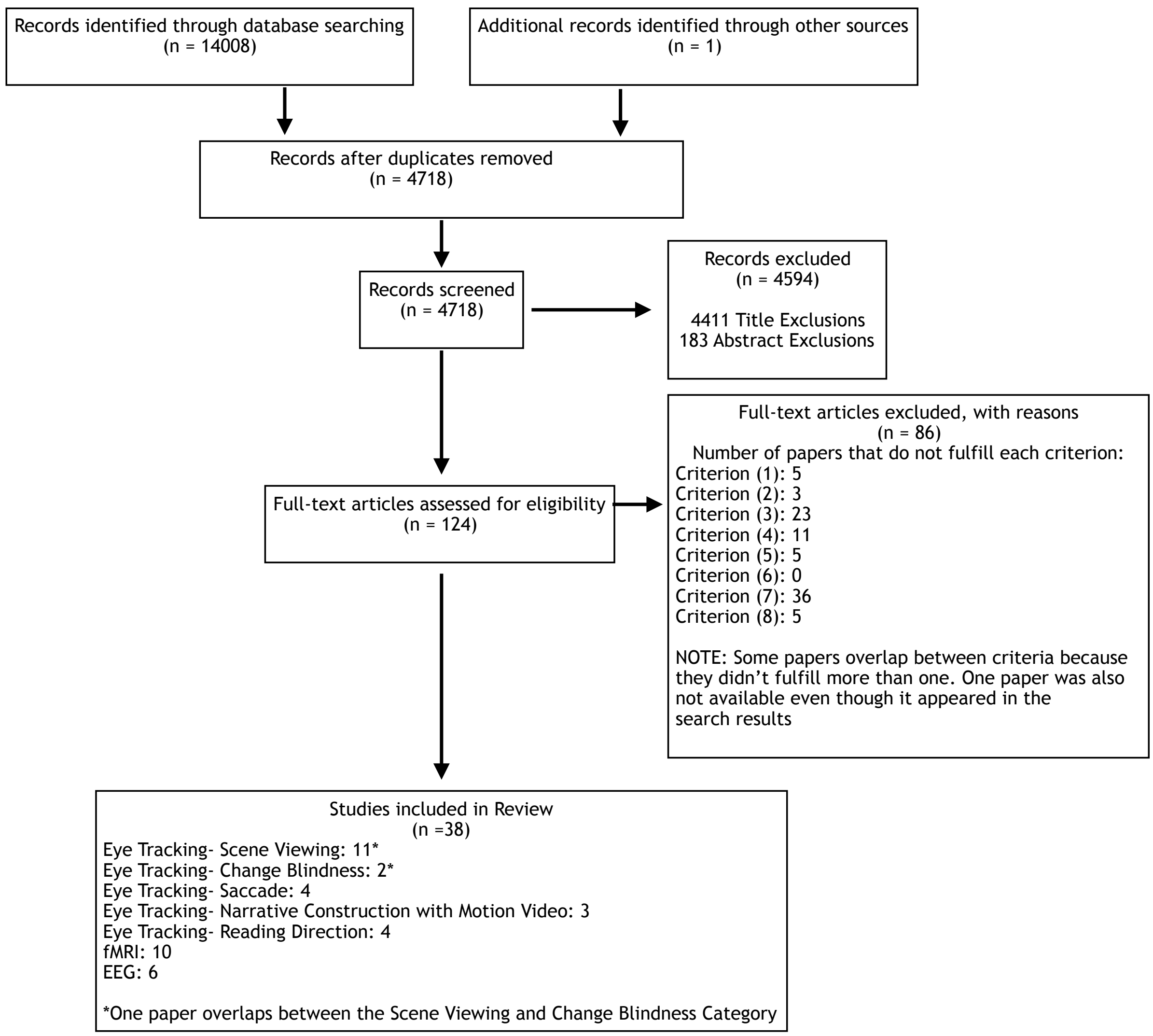

Figure 2.1. PRISMA Selection Flow Chart

A total of 4718 potential articles were identified from the electronic search of the databases after removing duplicates. We excluded 4411 references based on their title. After applying the eligibility criteria to the abstracts of the remaining references, we excluded an additional 183 articles. After reviewing the full-text of the 124 remaining papers, we identified 38 articles for inclusion in the current review. Figure 2.1 details the articles screened and excluded/included (for full details of selection process, see Appendix). Table 2.1 shows the first author, year of publication, experimental design, and the quality assessment score given according

Table 2.1. Summary of articles including first author, year of publication, experimental design and quality assessment scores.

Article	Experimental Design	Quality Assessment Score	
		Rater 1	Rater 2
EYE-TRACKING			
Chua et al. 2005	Scene Viewing - Memory Task	73	71
Rayner et al. 2007	Scene Viewing - Memory Task	61	
Evans et al. 2009	Scene Viewing - Memory Task	68	
Goh et al. 2009	Scene Viewing - Free Viewing_Visual Novelty	80	
Rayner et al. 2009	Scene Viewing - Passive_Unusual Scenes	66	
Miellet et al. 2010	Scene Viewing - Extrafoveal Information Use	82	
Ueda and Komiya 2012	Scene Viewing - Likeness Rating	88	87
Zhang et al. 2015	Scene Viewing - Food Saliency/Free Viewing	87	
Duan et al. 2016	Scene Viewing - Memory Task	71	
Wang et al. 2016	Scene Viewing - Free Viewing	87	
Masuda et al. 2016	Change Blindness - Visual Flicker Task	94	
Alotaibi et al. 2017	Change Blindness - Visual Flicker Task	91	
Abed et al. 1991	Reading - Symmetrical Pattern	74	
Afsari et al. 2016	Reading - Priming and Complex Picture Viewing	77	
Hernandez et al. 2017	Reading - Picture viewing	86	
Afsari et al. 2017	Reading - Picture viewing	83	
Papafragou et al. 2008	Motion - Narrative Construction	80	81
Senzenki et al. 2014	Motion - Narrative Construction	77	
Goller et al. 2017	Motion - Similarity Rating	91	
Amatya et al. 2011	Saccade - Gap/Overlap Paradigm	76	
Knox et al. 2014	Saccade - Gap/Overlap Paradigm	86	
Knox et al. 2017	Saccade - Gap/Overlap Paradigm	80	
Petrova et al. 2013	Gaze Trajectory	86	
EEG			
Lewis et al. 2008	Odd-Ball Paradigm (numbers/letters	87	
Lin et al. 2008	Navon Letters	76	
Goto et al. 2008	Congruent/Incongruent Scenes	92	94
Kityama et al. 2013	Odd-Ball Paradigm (scenes)	78	
Wang et al. 2014	Odd-Ball Paradigm (shapes/objects)	78	
Mecklinger et al. 2014	Architecture/Objects	93	
fMRI			
Gron et al. 2003	Learning Memory	77	
Gutchess et all. 2006	Memory Recall	89	90
Goh et al. 2007	Scene Viewing - Passive	85	
Hedden et al. 2008	Absolute/Relative Judgements	82	
Aron et al.2018	Absolute/Relative Judgements	85	
Jenkins et al. 2010	Congruent/Incongruent Scenes	79	77
Goh et al. 2010	House Scene Viewing	83	
Goh et al. 2013.	Visospatial Judgement	85	
Liddell et al. 2015	Navon Shapes	89	91
Paige et al. 2017	Object Similarity Judgement	80	
Total Average		81.6	84.4

to the adapted CCAT for all papers used in this review and the scores of the six papers rated by the second rater.

Cultural Framework

The cultural framework categories described include: Easterners vs. Westerners; East Asians vs. Westerners; East Asians vs. North Americans; Chinese vs. Westerners; Independence vs Interdependence; Individualist vs Collectivist; Holistic vs. Analytic; Context Independence vs. Context Dependence; Relative vs. Absolute, Physical Environment; Theory of Basic Human Value; Biological; and Language System, e.g. Right-to-Left readers vs. Left-to-Right readers (see Appendix for examples of how these frameworks have been portrayed or described). In certain cases, the authors described cultural differences found between specific cultures used in past research without specifying any one particular cultural framework. These papers were categorized as Chinese, Japanese, Korean vs. Northern Americans, Western Europeans to indicate that these papers used some combination of these cultures as the precedent for their article.

In terms of the cultural frameworks examined, many papers had described multiple frameworks and had interlinked many of the frameworks to each other (see Appendix for quotes that exemplify the interlinking of different frameworks). The number of papers that referred to a cultural framework individually was calculated (before establishing how many papers interlinked various frameworks); of the 38 papers, 17 papers referred to East Asians vs. Westerners, 11 papers referred to Easterners vs. Westerners, seven papers referred to East Asians vs. North Americans, one paper referred to Chinese vs. Westerners, 22 papers referred to Object, Context Independent vs. Context, Context Dependent, 16 papers referred to Holistic vs. Analytic, 13 papers referred to Independent vs. Interdependent, nine papers referred to Individualist vs. Collectivist, two papers referred to Relative vs Absolute, nine papers referred to Language System, three papers referred to Physical Environment framework, two papers referred to the Biological framework, and one paper referred to the Theory of Basic Human Values framework. Table 2.2

illustrates the cultural frameworks described in each paper (see Appendix for quotes extracted from each article exemplifying frameworks).

Table 2.2. Summary of cultural frameworks described in each article used in the systematic review.

Article	Westerners vs. Easterners	Westerners vs. East Asians	North American vs. East Asian	Chinese vs. Westerners	Chinese, Japanese, Korean vs. North American, European Canadian, Western Europe	Independence vs.	Individualist vs. Collectivist	Analytical vs. Holistic	Object, Context Dependent vs. Context, Context Independent	Relative vs. Absolute	Physical Environment	Theory of Basic Human Value	Biological	Language System
	Cultural Framework													
EYE-TRACKING														
Abed 1991	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
Chua et al. 2005	-	✓	✓	-	-	-	-	✓	✓	-	-	-	-	
Rayner et al. 2007	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
Papafragou et al. 2008	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
Evans et al. 2009	-	-	-	-	✓		✓	✓	✓	-	-	-	-	-
Goh et al. 2009	✓	✓	-	-	-	✓		✓	-	-	-	-	-	-
Rayner et al. 2009	-	-	-	-	✓	-	-	-	-	-	-	-	-	-
Miellet et al. 2010	✓	✓	-	-	-	✓	✓	✓	✓	-	-	-	-	-
Amatya et al. 2011	-	-	-	-	-	-	-	-	-	-	-	-	✓	-
Ueda et al. 2012	-	✓	-	-	✓	-	-	✓	✓	-	✓	-	-	-
Petrova et al. 2013	-	✓	-	-	-	-	-	✓	✓	-	-	-	-	-
Senzeki et al. 2014	-	-	✓	-	-	-	-	✓		-	-	-	-	✓
Knox et al. 2014	-	-	-	-	-	-	-	-	-	-	-	✓	✓	-
Zhang et al. 2015	✓	✓	-	-		✓		✓	✓	-	-	-	-	-
Masuda et al. 2016	-	✓	-	-	✓	-	-	-	✓	-	-	-	-	-
Duan et al. 2016	✓	-	-	-	-	-	✓	-	✓	-	-	-	-	-
Afsari et al. 2016	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
Wang et al. 2016	-	✓	-	✓	-	-	-	✓	✓	-	✓	-	-	-
Hernandez et al. 2017	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
Knox et al. 2017	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
Alotaibi et al. 2017	✓	-	-	-	-	✓	✓	✓	-	-	-	-	-	
Afsari et al. 2018	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
EEG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lewis et al. 2008	-	-	✓	-	-	✓	✓	-	✓	-	-	-	-	-
Lin et al. 2008	✓	-		-	-	✓	-	-	✓	-	-	-	-	-
Goto et al. 2010	-	✓	✓	-	-	✓	-	✓	✓	-	-	-	-	-
Kitayama et al. 2013	✓	-	✓	-	-	✓	-	✓	-	-	-	-	-	-
Wang et al. 2014	✓	-	-	-	-	-	-	-	✓	-	-	-	-	-
Mecklinger et al. 2014	-	-	-	-	-	-	-	-	-	-	✓	-	-	-
fMRI	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gron et al. 2003	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
Gutchess et al. 2006	✓	✓	-	-	-	✓	-	-	✓	-	-	-	-	-
Goh et al. 2007	-	✓	-	-	-	-	✓	-	✓	-	-	-	-	-
Hedden et al. 2008	-	✓	✓	-	✓	✓	-	-	✓	✓	-	-	-	-
Aron et al. 2010	-	✓	-	-	✓	✓	-	-	✓	✓	-	-	-	-
Goh et al. 2010	✓	✓	-	-	-	✓	✓	✓	✓	-	-	-	-	-
Jenkins et al. 2010	-	✓	-	-	-	-		✓	✓	-	-	-	-	-
Goh et al. 2013	-	✓	-	-	-	-	✓	✓	✓	-	-	-	-	-
Lidell et al. 2015	-	✓	-	-	-	✓	✓		✓	-	-	-	-	-
Paige et al. 2017	✓	-	✓	-	-	-	-	✓	✓	-	-	-	-	-

"✓": The presence of that cultural framework.
"-": Indication that that measurement was not taken in the study.

Twenty-five of the 38 papers linked the Easterners vs. Westerners, East Asians vs. Westerners, East Asians vs. North Americans, Chinese vs. Westerners, and/or Chinese, Japanese, Korean vs. North American, European Canadian, Western Europe frameworks to all or some combination of the Individualist vs. Collectivist, Holistic vs. Analytic, Object, Context Independent vs. Context, Context Dependent, and Relative vs. Absolute frameworks. Of these 25 papers, seven papers utilized Chinese participants, four papers utilized Chinese Singaporean participants, four papers utilized East Asian participants in which the exact ethnic make-up of the participants was not specified, three papers utilized East Asian Americans, two papers utilized Japanese participants, one paper utilized Chinese speakers, one paper used Japanese scenes, one paper measured for Collectivism, one paper primed participants for Interdependence, and one paper used a Left-to-Right reading culture to represent the Easterner/East Asian/Interdependent/ Collectivism/ Relative/Holistic/Context Dependent archetype. It should be noted that though Lewis et al. (2008) had an 'East Asian' American sample group, 16 of the 20 participants in this sample were Chinese American.

Fourteen papers utilized American participants, two papers utilized Canadian participants, one paper utilized 'Western Caucasian' participants, one paper utilized English speakers, one paper utilized African participants, one paper utilized Australian participants, one paper utilized German participants, one paper used American scenes, one paper measured for Individualism, one paper primed their participants for Independence, and one paper utilized Right-to-Left readers to represent the Westerners/Independent/Individualism/Absolute/Analytic/Context Independent archetype. Table 2.3 illustrates the cultural groups taken in all the studies.

Table 2.3. Summary of cultural groups described in each article used in the systematic review.

Article	R-L Reading	L-R Reading	Multidirectional Reading	Independence	Interdependence	Individualist	Collectivist	African	American	Australian	Arab	British	Canadian	Caucasian	Chinese	Chinese American	Chinese British	Chinese Singaporean	East Asian American	East Asian	Egyotian	German	Han Chinese	Japanese	Saudi	Western Caucasian	Native English Speaker	Native Greek Speaker	Native Chinese Speaker	Bilingual	Japanese Scenes	American Scene
EYE-TRACKING																																
Abed 1991	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chua et al. 2005	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rayner et al. 2007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	✓	✓	-	-
Papafragou et al. 2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	✓	-	-	-	-
Evans et al. 2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	✓	-	-	-
Goh et al. 2009	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rayner et al. 2009	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Miellet et al. 2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓	-	-	-	-	-	-
Amatya et al. 2011	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-
Ueda et al. 2012	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	✓
Petrova et al. 2013	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-
Senzeki et al. 2014	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-
Knox et al. 2014	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	✓	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zhang et al. 2015	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Masuda et al. 2016	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-
Duan et al. 2016	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Afsari et al. 2016	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wang et al. 2016	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hernandez et al. 2017	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Knox et al. 2017	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alotaibi et al. 2017	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Afsari et al. 2018	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	✓	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-
EEG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lewis et al. 2008	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-
Lin et al. 2008	-	-	-	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goto et al. 2010	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-
Kitayama et al. 2013	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-
Wang et al. 2014	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-
Mecklinger et al. 2014	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-
fMRI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gron et al. 2003	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gutchess et al. 2006	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goh et al. 2007	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hedden et al. 2008	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-
Aron et al. 2010	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-
Goh et al. 2010	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jenkins et al. 2010	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goh et al. 2013	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lidell et al. 2015	-	-	-	-	-	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paige et al. 2017	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-

"✓": The presence of that culture. Blank space indicates the absence of that culture.
"-": Indication that that measurement was not taken in

Quality Assessment

The average score of the seven papers that were rated by two investigators were 86.2 and 84.4, with individual ratings correlating at rho=0.991. This suggests that the adapted CCAT is reliable. The average score of all the studies is 81.5 showing that the quality of the studies overall is fairly high (See Table 2.1). When looking at the average score of the studies within the aforementioned categories, we see that the score for Scene Viewing falls below the average (76.3) and that Change Blindness is above (92.5).

Eye-Tracking

Starting from the early 2000s, eye-tracking has been used to measure eye movements to understand the link between culture and cognition. However, there is some dispute as to whether or not a cultural difference is evident.

A total of 22 papers were found to investigate cultural differences in scene/object perception using eye-tracking. These papers were categorized based on the general paradigm used: Scene Viewing; Change Blindness; Saccades; Narrative Construction with Motion Videos; and Reading Direction. The following is a breakdown of these various categories.

Scene Viewing

A total of 10 papers investigated culture specific eye movements during scene viewing. In addition, Masuda et al. (2016)'s paper was added to this analysis since no change trials were included in their change blindness study (see *Change Blindness* section). Four of these papers presented participants with images that consisted of an object(s) against a scenic background. Participants rated these images on a 1-7 likeness scale without knowing about a subsequent memory task. Both Chua et al. (2005) and Duan et al. (2016) were able to consistently find cultural differences in the number of fixations and fixation duration. However, Rayner et al., (2007) and Evans et al., (2009) were not able to replicate the findings. Results are shown in Table 2.4.

Table 2.4. Eye movement measurements taken in studies that used the scene memory task paradigm.

Articles	Fixation Count			Fixation Duration				Probab ility		Time To Look at Focal Object	Eye Movement Pattern Over time
	Total	Object	Background	Total	Object	Background	Av. Fixation Duration: Background	First Look to Object	Generally Fixating on the Object		
Chua et al. 2005 - All	✓	x	✓	-	-	-	✓	✓	-	✓	✓
Rayner et al. 2007 - All images	✓	-	-	✓	-	-	-	-	-	-	-
Rayner et al. 2007 - Subsection of Images	-	-	-	-	x	x	-	-	-	-	x
Rayner et al. 2007 - Subsection of Images w/ only 1 foregrounded object	x		✓	x	✓	x	-	-	-	-	-
Evans et al. 2009 - Encoding: All images	x	x	x		x	x	x	x	x	x	-
Evans et al. 2009 - Encoding: - Subsection of Images	x	x	x		x	x	x	x	x	✓	-
Evans et al. 2009 Test: All images	x	x	x		x	x	x	x	x	x	-
Duan et al. 2009	x	✓	✓	x	✓	✓	-	-	✓	-	✓

"✓": The presence of a cultural difference.
"x" : The absence of a cultural difference
"-": Indication that that measurement was not taken in the study

Of the remaining seven studies, six found a cultural difference in at least one of the measures taken however, where these cultural differences were found varied across the studies. The paradigms used in these six studies ranged from different variations of the aforementioned scene viewing paradigm (Rayner et al., 2009, Masuda et al., 2016), visual novelty (Goh et al., 2009), manipulation of focal object saliency (Zhang et al., 2015), utilizing blindspots (Miellet et al., 2010), testing for cultural affinity towards pictures of natural or cityscape scenes (Wang et al., 2016), and investigating the effects of priming by using pictures of culturally specific environments (Ueda and Komiya, 2012).

Rayner et al., (2009) investigated the effects of unusual or weird images in eye pattern movement, the thought being that Chinese participants would more quickly fixate and make more fixations to something unusual in the background of a scene, and the reverse would be true for the American participants. However, this was the only study of the remaining seven studies that found no cultural difference at all.

Change Blindness

Change Blindness is when an aspect of a visual stimulus is changed but goes unnoticed by the observer. This paradigm has been used to demonstrate the difference between “looking” and “attending” to something.

Masuda et al., (2016) and Alotaibi et al., (2017) both used this paradigm to investigate cultural differences in scene perception. It was thought that if certain cultures propelled attention towards the background more than others, then it would show that one would be better at detecting changes to the background than in the focal object and vice versa. The logic follows the Western-Eastern or Individualistic-Collectivistic framework whereby people from Western/ Individualistic cultures would be more efficient at detecting focal object changes, and people from Eastern/Collectivistic cultures would be more efficient at detecting changes to the background. In the included studies the comparison was between European Canadian/British participants and Japanese/Saudi Arabian participants respectively.

In both studies, participants were asked to detect changes that occurred in either the background or the focal object of a scene. Both studies found that regardless of culture, individuals tend to allocate more attention to the focal object than to the background. All participants detected focal changes faster than changes occurring in the background. However, the Japanese participants in Masuda et al., (2016)’s study were able to generally detect changes faster than the European Canadian participants. Contradictory to this, the Saudi Arabian participants in Alotaibi et al., 2017’s study took a longer time to detect changes compared to the British participants, however, this may be because the stimuli in this study were not presented as a flicker task but as pairs of images presented side by side, thus allowing the Saudi participants to scan the images for longer.

Both studies found no differences in the number of fixations made in the areas of interest (focal vs. background). In addition, Masuda et al. (2016) found no differences to the total number of fixations made, however Alotaibi et al. (2017) did find that the Saudi Arabian participants generally made more fixations. This along with Saudi Arabians taking more time to detect change, suggests that the task was more demanding/difficult for them.

Masuda et al., 2016 also found that European Canadians spent more time looking at the focal object than the background compared to the Japanese who distributed their attention more between the focal object and the background. This behavior in the European Canadians was exaggerated when the change occurred in the background, indicating a more focused attention to individual objects compared to the Japanese. No such differences were found in Alotaibi et al. (2017)'s study however, Saudi Arabians were found to take a significantly longer time between their first fixation on the change to their last fixation on the change when their final answer was recorded.

To further investigate differences in search strategy, Alotaibi et al., 2017 conducted a ScanMatch analysis whereby a score is given indicating similarity of scan paths between participants. Results showed that the scan paths were more consistent amongst British participants whereas there was greater variation in scan paths amongst the Saudi Arabian participants. Results of eye movement are shown in Table 2.5.

Table 2.5. Eye movement measurements taken for change blindness studies.

Article	Fixation Count	Fixation Duration	ScanMatch Analysis
Masuda et al.2016	x	✓	-
Alotaibi et al. 2016	✓	✓	✓

"✓": The presence of a cultural difference.
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Saccades

Saccadic eye movements are rapid, jerky movements of the eyeballs that occur when changing the point of fixation to a different location. Usually these movements occur 200 ms after the onset of a target stimuli (this is referred to as saccade latency), however reflexive eye movements can occur from time to time within 80-120 ms called express saccades (ES). ES have been shown to occur with greater frequency in monkeys than in humans though they can be elicited in humans if the experimental design incorporates a blank period (or a gap) between the fixation point and the appearance of the target as opposed to an absence of a blank period (or overlap).

Amatya et al. (2011) and Knox et al. (2017) both investigated the presence of express saccades (ES) in Chinese and British samples using the gap/overlap paradigm. Knox et al. (2017) took this a step further by including a sample of British Chinese individuals who were raised in the UK by Chinese parents. Both studies found a higher proportion of ES in the Chinese samples in the overlap condition. Though this showed that different groups of people can exhibit varying degrees of this sort of reflexive eye movement, it is still unclear as to the role culture plays in this difference in eye movement behavior. To take steps towards answering this question, Knox then conducted the same study with a group of Egyptians and compared the data to the Chinese and British data collected in the previous study. The study showed that Egyptians had a higher proportion of ES than the British but only slightly, and though the proportion was closer to that of the British, it did not reach significance when compared to the Chinese participants.

Petrova et al. investigated whether cultural differences existed in the nature of the curve saccadic eye movements take if the distractor and target are placed at different proximities to each other. Participants were asked to fixate on a centralized cross, but to shift their point of fixation whenever a target grey rhombus appeared either above or below the fixation cross. If a distractor grey ellipse appeared simultaneously in one of the four quadrants of the screen, the participants were asked to ignore it and to only look at the rhombus. The results showed that when the target and distractor were in opposite sides, the curvature of the saccade was greatest across all participants. However, the difference in curvature resulting from the different combinations of target and distractor locations within the Chinese sample was significantly greater than that seen in the German sample. This complies with the theory that Chinese people have a wider field of vision and can therefore, be more affected by distractors.

Narrative Construction with Motion Videos

Three studies investigated the influence of language on attention allocation while viewing short videos depicting various actions. In the studies done by Papafragou et al. (2008) and Senzeki et al. (2014), participants were randomly split between a Linguistic condition and a Non-Linguistic condition. Those in the Linguistic condition were informed prior to viewing the videos that they would have to describe what they had seen, while those in the Non-linguistic Condition were not made aware of this. In both studies, cultural differences only emerged in the Linguistic condition such that eye movements reflected the narrative structure of the language the participant spoke. It should be noted that cultural differences also emerged in the Non-Linguistic condition of Papafragou et al.'s (2008) study but only at the end of each video when the last frame was kept frozen for an additional two seconds. Participants in both conditions were given a memory test based on this last frame, however, only those in the Non-Linguistic condition were made aware of the memory test.

Goller et al. (2017) presented participants with pairs of videos depicting actions from four different categories: loose in, tight in, loose on, and tight on. Participants were asked to rate how similar the pair was. In congruence with the previous studies, participants' eye movements and ratings matched the way in which such actions were categorized in their native language. Results of eye movements are shown in Table 2.6 (See Appendix for full data).

Table 2.6. Summary of eye movement measurements taken for narrative construction studies.

Article	Fixation Count	First Look Type	Fixation Duration	Gaze Trajectory
Papafragou et al. 2008: Non-Linguistic Condition	x*	x	x	-
Senzaki et al. 2014: Non-Linguistic Condition	-	-	x	-
Papafragou et al. 2008: Linguistic Condition	✓	✓	x	-
Senzaki et al. 2014: Linguistic Condition	-	-	✓	x
Goller et al. 2017	✓	-	✓	-

"✓": The presence of a cultural difference.
"x" : The absence of a cultural difference
"-": Indication that that measurement was not taken in the study
*No differences were seen while the video was playing, however a significant difference was seen only after the video stopped and the last image was frozen.

Reading Direction

Four studies investigated the influence of habitual reading direction on spatial bias of attention when viewing images. Abed et al. (1991) had presented symmetrical, geometric images to participants whose native reading habit was either right-to-left (RTL), left-to-right (LTR), or vertical. Similarly, Hernandez et al. (2017) presented RTL and LTR readers with a webpage consisting of a series of various pictures and logos. This was to investigate whether the lower right corner of a webpage (referred to as the “corner of death” by web designers) still received the least amount of attention among RTL readers. Both studies found all participants to have leftward bias, particularly the top left corner, however both RTL and vertical readers showed a greater distribution in spatial attention.

Afsari et al. (2016 & 2017) continued to explore spatial bias and reading habits by investigating whether priming individuals who were bidirectional in their reading habits (i.e. have learned to read languages that are culturally written in the opposite directions) influenced where fixations were being made when presented with a natural scene or artificial fractal images. Both studies also found an overall leftward bias. Fixations for native LTR readers still maintained a leftward bias in all priming conditions however, the bias was reduced for the RTL condition. Priming only had an effect in the initial exploration of native RTL readers such that initial fixations where being made in accordance with the priming. After this initial exploration, spatial attention moved more to the left.

Overall, these studies show that regardless of culture, a leftward bias exists when viewing images. However, habitual reading direction does influence spatial attention which can be modulated to a degree by priming. Table 2.7 shows the results of eye movement measures taken.

Table 2.7. Summary of eye movement measurements taken for reading direction studies.

Article	No. of Fixations		Direction of Saccade		No. of Saccades		Total Fixation Duration
	Left	Right	Horizontal	Vertical	LTR	RTL	
Abed et al., 1991	x	x	✓	✓	✓	✓	-
Afsari et al., 2016	✓	✓	-	-	-	-	-
Afsari et al., 2017	✓	✓	-	-	-	-	-
Hernandez et al., 2017	x	✓	-	-	-	-	✓

"✓": The presence of a cultural difference.
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EEG

Six papers were found to investigate cultural differences in scene/object perception using EEG. The specific component waves that were studied across these papers include the P1, N1, N2, the Novelty P300/P3a/Novelty P3, P300/P3/Target P3, the Slow Wave (SW), the N350, the Late Positive Components (LPC), and the N400. These components are thought to be involved in attention, orientation, or semantic processing (see Appendix for summary of the different wave components.)

Three studies (Lewis et al. 2008; Kityama et al. 2013; Wang et al. 2014) investigated the Target P3 and Novelty P3 wave using different iterations of the 3-stimulus oddball paradigm, a task commonly used to measure attention. Here, a standard, a target, or a distractor object is presented randomly to the participants. The participant is tasked with having to report when the target object appears. Two of the three studies found a cultural difference.

The other waves that were investigated include P1, N1, N2, SW, N350, LPC, and N400 waves—cultural differences were seen for all except the N1 wave. Table 2.8 shows all studies that have used EEG to investigate cultural differences and which waves where investigated in which study.

Table 2.8. Summary of eye movement measurements taken for EEG studies.

Article	P1	N1	N2	P3 Target	P3 Novelty	SW	N350	LPC	N400
Lewis et al. 2008	-	-	-	✓	✓	-	-	-	-
Lin et al. 2008	✓	x	-	-	-	-	-	-	-
Goto et al. 2008	-	-	-	-	-	-	-	-	✓
Kityama et al. 2013	-	-	✓	x	x	✓	-	-	-
Wang et al. 2014	-	-	-	✓	✓	-	-	-	-
Mecklinger et al. 2014	-	-	-	-	-	-	✓	✓	-

"✓": The presence of a cultural difference.
"x" : The absence of a cultural difference
"-": Indication that that measurement was not taken in the study

fMRI

Ten papers investigated cultural differences in scene/object perception using fMRI. The paradigms used across the studies varied widely and included: learning memory, memory recall, passive scene viewing, absolute vs. relative judgements, congruent vs incongruent scene viewing, viewing of pictures of houses, visuospatial judgements, Navon shapes, and object similarity judgements (see Table 1).

Both Gutchess et al., (2006) and Goh et al., (2007) showed that Americans had greater activation in cortical areas associated with object processing compared to the Chinese sample when presented with scenes. This corresponded to the results seen in Grön et al., (2003) whereby Caucasian participants, during the viewing of geometrical shapes, showed greater activation for object processing and Chinese participants showed greater activation of cortical areas involved in visuospatial processing.

In accordance with the aforementioned studies, Hedden et al., (2008) and Goh et al., (2013) were able to show that when making relative versus absolute judgements - tasks that involve making judgements of a particular object relative to a specific context, e.g. the size of something relative to its frame, or based solely on the object itself and nothing else, the American sample taken in both studies showed greater neural activation in attentional networks during relative judgements, while the East Asian and Chinese Singaporean samples respectively showed greater activation during absolute judgement making. It should be noted that these attentional networks were involved in the processing of the object only, however, the greater effort required in processing objects during absolute judgements for Chinese and Chinese Singaporean participants indicates that more attention for object processing is needed to filter out the superfluous information of the context and vice versa for Americans. Similarly, when comparing self rated 'collectivists' with 'individualists' in their patterns of activation of attentional neural networks during local or global processing during a Navon task, Liddell et al., (2015) saw the same results as the East Asian/Chinese Singaporean and Americans respectively. In the same light, Jenkins et al., (2010) showed that Chinese participants had greater activation of cortical areas involved in object processing when presented with incongruent scenes (e.g. a crab in a parking lot) compared to congruent scenes (e.g. a crab on the beach), whereas American participants showed no significant difference in activation between the two scene types, suggesting that Chinese participants are influenced by contextual information during object processing more than Americans.

Though a strong case can be made regarding the presence of a cultural difference, it should be noted that cultural differences were not found in the parahippocampal place area (PPA) and the lingual landmark area (LLA), cortical areas associated with the processing of scenes as a whole and environmental landmarks (Goh et al, 2010). Also, contrary to what is expected, Paige et al., (2017) found that East Asians had greater activation for object processing when presented with pictures of objects without a background compared to the American participants.

Discussion

This systematic review examined 38 studies that have investigated the presence and nature of cultural differences in the visual perception of scenes and objects. These 38 papers were split into 3 main categories based on the type of technology used (EEG, eye tracking, and fMRI), and the presence of a cultural difference was noted in the types of measurements taken in each category. These papers were also evaluated for the cultural framework within which the studies were undertaken, along with the cultures used as samples to emulate the cultural framework.

A large majority of the studies were classified as using the Easterners vs. Westerners, East Asian vs. Westerners, Individualism vs Collectivism, Independence vs Interdependence, Analytic vs. Holistic, and Object, Context Dependent vs. Context, Context Independent cultural framework. These dichotomies have been used interchangeably in most of these studies; for example, Easterners/East Asian cultures have been described as being harmonious, following a more collectivist philosophy that rely on the interdependence of the denizens of such societies. Those belonging to this way of life are thought to be more prone towards holistic, context dependent perceptual processing. Westerners, on the other hand, are described as being more individualistic, greatly valuing one's independence within their society and are, therefore, thought to be more prone towards analytic/context independent perceptual processing (Goh et al, 2010; Miellet et al, 2010). When looking into the cultural groups included in these studies, Chinese, Chinese Singaporeans, and Han Chinese people were mainly used to exemplify Easterners/East Asian/Collectivism/Interdependence/Holistic/Context Dependence, and Americans were used to exemplify Westerners/Individualism/Independence/Analytical/Context Independence. This could mean that differences in behavior detected, and the types of measurements taken are more indicative of differences between these Chinese groups and Americans as opposed to Easterners and Westerners, Individualists and Collectivists, Independent and Interdependent, etc., people. It is important to note this because behaviors that are associated with specific cultural groups are being linked to larger concepts with the risk of over generalization. This could also mean that future research is being geared towards looking out for specific types of measurements, potentially making investigators less sensitive to other measures in which behavioral differences could manifest. This bias could also explain certain cultural differences found that don't match the expected patterns of eye movements. For example, Wang and Sparks, (2016) found that Australians made more overall eye fixations and had a longer fixation duration than the Chinese. Australians being the 'Westerners' and Chinese being the 'Easterners', one would expect the reverse to occur—Chinese participants would be expected to have a greater number of fixations as described in the study done by Chua, Boland, and Nisbett (2005). Thus to stringently ascribe a list of behaviors to specific categories like "East" and "West" can either blind us to what the true reasons behind the differences in behavior are-perhaps the difference in fixation numbers have nothing to do with being "Eastern" or "Western", but trying to pigeon-hole the justification as such might prevent us from seeing what are actually the leading factors.

Though this sort of Taylorean rhetoric existed in cultural cognitive research well before the use of eye tracking or neuroimaging technology, the dangers of its use now is the essentialization of social characteristics to a biological level, thus potentially perpetuating social issues that are a result of a colonial past. For example, "Westerners" have been characterized as independent and individualistic, qualities that have historically been associated with freedom, and "Easterners" have been characterized as being interdependent and harmonious, qualities that have historically been associated with restriction. Regardless of intention, these characteristics not only over-generalize large groups of people, it also maintains the inherent hierarchy of the West being "better" or more desirable than the East. This is not to say that social factors do not influence biology, simply that care must be taken in how these issues are discussed.

A total of six papers investigated cultural differences in scene perception using EEG. Nine different EEG waves were measured between the six papers, eight of which showed the presence of a cultural difference pertaining to object processing. However, only the P3 Target and P3 Novelty waves were investigated more than once, and the results are inconsistent despite all studies using the 3-stimulus oddball paradigm. It should be noted that Kitayama and Murata (2013), unlike the other studies, used scenes consisting of a background and a focal object instead of basic geometric shapes, letters, or numbers. Either the background or the focal object where changed to create the target and distractor stimulus. The P3 Target wave is thought to represent neural activity involved in detecting an infrequent stimulus that is actively being sought out for (Hruby and Marsalek, 2003). The P3 Novelty wave is thought to be elicited when one is presented with an infrequent stimulus that is irrelevant to the task at hand (Hruby and Marsalek, 2003). Though these waves are brought about for two different reasons, they are both the result of attentional processing. Therefore differences between them may be more clearly seen when the experimental stimuli are simple-basic geometric shapes-however complex stimuli-realistic scenes-may interfere with attention enough to make cultural differences less obvious. None-the-less, when taken all together, the EEG studies indicate that the cultural difference in perception most closely follows the holistic vs analytic dichotomy in that the East Asian American and Chinese participants were more sensitive to contextual information, allocating more attention to semantics—the meaning and relationship between objects and the scene as a whole—where as the American and German participants were less concerned for contextual information and attended more towards target objects. Though these studies indicate cultural differences in perception, more studies need to be done to verify the results of the extant studies.

The results of the EEG studies are partially congruent with the 10 papers that have investigated cultural differences in scene/object perception using fMRI. These studies have consistently shown a difference in activation in areas that are known to be involved in object processing as contained units, not part of a larger context or scene. However, whether background processing differs between cultures remains unclear. The remaining 22 papers utilized an eye-tracker to investigate cultural differences in scene perception. These 22 papers were split into 5 subcategories: Scene Viewing, Change Blindness, Saccade, Narrative Construction with Motion Video and Reading Direction. Most studies were in the Scene Viewing category which is also where the most discrepancies were seen. This could be because the tasks varied widely, some of which involved tasks that may not have demanded enough attention from the participants. In addition, saliency of the focal object plays a factor in detecting cultural differences in that the two appear to have a positive relationship—more salient the focal object, the more likely a cultural difference is detected. Furthermore, based on the collective results seen in the Change Blindness and the Narrative Construction and Motion Video categories, cultural differences appear to emerge more distinctly when top-down processing is involved. When comparing quality assessment scores, we can see that the scores within the Scene Viewing category are slightly lower than that of studies in the other categories, but not enough to be able to conclude a definite relationship (See Table 1).

The overall quality of the studies averaged high (81.6/99), however the range of quality ranged the widest within the eye-tracking studies (61-94) which may have contributed to differences in results.

These studies aimed to understand whether cultural differences in scene perception exist, and if so, under what conditions do these differences emerge, and at what stage of perception does differentiation occur. Results indicate that cultural differences do exist under certain conditions, however, enough studies repeating the same conceptual paradigm, or taking the same kinds of measures have not been carried out with eye tracking and EEG studies, thus rendering the reliability of the results unclear. Furthermore, studies that have been undertaken for the purpose of replication show conflicting resulting bringing into question the validity of the measurements taken to show cultural differences. Examining the quality assessments of these studies, we see that the quality of the studies was fairly consistent with the exception of the Change Blindness studies, which scored higher than average, and the Scene Viewing studies, which scored lower than the average. Variations in results within the Scene Viewing category could possibly, in part, be explained by the quality of the studies themselves, however, it is important to note that only a limited number of studies in this field of study have been done and it is, therefore, too soon to definitively conclude the extent to which this has driven the disparities seen. The fMRI studies are the only category of studies that have shown consistency in their results, providing the strongest case that cultural differences occur during encoding, consistency in cultural differences mainly being evident in the differences in level of activation in response to viewing objects. However, further research needs to be done in order to gain greater depth and clarity.

It should also be noted that all but one study only investigated scene perception, making it unclear whether there are cultural differences in object perception specifically or only in objects as part of scenes. Future research should not only focus on trying to expand understanding of whether these technologies can reliably detect cultural differences in perception, but also expand upon the investigation of whether there are cultural differences in viewing objects alone, rather than objects in scenes.

Furthermore, future research should be aware of the types of rhetoric used in their studies, so as to avoid potentially perpetuating preconceived notions and over generalizations.

Some limitations of this review must be highlighted. The methodological heterogeneity between the different articles prevented us from being able to conduct a more quantitative, or meta-analysis, which would potentially clarify better where cultural differences in perception are and which measurement among the fMRI, EEG, and eye tracker can best detect these differences. Our search was limited to the use of fMRI, EEG, and eye tracker technologies, but this means that other technologies used to examine cultural differences in perception may have been missed (though no other technologies were noted in the included studies). In terms of reliability of study selection, the selection of studies was undertaken by a single researcher and it is acknowledged that it would have been better to have a second researcher complete selection of some or all of the identified titles/abstracts. However only one paper was identified from other sources giving some indication that key papers were not missed from the search process. This review was also limited to just object/scene perception and did not explore other types of perception, such as color perception or face perception.

None-the-less, when taken altogether, the various technologies have allowed us to see an indication that when individuals are presented with new information without a specific goal or with a task that does not require much concentration, our methods of exploration, attentional allocation, and processing largely overlap with one another, regardless of culture. However, when deeper meaning is being derived, or when individuals are presented with information that demands greater attention or more topdown processing, culturally different perceptual processing occurs. For example, in the linguistic studies, cultural differences were only seen when individuals knew that they had to describe what they had seen—top down processing. These cultural differences are not set in stone and can, therefore, adopt the strategies used with the new "environment" as demonstrated when individuals were primed towards specific social orientations.

This review ultimately informs us on how to understand where cultural differences potentially lie and provides a platform from which one can explore differences in other cultures that have been less explored. This can allow for a greater understanding of why disparities in other fields, like that seen in Clinical Neuropsychology (Puente & Agranovich, 2003), and opens up an avenue towards investigating and understanding the driving forces behind them.

3.Variations in Performance During Scene Perception between Indians and the British: An Eye-Tracking Study

Abstract

Background: Over the last 15 years, there has been a renewed interest in the use of eye-tracking to understand cultural differences in perception and memory. Many of these studies claim that Westerners follow a more analytical cognitive style, attending more to focal objects, whereas East Asians follow a more holistic cognitive style, attend more to contextual information. However, a majority of these studies have shown these differences between Americans and Chinese. Studies have not investigated whether this theory would hold true for Indians and the British.

Method: In the present study, we measured the eye movements of Indian and British participants while viewing pictures of scenes consisting of a focal object against a complex background. After viewing the images, participants were then asked to complete a recall task. The scene perception-recognition paradigm was then followed by the use of the Singelis self-contrual scale. This scale was used to measure self-perceived adherence to collectivist or individualist values. The data were statistically evaluated using a generalized linear mixed models (GLMMs) framework.

Results: The British were able to accurately recall focal objects significantly better than the Indians. No difference in eye movements were seen between the Indians and the British in the background; differences were seen only within the focal object. Within the focal object, the British made a comparable number of shorter fixations and saccades to the Indians, but made significantly fewer longer fixations and saccades than the Indians. The Singelis self-construal scale showed that Indians were more collectivist than the British but the difference in score did not reach significance.

Conclusion: Though a difference in eye movement patterns were present between Indians and the British, they didn't adhere to the patterns expected by individuals from countries historically considered to be part of the East(India)and West(UK).

Introduction

Cultural psychologists have emphasized the role of culture in perception for many years. Many have demonstrated variations in behavioral responses, specifically reflecting different modes of attention, between people belonging to fundamentally different societal structures (Segall et al., 1966; Bornstein, 1975). For example, Masuda and Nisbett (2001) reported a comparison of European American and Japanese participants who were shown animated videos of underwater scenes and asked to describe the content. Results revealed that the Japanese participants were more likely than European Americans to refer to aspects about the background, and also about relationships between the background and the foregrounded objects. Furthermore, description styles revealed that Japanese participants put more emphasis on relational, temporal, behavioral, and feelings-related information (e.g. "At the beginning, a big fish was swimming towards the green seaweed;" or "the red fish must be angry because its scales were hurt") whereas European American participants were more likely to describe physical characteristics and actions specific to the object (e.g. "I saw three big fish swimming from left to right). Researchers concluded that Japanese participants allocated their attention evenly between the foreground and the background, whereas Americans selectively attended more to the foreground than to the background. These findings were then corroborated by Senzaki, Masuda, and Ishii (2014) who replicated the study using an eye-tracker, further demonstrating that participants' language structures corresponded to their eye movements; however, this was only in the case of participants having prior knowledge that they would be answering questions based on the videos. Similarly, Chua et al. (2005) measured eye movements of American and Chinese participants who were asked to view scenes consisting of a foregrounded object against a scenic background and rate how much they liked the picture. The results showed that Americans looked at the focal object sooner and for longer than the Chinese participants, and that the Chinese participants fixated on the background more compared to the North American participants. Researchers concluded that, like that seen in the Masuda and Nisbett (2001) study, Chinese participants allocated their attention to both the foreground and the background, whereas Americans selectively attended more to the foreground than the background. Similar results have been demonstrated in many studies including: a study done by Goh et al. (2009) in which Chinese Singaporean and Americans were exposed to visually novel information; in the "no change" trials of a change blindness study involving Japanese and Canadian participants (Masuda et al. 2016); and in a study investigating the effect of object saliency on eye movements in Chinese and Americans (Zhang et al., 2015). However, these findings have not always been consistent. Rayner et al. (2007) and Evans et al. (2009) both were unable to completely reproduce results seen in Chua et al.'s (2005) study despite having overlapping paradigms and all studies having recruited Chinese and American participants. Similarly, Rayner et al. (2009) was unable to detect cultural differences in eye movements between Chinese and Americans when asked to detect "weird" aspects of a picture that were either present on the focal object or somewhere in the background, nor was Miellet et al. (2010) able to detect cultural differences between British and Chinese participants in the use of extra-foveal information during scene viewing and object detection.

Many researchers have theorized on the driving forces behind cultural variations in attention. Nisbett and colleagues have argued that "Westerners" have developed a perspective that emphasizes individualism, where importance is placed on independence and self reliance (Nisbett, 2003). Thus, "Westerners" tend towards a more object-oriented/analytic mode of attention. By contrast, "Easterners" have developed a perspective that emphasizes collectivism, where interdependence promotes a more harmonious social structure. As a result, they tend towards the context-oriented/holistic mode of attention (Nisbett, 2003). Though merit should be given to the general concept that one's environment strongly shapes one's cognition, whether cognitive styles can be generalized to concepts like "Western" and "Eastern" or collectivism and individualism is unclear. Especially since the "West" and "East" do not have distinct geographical locations, and those countries that have been traditionally considered to be part of the "West" (e.g. the USA or Germany) and the "East" (e.g. China and India) contain within themselves cultures different enough from each other that such rhetoric has the potential to lay folly to over generalizations. For example, when looking at the cultural groups used in studies that have incorporated eye-tracking to measure cultural differences in object/scene perception, we see that a majority of studies have used Americans to exemplify the "West"/individualism and either Chinese or Japanese people to exemplify the "East"/collectivism. However only a few studies have investigated whether similar task performance differences and eye movement patterns are seen between other cultures that are considered to be "Western"/individualist and "Eastern"/collectivist (Miellet et al., 2010; Duan et al., 2016; Alotaibi et al., 2017). Furthermore, no studies that have used eye-tracking to investigate cultural differences in eye movement during object/scene perception have corroborated whether these cultures (or at least the study participants) indeed follow a value system that tends towards individualism or collectivism. These studies categorized the cultural groups as such based on historical context.

This present study aimed to determine whether comparable task performance and eye movement differences are evident between Indians and British people, two cultures that have been considered to be "Eastern"/collectivist and "Western"/individualist respectively. We used the same methodology as Chua et al. (2005), but also used the Singelis Self-Construal Scale, a scale of collectivism/individualism consisting of 30 statements regarding different social situations. Based on previous studies that have used eye tracking to investigate the influence of culture on the perception of objects and scenes, the eye movement measurements taken in this study included: Number of Fixations, Average Fixation Duration, and Number of Saccades. In addition to these measurements, Saccade Duration, Saccade Amplitude, Saccade Velocity, and Pupil Size were also recorded. If Indians and British people do tend towards collectivism and individualism respectively, we would expect their Singelis scores to coincide as such, and accordingly, we predicted that Indians would allocate more attention to the background compared to the British and that the British would allocate more attention to the focal object than to the background. Furthermore, we predicted Indians to be more influenced by the background than by the focal object when asked if they recognized the focal object during the recall portion of the study.

Methodology

Participants and Recruitment

Thirty-four British participants were recruited at the University of Glasgow (16:18 female:male, mean age: 23, age range: 19-36, age IQR: 5, mean years of education: 16) and 33 Indian participants were recruited at the National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore (18:15 female:male, mean age: 28, age range: 21-41, age IQR: 4 mean years of education: 20). All Indian and British participants were born and raised in India and the UK respectively.

The sample size that was aimed for was 66 (33 participants in each group). Previous studies had recruited between 20-25 participants (e.g. Chua et al., 2005; Rayner et al. 2007, Evans et al. 2009, Duan et al. 2016). Chua et al., (2005) reported cultural differences in memory for objects in a scene perception task with an effect size of d=0.72. Eye tracking differences had effect sizes ranging from d=0.64 to 0.94. Effect sizes for cultural differences in eye tracking measures in Duan et al., 2016 ranged from d=0.57 to 3.62. In Rayner et al., (2007) and Evans et al.,(2009) the primary eye movement outcome variables in a scene perception task comparing cultures had non-significant small effect sizes. It was evident therefore that effect sizes are variable across studies from small through to very large. For the present study it was decided to power the study to be able to detect an effect size broadly consistent with that of Chua et al, (2005) as their findings seem to represent a mid point of effect sizes found across studies. In relation to comparing cultural groups on the behavioral and eye-movement variables investigated, the present study was therefore powered to be able to detect an effect size of 0.7, with an $\alpha = 0.05$, and power = 0.8, meaning that a total sample size of 33 in each participant group was required (Faul, Erdfelder, Lang, & Buchner, 2007; Faul, Erdfelder, Buchner, & Lang, 2009).

Participants in the UK were recruited via online ads placed on commercial websites (e.g., Gumtree), community forums (e.g., The Student Voice), and social media (e.g., Facebook, Twitter). Additionally, individuals registered with the University of Glasgow Subject Pool, maintained by the Psychology Department, were emailed an advert for the study. Volunteers were paid £6/hr for their participation in the study.

Participants in India were recruited through known associates at NIMHANS. Participants were provided with tea or water and biscuits, and any travel expenses were covered. Participants were not paid for participating as this was not normal practice at the Institute.

Ethics Approval

All procedures and materials used were approved by the Review Boards of both the University of Glasgow College of Medical, Veterinary and Life Sciences (application number: 200160097), and the National Institute of Mental Health and Neurosciences, Bangalore. All participants who passed the initial screening gave written informed consent before proceeding.

Screening

All participants were asked to fill out a demographic form where they were asked about their age, gender, years of education, where they have lived and for how long. They were also asked to self-identify their ethnicity, and the ethnicity of their parents and grandparents (both maternal and paternal). Anyone who was under the age of 18 or did not self-identify themselves or their family members as solely one of the British or Indian ethnic groups were excluded. Participants were also ask if they had a history of brain injury or cognitive disfunction and were excluded if they did. Those who passed this initial screening then proceeded to the experimental tasks.

Apparatus

Eye movements were recorded using an Eyelink 1000 eye tracker in both the UK and India. Ocular dominance of the participants was determined using the Miles test (Miles, 1930). For this test, participants were asked to hold up a piece of paper with a hole cut out. While focusing on a designated spot on the wall through the hole, participants were then asked to bring the paper towards their face. Which ever eye the hole naturally landed on indicated the participant's dominant eye. Ocular dominance is the preferred eye by an individual for visual input. The image that falls within the retina of the dominant eye is more accurate, clear, stable, and larger (Shneor & Hochstein, 2005). In one study, the dominant eye was shown to have perceptual processing priority (Shneor & Hochstein, 2006). Thus, it was necessary to identify each participant's dominant eye. Once determined, participants were asked to sit in front of a computer screen (screen dimensions: 53.2 X 30 cm, resolution: 1920 X 1080) and to place their chin on a chin rest positioned at 57 cm from the screen. The height of the chin rest was adjusted according to the participant's comfort level. The Eyelink 1000 was then set to track the participant's dominant eye only and a nine point calibration and validation procedure was carried out. Between each trial, a central fixation point appeared on the screen in order to conduct a drift correction.

Materials and Procedure

The materials and procedures used were the same as that in Chua et al., 2005 study. Briefly, for the study phase, 36 scenic pictures composed of a single foregrounded object that was either living or nonliving against a background was used. During the object recognition phase, these 36 objects and backgrounds were then mixed and matched with 36 new objects and backgrounds. This set of 72 images can be split into 4 different conditions: 1) Old Object/Old Background: 18 previously seen objects against the original background, 2) Old Object/New Background: 18 previously seen objects against a new background, 3) New Object/Old Background: 18 new objects against previously seen backgrounds and, 4) New Object/New Background: 18 new objects against new backgrounds. All participants saw the same set of pictures however the order of the trials was randomized between participants. It should also be noted that the study was conducted completely in English as the researcher had no knowledge of the languages spoken in Bangalore.

During the study phase, we asked participants to place their chin on a chin rest and we proceeded with the calibration process as described above. Once calibrated, participants were asked to keep their head as still as possible and to only move their eyes. The screen in front presented them with instructions for the phase which the researcher read out and ensured that the participants understood what was being asked of them. Participants then proceeded with a practice trial before being presented with the study trials. Thirty-six pictures were presented to each participant for 3s each during which participants were free to move their eyes to view the picture. After viewing each picture, participants were asked to rate how much they liked the picture on a scale of 1-7 by pressing the number on the keyboard before moving onto the next trial. Between each trial, a central fixation point appeared and participants were asked to look directly at the point in order to conduct the drift check. After this phase, participants were administered the Mini-Mental State Examination (MMSE) as a distractor before continuing onto the object recognition phase (Tombaugh, Kristjanson, & Hubley, 1996). The MMSE is a widely used test of cognitive function and consists of 30 questions testing for orientation, attention, memory, language and visual-spatial skills. It should be noted that since all participants were fluent in English, the English version of the MMSE was administered. Participants had no prior knowledge of the object recognition phase. During the object recognition phase, we, once again, asked participants to place their chin on the chin rest and re-calibrated their dominant eye. The same screen then presented the participants with the instructions for the current task, and the researcher, once again, read out the instructions and ensured that the participants understood what was being asked of them. Participants then proceeded with two practice trials before continuing onto the the study trials. The set of 72 pictures mentioned above were presented to the participants. Once again, the images were presented for 3s each with a fixation point appearing between trials for a drift check. Participants were asked to judge within the 3s, whether or not they had seen the foregrounded object in the previous study phase by pressing designated keys for “yes” and “no”.

After completing the object recognition phase, participants were once again presented with the 72 images and were then asked to name the foregrounded object and to judge how familiar they were with it on a scale of “Not Familiar At All” to “Very Familiar”. At the end of the task, participants were then asked to complete the Singelis Self-Construal Scale. This scale consists of 30 statements regarding social situations, 15 of which describe situation that are more characteristic of individualism (e.g. I do my own thing, regardless of what others think) and the other 15 are more characteristic of collectivism (e.g I will sacrifice my self interest for the benefit of the group I am in). Participants were asked to rate how much they agreed or disagreed with each statement on a 1-7 Likert Scale. The scores of the 15 individualistic statements and 15 collectivist statements are added up separately and a score is calculated using the following formula: Total Score Individualism - Total Score Collectivism. A more negative score is indicative of greater collectivism and vice versa.

Data Analysis

Due to a recording error, the data for reaction time were corrupted rendering them unanalyzable, and were therefore excluded from the analysis. In further scrutiny of the data, two images from the object recognition phase of the study were excluded because the images was presented multiple times in a single trial, and one participant’s responses for the recognition phase were not recorded. Thus, for the study phase, the total sample size was N = 67, and for the recognition phase, N = 66.

First-level descriptive statistics were done to compare Indian and British groups in order to understand where potential differences in perception may lie.

Generalized linear mixed models (GLMMs) were used to determine if there were cultural differences in participants’ responses to the scene perception task. As there are many ways to quantify participant responses, we chose 16 response variables that were considered most likely to show cultural differences: Accuracy, Total Fixation Count, Focal Fixation Count, Background Fixation Count, Average Fixation Duration, Average Focal Fixation Duration, Average Background Fixation Duration, Total Saccade Count, Focal Saccade Count, Background Saccade Count, Average Saccade Duration, Average Focal Saccade Duration, Average Background Saccade Duration, Saccade Amplitude, Saccade Velocity, and Pupil Size. Note that the average durations refer to the average length of time of any given fixation or saccade as opposed to the average total length of time of fixations or saccades. Similarly, counts refer to the number of fixations or saccade in reference to a given image as oppose to fixations and saccades across all images together.

GLMMs present a flexible and convenient statistical framework with which to evaluate multiple hypotheses with respect to how variables interact with each other (if at all) and how they affect the participant response. Furthermore, the evaluation is done while correcting for non-independence. GLMMs pose advantages over analysis of variance (ANOVAs) for many reasons: 1) They allow for both categorical and continuous variables to be modeled ("mixed") simultaneously; 2) They account for non-independence through the hierarchal modeling of random factors (e.g., participant); and 3) They have greater statistical power since the analysis uses individual data points (with non-independence accounted for by the random effect) as opposed to using averages (Kliegl et al., 2010; Barr et al., 2013; Bates et al., 2015; Singmann et al., In Press). This GLMMs framework was ideal for this study because the study considered continuous, categorical/count, and binary fixed effects of 67 participants evaluating the same set of pictures. In other words, multiple responses by a single participant are by definition non-independent, because they are done by the same individual. Thus by modeling participant as a random factor, we were able to control for this non-independence while taking advantage of the power provided by using multiple data points per participant.

The analysis was performed using the R package *lme4* (Bates et al., 2015) for the binomial, count, and continuous response variables. We used the "glmer()" command for binomial and count responses. This command allowed us to specify the family of distribution—binomial and poisson respectively. By specifying the family, we were able to perform a logistic or poisson regression, contingent on the random effects. The “lmer()” command was used for the continuous responses, which essentially performs a linear regression given a normal distribution, contingent on the random effects. Using the 16 response variables, we built global models that included the following variables as explanatory variables: saccade location, country of origin, Singelis, age, gender, years of education, and MMSE (Table 3.1, see Table 3.2 for list of abbreviations used in models).

We systematically eliminated non-influential variables from the global model until we identified the simplest model that best explained the data (the most parsimonious model), and we based our conclusions on this best-fit model. Specifically, to systematically reduce variables from the global model, the *drop1* command was used to identify variables that did not explain a significant amount of variation in the response. We evaluated these uninfluential variables one-by-one, starting with the least influential one, by comparing the complex model to a reduced model that excluded the uninfluential variable. If a likelihood ratio test indicated no significant difference between the two nested models, the simpler model was then selected and the process of using the *drop1* command and likelihood ratio test was repeated until a significant difference was found between models, indicating that continuing to drop variables would represent a significant loss of explanatory power. At this point, the Akaike information criterion (AIC)—a measure that estimates the quality of each model relative to each other—for the two models was compared to determine which model was the better fit. This process continued until the more complex of the two models was considered to be the best-fit model, and we based our conclusions upon this best-fit model. All best fit models were also tested against the null hypothesis as further confirmation. The variables included in all best-fit models are considered significant at $P < 0.05$. All variables excluded was due to non-significance at $P > 0.05$.

For all best fit models for which a poisson or binomial distribution was selected, goodness of fit was assessed by confirming that the ratio of residual variance and degrees of freedom approached 1. Best fit models for background fixation count

Table 3.1. Global models created to predict participants' responses to the scene perception task. All GLMMs models take the form: response variable ~ explanatory variables + (1|random effects). In addition to the variables shown below, all GLMMs models contain the following explanatory variables and random effects: age+gender+yoe+mmse+(1|participant)+(1|picture).

Response Variable	**Explanatory Variables**	Distribution
Accuracy	country * condition + singelis * condition + country * familiarity + singelis * familiarity	Binomial
Total Fixation Count[1]	country *[2] av_fix_dur + singelis * av_fix_dur	Normal
Focal Fixation Count	country * focal_av_fix_dur + singelis * focal_av_fix_dur	Poisson
Background Fixation Count[3]	country * back_av_fix_dur + singelis * back_av_fix_dur	Normal
Average Fixation Duration	country * tot_fix_count + singelis *	Normal
Average Focal Fixation Duration	country * focal_fix_count + singelis * focal_fix_count	Normal
Average Background Fixation Duration	country * back_fix_count + singelis * back_fix_count	Normal
Total Saccade Count[3]	country * av_sacc_dur + singelis * av_sacc_dur	Normal
Focal Saccade Count	country * focal_sacc_dur + singelis * focal_sacc_dur	Poisson
Background Saccade Count	country * back_sacc_dur+singelis * back_sacc_dur	Poisson
Average Saccade Duration	country * tot_sacc_count + singelis * tot_sacc_count	Normal
Average Focal Saccade Duration	country * focal_sacc_count + singelis * focal_sacc_count	Normal
Average Background Saccade Duration	country * back_sacc_count + singelis * back_sacc_count	Normal
Saccade Amplitude[3]	country * sacc_loc + singelis * sacc_loc	Normal
Saccade Velocity	country * sacc_loc + singelis * sacc_loc	Normal
Pupil Size	country * fix_loc + singelis * fix_loc	Normal

[1]A GLMs was conducted for this variable instead of a GLMMs. See Methodology for details.
[2]"*": Denotes both the interactive and the additive effect
[3]The following tranformation was made on the response variable: sqrt(y)

Table 3.2. List of Abbreviations Used

Abbreviation	Meaning
av_fix_dur	average fixation duration
av_sacc_dur	average saccade duration
back_av_fix_dur	average fixation duration of fixations made in the background
back_fix_count	total number of fixations made in the background
back_sacc_count	total number of saccades made in the background
country	country of origin of participant
fix_loc	fixation location
focal_av_fix_dur	average fixation duration of fixations made in the focal object
focal_fix_count	total fixation number of fixations made in the focal object
focal_sacc_count	total number of saccades made in the focal
mmse	Mini Mental State Examination
sacc_locc	saccade location: focal or background
sqrt	square root
tot_fix_count	total fixation count
tot_sacc_count	total saccade count
yoe	years of education

and total saccade count indicated a poor fit with their natural distribution—poisson distribution. The data were then transformed using a square root (sqrt) transformation for which a normal distribution was chosen. All best fit models for which a normal distribution was selected were confirmed graphically using a qqplot, to check that the distribution of the residuals matched our selected distribution. Table 3.1 indicates which distributions were chosen for each response variable for which goodness of fit was confirmed.

For total fixation count, the data poorly fit the model despite having tried different transformations and distributions. As a result, we concluded that the GLMMs framework did not suit the analysis for this response variable. We therefore sacrificed statistical power by analyzing aggregated means in a general linear models (GLMs) framework—a framework analogous to an ANOVA. Since, data were aggregated means, a normal distribution was chosen for analysis, and goodness of fit was assessed and confirmed as described above.

Response variables presented in all graphs on the y-axis are predicted values derived from best fit models. In other words, graphs are not depictions of the raw data, but rather are depictions of the expected behavior based on the best fit model.

Results

In this study, we investigated whether the eye movement patterns of Indian and British participants while viewing scenes matched the patterns theorized in previous studies regarding Western/individualistic and Eastern/collectivist cultures. The eye movement measures taken included 15 different variable. In addition, Singelis and Accuracy were also investigated. Best fit models for these variables are shown in Table 3.3.

First-level descriptive statistics were done to on the eye movement data to compare Indian and British groups in order to understand where potential differences in perception may lie (Table 3.4).

Table 3.3. Best fit models for participants' responses in the scene perception task. Unless otherwise noted, all models contains the random effects: (1|participant)+(1|picture).

Response Variable	Best Fit Model
Accuracy	country * condition
Total Fixation Count[1]	country *[2] av_fix_dur + singelis + age
Focal Fixation Count	country * focal_av_fix_dur
Background Fixation Count[3]	back_av_fix_dur
Average Fixation Duration	singelis * tot_fix_count
Focal Fixation Duration	country * focal_fix_count
Background Fixation Duration	yoe
Total Saccade Count[3]	country * av_sacc_dur
Focal Saccade Count	null
Background Saccade Count	av_back_sacc_dur + age
Total Saccade Duration	tot_sacc_count
Focal Saccade Duration	null
Background Saccade Duration	back_sacc_count
Saccade Amplitude[3]	country + sacc_loc
Saccade Velocity	sacc_loc
Pupil Size	fix_loc + mmse

[1]A GLM was conducted for this variable instead of a GLMM. See Methodology for details

[2] "*": Denotes both the interactive and the additive effect

[3]The following tranformation was made on the response variable: sqrt(y)

Table 3.4. Means of response variables measured in scene perception task. Format of data is: Mean (SE).

Response Variables	India	UK
Total Fixation Count	9.99 (0.2)	9.89 (0.2)
Focal Fixation Count	5.1 (0.16)	5.36 (0.13)
Background Fixation Count	4.89 (0.18)	4.5 (0.17)
Average Fixation Duration (sec)	0.27 (0.008)	0.25 (0.006)
Average Focal Fixation Duration (sec)	0.25 (0.008)	0.25 (0.006)
Average Background Fixation Duration (sec)	0.25 (0.006)	0.23 (0.005)
Saccade Count	9.20 (0.2)	9.11 (0.19)
Focal Saccade Count	4.76 (0.16)	4.99 (0.13)
Background Saccade Count	4.45 (0.18)	4.12 (0.17)
Average Saccade Duration (sec)	0.07 (0.004)	0.07 (0.006)
Avergage Focal Saccade Duration (sec)	0.05 (0.003)	0.06 (0.003)
Average Background Saccade Duration (sec)	0.07 (0.005)	0.08 (0.01)
Saccade Amplitude	6.34 (0.17)	6.86 (0.18)
Saccade Velocity	131.63 (3.17)	132.01 (3.17)
Pupil Size	1352.687 (71.32)	1402.449 (67.99)

Significant differences between the British and the Indians were found in Total Fixation Count, Focal Fixation Count, Average Focal Fixation Duration, Total Saccade Count, Saccade Amplitude, and Saccade Velocity. Significant differences were also found in Accuracy (see below).

Singelis - Collectivism vs Individualism

Participants from India and the UK showed no significant difference in their self construal rating (M_{India} = -8.71(0.09), M_{UK} = -3.91(0.62); t = -1.382, p = 0.18, d = 0.340036).

Accuracy

Our best fit model for accuracy included the interactive effect of country of origin and condition (Table 3.3). Overall, the UK participants were significantly better than the Indian participants in accurately recognizing the previously seen focal object (Table 3.5).

Table 3.5. The average proportion of correct responses of participants within each condition of the recognition phase of the scene perception task. Data are the raw data in the format: Mean (SE). Sample size: n_{India} = 33; n_{UK} = 33.

Condition	**India**	**UK**
Old Object/Old Background (O/O)	0.24 (0.02)	0.73 (0.04)
Old Object/New Background (O/N)	0.54 (0.02)	0.49 (0.03)
New Object/Old Background (N/O)	0.42 (0.03)	0.64 (0.03)
New Object/New Background (N/N)	0.27 (0.02)	0.73 (0.03)

Specifically, UK participants out performed the Indian participants in all conditions except when the original focal object was placed against a new background—both Indian and UK participants performed comparably. Figure 3.1 depicts the predicted accuracy rates based on the best fit model. In other words, the graph shows the expected accuracy rate for the specific condition for each cultural group. These values are not the raw data, but rather a prediction of accuracy rate derived from the best fit model that is based on the data collected.

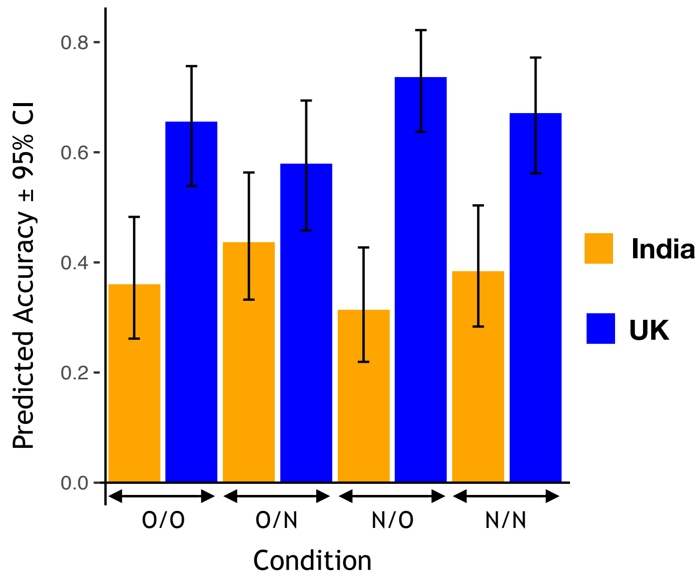

Figure 3.1. Predicted accuracy rates from the object-recognition phase. Data shown refer to the predicted accuracy with which Indians and the British were able to correctly identify the focal object as being the exact same object in the study phase. Data were derived from the best fit model for accuracy. Images in the object recognition phase belonged to one of four different conditions: Old Object/Old Background (O/O), Old Object, New Background (O/N), New Object/Old Background (N/O), and New Object/New Background (N/N). Object refers to the single foregrounded object (living or nonliving) in the picture; background refers to the remaining, complex spatial area in the visual picture.

Total Fixation Count

Our best fit model for the total fixation count included the interactive effect of country of origin and the average fixation duration, plus the additive effects of Singelis and age (Table 3.3). Singelis showed a positive relationship with the predicted average fixation count; this was consistent across country of origin, age, and average fixation duration. Average fixation duration and average fixation count were negatively correlated (Figure 3.2a-c). At shorter fixation durations, the number of fixations made by both Indians and the British were comparable (Figure3.2a); however, as the average fixation duration increased, the British made significantly fewer fixations than the Indians (Figure 3.2c). Age was positively correlated with predicted average fixation count. In other words, older individuals fixated more.

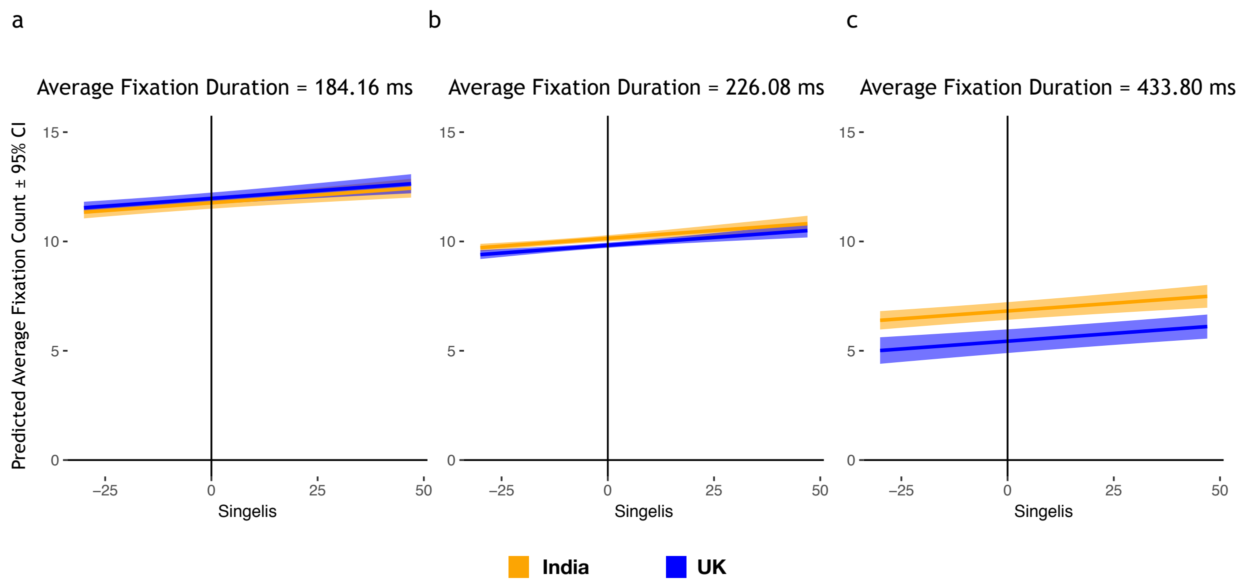

Figure 3.2. Predicted average fixation count during study phase. Data refers to the predicted average number of fixations made by Indians and British on any given image, at various average fixation duration time points, and across a Singelis scale-lower numbers refer to greater collectivist values, higher numbers refer to greater individualist values. Predicted values were derived from the best fit model for average fixation count. Data also represent participants at the age of 25-average age of all participants.

Focal Fixation Count

Overall, participants made more fixations to the focal object than to the background (focal fixations = 53%, background fixations = 47%). Our best fit model for the total focal fixation count showed the interactive effect of country of origin and focal fixation duration as a significant predictor of total focal fixation count; however, Singelis did not explain a significant amount of the variance (Table 3.3). The interactive effect was strong: the British showed a negative relationship between average focal fixation duration and the predicted fixation count, whereas the Indians showed no relationship at all. In other words, when fixating at any given point within the focal object for a shorter period of time, Indians and the British made a comparable number of fixations. However, when individuals started to fixate for longer periods of time, the number of fixations made by the British continued to decrease while the number of fixations for Indians remains unchanged, ultimately exceeding that seen by the British (Figure 3.3).

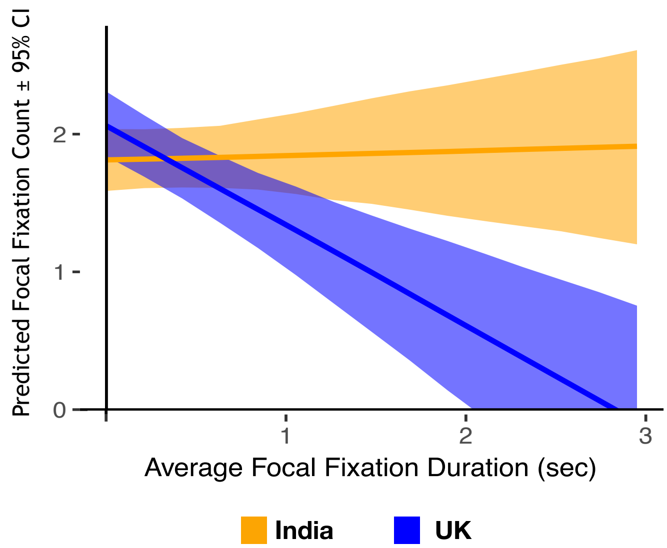

Figure 3.3. Predicted average fixation count within the focal object during study phase. Data refers to the predicted average number of fixations made by Indians and British within the focal object of any given image, across different average fixation durations within the focal object. Predicted values were derived from the best fit model for focal fixation count. Average focal fixation duration refers to the average length of time spent at any given fixation within the focal object. The focal object refers to the single foregrounded object (living or nonliving) in the picture.

Background Fixation Count

Our best fit model for total background fixation count suggested that neither country of origin nor Singelis explained a significant amount of the variance. The only variable retained was the average background fixation duration which had a positive correlation with total background fixation count—the number of fixations in the background increased as individuals fixated at any given point in the background for longer periods of time.

Average Fixation Duration

Average fixation duration refers to the average length of time spent on any given fixation. Our best fit model for average fixation duration showed the interactive effect of Singelis and total fixation count as significant predictors of the average fixation duration, however, country of origin did not explain a significant amount of the variance (Table 3.3). The slope of the negative correlation between the average fixation duration and total fixation count became steeper as individuals scored higher on the Singelis scale—i.e., more individualistic (Fig. 3.4). In other words, when more fixations were made, less time was spent fixating on any given point. This pattern intensified in people who are more individualistic.

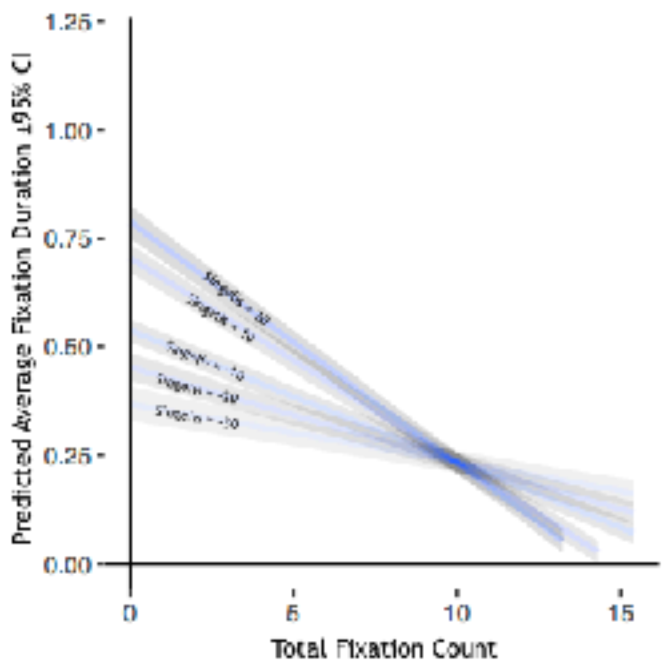

Figure 3.4. Predicted average fixation duration during the study phase. Data refers to the predicted average fixation duration made by Indians and British on any given image, across different total fixation counts. Predicted values were derived from the best fit model for average fixation duration. Average fixation duration refers to the average length of time spent on any given fixation.

Average Focal Fixation Duration

Average fixation duration refers to the average length of time spent on any given fixation within the focal object. Our best fit model for the average fixation duration for fixations made in the focal object showed the interactive effect of country of origin and focal fixation count as significant predictors of average fixation duration (Table 3.3). The British showed a negative relationship between focal fixation count and the predicted average fixation duration, whereas the Indians showed no relationship at all. These results correspond with our results for focal fixation count.

Average Background Fixation Duration

Average fixation duration refers to the average length of time spent on any given fixation within the background. Our best fit model for the average fixation duration of fixations made to the background suggested that neither country of origin nor Singelis explained a significant amount of the variance (Table 3.3). The only variable retained was years of education which had a positive correlation with average fixation duration of background fixations. In other words, individuals with more years of education fixated longer at any given point within the background.

Total Saccade Count

Our best fit model for the total saccade count showed the interactive effect of country of origin and the average saccade duration as a significant predictor of the total saccade count; however, Singelis did not explain a significant amount of the variance (Table 3.3). Total saccade count is negatively correlated with total saccade count. This negative correlation was steeper for the Indians than the British. In other words, there was no difference in number of short saccades between Indians and British, but the Indians made few longer saccades than the British (Figure 3.5).

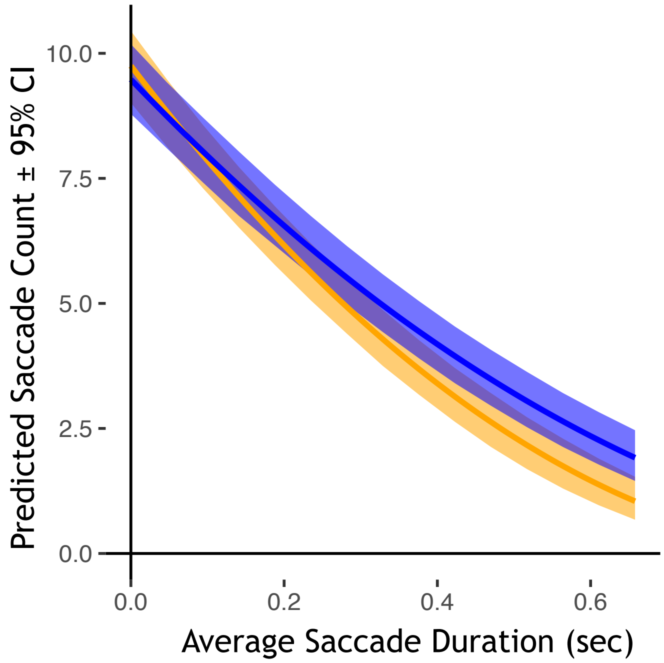

Figure 3.5. Average saccade duration during the study phase. Data refers to the predicted average saccade count made by Indians and British on any given image, across different average saccade durations. Predicted values were derived from the best fit model for average saccade duration. Average saccade duration refers to the average length of time for any given saccade.

Focal Saccade Count

Our best fit model for the total saccade count was the null model; none of our explanatory variables were significant predictors of the focal saccade count (Table 3.3).

Background Saccade Count

Our best fit model for the background saccade count suggested that neither country of origin nor Singelis explained a significant amount of the variance (Table 3.3). The only variables retained was the average saccade duration of saccades made to the background, which had a negative correlation with background saccade count, and age, which had a positive relationship with background saccade count. In other words, individuals made fewer saccades in the background when their saccades were longer. Furthermore, older individuals made more saccades in the background than younger individuals.

Average Saccade Duration

Average saccade duration refers to the average length of time for any given saccade. Our best fit model for the average saccade duration suggested that neither country of origin nor Singelis explained a significant amount of the variance (Table 3.3). The only variable retained was the total saccade count which had a negative correlation with average saccade duration. In other words, individuals who had longer saccade made fewer saccades overall.

Average Focal Saccade Duration

Average saccade duration refers to the average length of time for any given saccade within the focal object. Our best fit model for the average focal saccade duration was the null model; none of our explanatory variables were significant predictors of the average focal saccade duration (Table 3.3). These results correspond with our results for focal saccade count.

Average Background Saccade Duration

Average saccade duration refers to the average length of time for any given saccade with the background. Our best fit model for the average background saccade duration suggested that neither country of origin nor Singelis explained a significant amount of the variance (Table 3.3). The only variable retained was the background saccade count, which had a negative correlation with the average background saccade duration. In other words, individuals made fewer saccades in the background when their saccades were longer. These results correspond with our results for background saccade count.

Saccade Amplitude

Our best fit model for saccade amplitude suggested that the additive effect of country of origin and the saccade location—in the focal object or in the background—were significant predictors of saccade amplitude; however, Singelis did not explain a significant about of the variance (Table 3.3).

Saccade Velocity

Our best fit model for the saccade velocity suggested that neither country of origin nor Singelis explained a significant amount of the variance (Table 3.3). The only variable retained was the saccade location. The velocity of the saccades made within the focal object were significantly less than the saccades made within the background.

Pupil Size

Our best fit model for pupil size suggested that neither country of origin nor Singelis explained a significant amount of the variance (Table 3.3). The only variable retained was saccade location. The pupil size of individuals was significantly larger when they were looking at the focal object than when they were looking at the background.

Discussion

This study evaluated whether the performance of British and Indians on a scene perception/recall-memory task is reflected in patterns of eye movements between British and Indian participants. Furthermore, we investigated whether differences in eye movement were a function of self-construal. When individuals fixated at any given point for a short period of time, Indians and the British made a comparable number of fixations; however, as individuals fixated for longer periods of time, the number of fixation made by the Indians were significantly greater than the British. This may be because as fixations on the focal object increased in time-length, the number of fixations made in the focal object decreased for the British but remained about the same for Indians—fixations to the background were comparable between the Indians and the British. In addition, when individuals made shorter saccades, the number of saccades between the Indians and the British were comparable to each other; however when individuals made longer saccades, the number of saccades made by the British was significantly greater than the Indians—these did not differ between the focal object or the background. These results imply that individuals fixate for a shorter period of time and make shorter saccades, the pattern of eye movement between the Indians and the British are very similar to one another; however, as fixations and saccades are made for longer periods of time, the British scan the whole image more than the Indians and allocate more attention to any given point in the focal object when they fixated in it. This is not consistent with the West/East theory which would assume the Indians to scan the image more.

The difference in eye movements between Indians and British were reflected in their accuracy of performance in that Indians were, in general, poorer than the British in correctly recognizing the focal object. Their performance was particularly negatively affected when a new object was presented in the original background implying that the Indians were relying on the background in making their response much more than the British.

Indians and British participants did not significant differ in their rating of their self construal-no one cultural group rated themselves to be significantly more collectivist or individualist than the other. The standard error of the British participants' Singelis score was very high suggesting that there was considerable variability in our participants with regard to their self-construal. Interestingly the Indian participants were more consistent in their responses. It is unclear as to whether the results for the British sample is a true representation of the population, but it is possible that self-construal as collectivist/individualist is not a consistent feature of British culture, whereas self-construal as collectivist is a more consistent feature of Indian culture. Hofstede's scores of cultural dimensions for the UK were found to be very similar to the scores of the United States. For example, the cultural dimension with the highest rating for both countries was found to be individualism (UK: 89, US: 91); however, parts of the UK, Scotland and Wales in particular, have adopted more collectivist values into their social policies (Birrell, 2009). Recent political events including Brexit, Scottish and Catalonian independence, etc. have also brought light to a change in social ideology in continental Europe (Gobel, Benet-Martinez, Mesquita, & Uskul, 2018). This study is also limited in that the sample size taken for the measurement of self-construal may not be large enough to capture if the people of a culture more strongly associates themselves as collectivist or individualist. Put together, the UK may not be so easily classified as one or the other in the collectivist-individualist dichotomy. It should be noted that previous studies that have used this experimental paradigm have assumed their groups to be collectivist or individualist based on historical context and did not confirm these assumptions with any measure qualitatively or quantitatively. The Singelis Self-Construal Scale was specifically designed to capture characteristics of collectivism and individualism hypothesized by Markus and Kitayama (1991). This scale has been widely used to study the relationship between self-construal and cultural difference in cognition, emotion, and motivation (Gudykunst & Lee, 2003), and has been used across different cultures (Besta, 2018; Dardara, 2018; D'Amico & Scrima, 2016). However, it has not been validated in India; no scales of self-construal have been validated for both Indian and UK populations. Future research should consider validating this scale or other widely used scales, like the Gudykunst et al. (1996) Self-Construal Scale or the Swartz Value Scale, in the cultures being explored. A different option would be to include an ethnographic evaluation of self-construal, and implement a mixed methods approach, i.e. use both qualitative and quantitative research methods, as opposed to relying solely on quantitative measures that can be too reductionist or basing assumptions purely on historical knowledge.

Singelis scores were associated with some eye movement measures in that individuals who rated themselves as more collectivist were less affected by the negative relationship between fixation count and fixation duration than individuals who rated themselves as more individualist. Singelis, however, did not appear to influence any other eye movement measurements, thus not providing a very strong argument that self-construal influences perceptual strategies.

This study had several limitations. India is a highly diverse country with 22 major languages and hundreds of dialects that can be split into two main linguistic roots: Indo-Aryan—mainly spoken by those in the northern half of India— and Dravidian—mainly spoken by those residing in the southern half of India. There are many cultural differences in society that are also highly linked to religion and caste. Participants recruited in India were all staff members or PhD candidates at NIMHANS, mainly individuals from South India, and belonged to a high caste. Participants were also all in the medical field in some form. Therefore, the sample was not very representative of the Indian population. A similar argument can be made about the UK sample in that a majority of participants were from Scotland, even though the UK consists of four distinct cultural groups (Scottish, English, Welsh, and Northern Irish). Future research should consider conducting this study across difference cultural groups within India, and the UK in order to further understand cultural influences on eye movements and perception.

Furthermore, many participants in the Indian sample were not able to participate during working hours and so for many, data were collected in the early evening. Thus, cognitive functioning may have been affected which could have contributed to the reduction in performance in Indians. Although all participants were fluent in English, the study was also not conducted in the native language of the Indian participants making it unclear if any incorrect answers were a result of a misunderstanding of instructions. The investigator of this study had also faced difficulty in calibrating the eye movement of Indian participants in part because of difficulty in encouraging participants to maintain a fixation long enough on any given calibration fixation point before and during the task. Furthermore, after the initial calibration, participants are required to keep their heads as still as possible which proved to be difficult for Indian participants because of a characteristic, side-to-side, Indian head nod that is common in social interactions. Calibration accuracy was therefore challenging, potentially affecting the quality of the eye movement measurements taken.

This study also did not take into account certain factors that could have played a role in understanding culture. For example, though years of education was recorded, quality of early education was not examined, a factor that has been shown to influence cognitive development later in life (Sisco et al., 2015). Education in India takes a greater variety in that different schools are taught in different languages and follow different standardized educational curriculums. Socioeconomic status and caste were also not taken into consideration which could have also had influenced perceptual and cognitive abilities (Nair, 2009).

A point to also take note of is the use of the MMSE as a distractor and as part of the statistical analysis. Though any distractor can be used, the MMSE was chosen because it provided a variety of tasks that appropriately filled the allotted time gap between the study and memory-recall phase. It also provided a very simple and quick added check that participants did not have gross cognitive dysfunction. Use of the MMSE to assess for cognitive impairment could be considered a limitation as its effectiveness as a cognitive screening tool has been debated (Carnero-Pardo, 2013). However, part of the initial screening included a short history of any prior brain injuries or other conditions likely to impair cognition. An additional limitation is that the English version of the MMSE was used. However, Indian participants all had a fluency and literacy level high enough for there to be no significant reason to suspect that participants would not be able to complete the tasks appropriately. This was further re-enforced in that no participants scored below the MMSE cut-off score for impairment.

The study is also limited in that the scene images used had only one distinct focal object. Cultural differences seen in this study may not exist when more complex images with multiple focal points are presented (Rayner, Li, Williams, Cave, & Well). This study also doesn't inform us on potential differences in eye movements during different kinds of tasks that may require greater attention (Masuda, Ishii, & Kimura, 2016). Furthermore, this study does not inform us on whether these differences in eye movement translate to when individuals are presented with single objects against no background. Future research should consider exploring differences in eye movement between Indians and British with various types of stimuli and various types of tasks that demand different levels of attention.

In summary, the UK and India have historically been labelled as being part of the “West” and “East” respectively, and in extension, have been thought to adhere to individualist and collectivist social structures. Differences in eye movements were seen between Indians and the British however the differences did not align with the analytical cognitive style of the individualistic West or the holistic style of the collectivist East that have been used to describe eye movement patterns in previous studies. According the West/East theory, one would expect Indians to attend more to the background and the British to attend more to the focal object. However, here we see that both groups attended to the background comparably and Indians made more longer fixation in the focal object than the British. Furthermore, though the UK and India may previously have exhibited individualist and collectivist social structures respectively, ideology and social policies of both countries have shifted and don’t reflect such discrete categorizations anymore. The dichotomy with which these concepts have been described may not capture the more gradient nature with which they actually exists, therefore, the eye patterns seen by Indians and the British in this study are not captured by the current rhetoric. Expanding the vocabulary used to understand cognitive styles may allow for a more in depth understanding of possible variations of the analytic and holistic styles, along with other cognitive styles that may exist beyond the analytic and holistic types.

4.A Comparison of the Performance of Indian and British Participants on the Silhouettes Subtest of the Visual Object and Space Perception Battery: An Eye-Tracking Study

Abstract

Background: Clinical Neuropsychology allows for the evaluation of the proper functioning of our various cognitive domains, after experiencing an event that might render our cognitive ability to be subpar (e.g. a stroke). This evaluation is based on conscious behavioral responses on tests created to target specific aspects of cognition. However, these standardized tests have mostly been created in the U.S.A and certain European countries. Thus, when presenting these tests to countries that culturally differ from the originating countries, responses to these tests begin to vary, making the evaluation procedure more uncertain. One such assessment that has shown inconsistent performance levels is the Silhouettes Subtest of the Visual Object Space Perception Battery (VOSP) between the Indian and British population. The aim of this study is to further investigate the driving forcing behind the performance difference by investigating potential perceptual differences, through the use of an eye-tracker.

Methods: British and Indian participants were presented with the Silhouettes Subtest while having their eye movements tracked. Participants were also asked to complete the Singelis Self-Construal Scale in order to evaluate social values as a potential factor. The data were then statistically evaluated using a generalized linear mixed models (GLMMs) framework.

Results: The British, overall, performed better than the Indians. The performance of individuals was negatively correlated to the difficulty level of the object, for which, the British were seen to be more sensitive to than the Indian. Difficulty levels were based on the British normative data. Country of origin was associated with saccade amplitude and saccade velocity. Singelis was not an influential variable in predicting performance or in any of the eye movement data.

Conclusions: Performance differences present between the Indians and the British may, in part, be explained by cultural relevance and may, in part, be explained by potential differences in perceptual strategies in eye movement; however further investigation is required in understanding cultural differences in eye movement in single objects. Furthermore, social values did not present as a driving force for performance differences, thus further investigation into other factors that distinguish the two cultures is needed in order to understand which factors are, indeed, driving these differences.

Introduction

Clinical neuropsychology is the study of brain dysfunction expressed as an externalized behavior. In a clinical setting, this fills a diagnostic niche in which medical health professionals can systematically evaluate an individual's cognitive functioning when the brain's ability to operate at an expected level has been compromised. This evaluation is carried out using assessments that target the main domains of cognition: perception, orientation, motor abilities, attention, language, memory, executive function, affect, and social behavior (Lezak, Howieson, Bigler, & Tranel, 2012).

Many of these assessment tools that are used globally were created according to the norms of the people living in the specific environment in which the test was created. One example is of this is intelligence testing. A test to assess 'IQ' was first created in the early 1900s by Alfred Binet and Theodore Simon in France as a way to evaluate students. An adapted American version was quickly developed, though it was heavily criticized for its racial, socioeconomic, and gender bias (Reynolds & Suzuki, 2013). It was also criticized by David Wechsler, particularly for basing intelligence on a single score that depended on the quickness of verbal responses. Wechsler's advocacy for a more multidimensional approach to intelligence testing led to the development of the Wechsler-Bellevue Intelligence Scale (WBIS) that took both verbal and non-verbal, or performance, skills into account. The WBIS and the revised versions that have followed including the Wechsler Adult Intelligence Scale

(WAIS), the WAIS-R, and most recently, the WAIS-IV published in 2008, were created with the intention of being relevant to a wider population. However, these assessments were created in the U.S.A and have been shown to be inadequate in evaluating individuals from other cultures with varying education levels (Dershowitz and Frankel et al., 1975; Shuttleworth-Edwards et al., 2004; Walker et al., 2010).

Like the WAIS, many other neuropsychological assessments have been evaluated for cultural compatibility and have shown disparities in performance (Puente & Agranovich, 2004). Of these studies, only a handful have investigated the effects of culture on the performance of standard, and widely used, neuropsychological visual perceptual assessments such as the Visual Object and Space Perception Battery (VOSP) (Calvo et al. 2013, Kosmidis et al., 2010; Bonello et al. 1997). The VOSP was created in the UK and is a collection of eight subtests designed to examine specific facets of object and space perception (Lezak et al., 2012). For example, the Silhouettes Subtest is a set of 30 images (15 animate, 15 inanimate) that are shadows of real objects. The task is to identify what the objects are based on their shadow. The test intends to assess one's threshold for object recognition when provided with minimal information from unusual angles (Warrington and James, 1991). Recently however, Dutt et al. (2016) conducted a study in which the VOSP was administered to 200 Indians residing in Kolkata, India. The data were compared to data collected in Spain, Greece, the USA, and the normative data of the UK that was originally collected during the creation of the VOSP. Their results showed that the Indians performed significantly worse on the object perception tasks of the VOSP, including the Silhouettes Subtest, compared to the Americans, British, Greek, and Spanish populations (Dutt et al., 2016). Though this study has contributed to increasing awareness of a cultural bias, it is still unknown as to what explains this apparent discrepancy between cultures.

One method of studying culture and perception is through the use of eye-tracking technology. Studies suggest that certain aspects of an individual's cultural environment encourage distinct eye movement patterns. For example, studies have shown that, despite having a bias towards the upper left visual field when viewing something, one's habitual reading direction can influence the degree to which the bias exists (Afsari et al. 2016, Hernandez et al., 2017, Afsari et al., 2018). Other studies have shown that eye movement can mimic the grammatical structure of a native language, provided that the individual knows that they will have to describe what they are viewing afterwards (Papafragou et al., 2008, Senzaki et al., 2014). The most commonly studied cultural factor is the relation between eye movement patterns and collectivism, a social structure that emphasizes cohesiveness amongst individuals and prioritizes harmony in a group over the self, vs. individualism, a social structure that emphasizes the interest of the individual over that of the group. Studies suggest that individuals whose value system falls within collectivism or individualism exhibit eye movements that are either context dependent or context independent respectively (Chua et al., 2005, Goh et al., 2009, Zhang et al, 2015, Masuda et al., 2016, Wang et al., 2016). These studies focus on scene perception and as a result, the findings of these studies are representative of what may occur if the stimuli presented have a distinct focal object embedded in a type of background (e.g. a deer -the focal object - in a forest - the background). For example, Chua, Boland, and Nisbett (2005) presented participants with pictures of scenes and participants were asked to rate the image based on how much they liked it, before being given an unexpected memory task on the images they had just seen. Results showed that American participants looked at the focal object sooner and for longer than the Chinese participants. Both cultures made comparable number of fixations to the focal object, but the Chinese participants made more fixations to the background that the Americans. The more equal distribution of fixations between the object and the background by the Chinese participants suggests that binding of the object and background is occurring. Similar results were found by Duan, Wang, and Hong (2016) who presented the same stimulus sets to African and Chinese participants. However, it should be noted that contradictions have been seen in eye movement patterns (Rayner et al. 2007, Evans et al., 2009, Rayner et al., 2009, Miellet et al., 2009) and that these studies have used Chinese/Chinese Singaporean/Japanese/East Asians and Americans/Australians/Canadians/Western Caucasian to exemplify collectivism and individualism respectively. Furthermore, no studies testing for cultural differences in attention through the use of eye tracking have used any form of measurement that would corroborate the participating individuals as being collectivist or individualist.

In the present study, eye-tracking was used to investigate the eye movements of British and Indian participants on the Silhouettes Subtest of the VOSP. No studies have used an eye-tracker to investigate cultural differences in single object perception and therefore the aim of the present study was to examine whether the differences in patterns of eye movement between cultures evident during scene perception would also apply to single objects. Self-construal as collectivist/individualist was measured using the Singelis Self Construal Scale to determine whether there were differences in self-perception in terms of collectivism/individualism and whether this dimension affected performance (and associated eye movements) on the Silhouettes task. Participants were presented with each image of the Silhouettes Subtest and asked to identify the object. After completion of the subtest, participants were then asked to complete the Singelis Self Construal Scale.

Based on previous studies that have used eye tracking to investigate the influence of culture on the perception of objects and scenes the eye movement measurements taken in this study included: Number of Fixations, Average Fixation Duration, and Number of Saccades. In addition, Saccade Duration, Saccade Amplitude, Saccade Velocity, Saccade Angle, and Average Pupil Size were also recorded.

This study aims to investigate three objectives:
Objective 1: whether the assumptions of individualism and collectivism about Indians and British participants holds true using the Singelis Self Construal Scale.
Objective 2: whether culture and/or Singelis influence accuracy and reaction time.
Objective 3: whether culture and/or Singelis influence eye movement.

The experimental hypothesis tested was that there would be significant differences in accuracy, reaction time, and eye-movements between Indian and British participants, which was contrasted with a null hypothesis of no significant between-culture difference.

Methodology

Participants and Recruitment

Participants in this study were the same participants that were recruited in the previous study (see chapter 3). To re-iterate, thirty-three British participants were recruited at the University of Glasgow (16:17 female:male, mean age: 23, mean years of education: 16) and 33 Indian participants were recruited at the National Institute of Mental Health and Neurosciences (NIMHNS), Banglaore (18:15 female:male, mean age: 28, mean years of education: 20). All Indian and British participants were born and raised in India and the UK respectively. The sample size was sufficient to be able to detect a difference between groups of d=0.7. The study by Dutt et al. (2016) found differences on the Silhouettes task between young (<50 years) Indian and Greek participants with an effect size of d=1.87.

Participants in the UK were recruited via online ads placed on commercial websites (e.g., Gumtree), community forums (e.g., The Student Voice), and social media (e.g., Facebook, Twitter). Additionally, individuals registered with the University of Glasgow Subject Pool, maintained by the Psychology Department, were emailed an advert for the study. Volunteers were paid £6/hr for their participation in the study.

Participants in India were recruited through known associates at NIMHANS. Participants were provided with tea or water and biscuits, and any travel expenses were covered. Participants were not paid for participating as this was not normal practice at the Institute.

Ethics Approval

All procedures and materials used were approved by the Ethics Committees of both the University of Glasgow College of Medical, Veterinary and Life Sciences (application number: 200160097), and the National Institute of Mental Health and Neurosciences, Bangalore. All participants who passed the initial screening gave written informed consent before proceeding.

Screening

All participants were asked to fill out a demographic form where they were asked about their age, gender, years of education, where they have lived and for how long. They were also asked to self-identify their ethnicity, and the ethnicity of their parents and grandparents (both maternal and paternal). Anyone under the age of 18 or did not self-identify themselves or their family members as solely one of the British or Indian ethnic groups were excluded. Participants were also ask if they had a history of brain injury or cognitive dysfunction and were excluded if they did. Those who passed this initial screening then proceeded to the experimental tasks.

Apparatus

Eye movements were recorded using the Eyelink 1000. Ocular dominance of the participants was determined using the Miles test (Miles, 1930). For this test, participants were asked to hold up a piece of paper with a hole cut out. While focusing on a designated spot on the wall through the hole, participants were then asked to bring the paper towards their face. Which ever eye the hole naturally landed on indicated the participant's dominant eye. Once determined, participants were asked to sit in front of a computer screen (screen dimensions: 53.2 X 30 cm, resolution: 1920 X 1080) and to place their chin on a chin rest positioned at 57 cm from the screen. The height of the chin rest was adjusted according to the participant's comfort level. The Eyelink 1000 was then set to track the participant's dominant eye only and a nine-point calibration and validation procedure was carried out. Between each trial, a central fixation point appeared on the screen in order to conduct a drift correction.

Materials and Procedure

All procedures were conducted in English, by the same researcher, for all participants in both the UK and in India. Prior to commencing the study, the English version of the Mini Mental State Examination (MMSE) was administered to all participants. The MMSE is a commonly used 30-point measure for the screening of cognitive impairment(s). This was done to ensure that all participants were cognitively "healthy". It should be noted that the English version of the MMSE was used. Indian participants all had a fluency and literacy level high enough for there to be no significant reason to suspect that participants would not be able to complete the tasks appropriately.

After administering the MMSE, participants were presented, one-by-one, with the 30 (15 animate, 15 inanimate) silhouetted objects of the Silhouettes Subtest of the VOSP, in random order. Participants were instructed to keep their head as still as possible and to fixate on the cross located at the center of the screen until an object was presented. When an object was presented, participants were free to move their eyes only, and were given up to one minute to identify the object. When the participants felt confident about their final answer, they then said their answers out loud while simultaneously pressing the spacebar, which provided a timestamp and allowed the participant to move on to the next image. Participants were informed that they were allowed to provide their final answer in whichever language best suited them. Verbal responses were recorded using a recording device. It should be noted that the VOSP is typically not administered in a computerized form. Furthermore, it should be noted that the administration of the Silhouettes Subtest in this study deviated from how it is typically done in a clinical setting. In addition to it not being a computerized assessment, in a clinical setting, the Silhouettes Subtest is administered by first presenting the animal silhouettes and then the inanimate object silhouettes, always in the same order. Patients are told what category the object belongs to and are then asked to identify it (e.g. "this is a drawing of an animal, can you name it?" and so on). This procedure is repeated for each image and is only discontinued if the patient makes five consecutive mistakes. The patient is also under no time limit in providing an answer.

After completing the all thirty images of the Silhouettes Subtest, participants were asked to complete the Singelis Self-Contrual Scale (Singelis, 1994). This scale consists of 30 statements regarding social situations, 15 of which describe situation that are more characteristic of individualism and the other 15 are more characteristic of collectivism. Participants were asked to rate how much they agreed or disagreed with each statement on a 1-7 Likert Scale. The scores of the 15 individualistic statements and 15 collectivist statements are added up separately and a score is calculated using the following formula: Total Score Individualism - Total Score Collectivism. A more negative score is indicative of greater collectivism and vice versa.

Data Analysis

An initial analysis was conducted to compare Indian and British participants on each of the variables measured.

We used generalized linear mixed models (GLMMs) to determine if there were cultural differences in participants' responses to the Silhouette subtest. As there are many ways to quantify participant responses, we chose ten response variables that were considered most likely to show cultural differences based on previous research: Accuracy, Reaction Time (rt), Number of Fixations (fix.count), Average Fixation Duration (av.fix.dur), Number of Saccades (sacc.count), Average Saccade Duration (sacc.dur), Saccade Amplitude (sacc.amp), Saccade Velocity (sacc.vel), Saccade Angle (sacc.angle), and Average Pupil Size (av.pup.size). Note that the average durations refer to the average length of time of any given fixation or saccade as opposed to the average total length of time of fixations or saccades.

The same statistical method used in Chapter 3 was also used in this study. The following is a repetition of the details of the type of statistical method used. GLMMs present a flexible and convenient statistical framework with which to evaluate multiple hypotheses with respect to how response variables interact with each other (if at all) and affect the participant response, and do so while correcting for non-independence. GLMMs have advantages over analysis of variance (ANOVAs) for many reasons: 1) They allow for both categorical and continuous variables to be modeled ("mixed") simultaneously; 2) They account for non-independence through the hierarchal modeling of random factors (e.g., participant number); and 3) They have greater statistical power since the analysis uses individual data points (with non-independence accounted for by the random effect) as opposed to using averages (Kliegl et al., 2010; Barr et al., 2013; Bates et al., 2015; Singmann et al., In Press). This GLMMs framework was ideal for our study because our study considered continuous, categorical/count, and binary fixed effects of 66 participants evaluating the same 30 pictures. In other words, multiple responses by a single participant are by definition non-independent, because they are done by the same individual. Thus by modeling participant as a random factor, we were able to control for this non-independence while taking advantage of the power provided by using multiple data points per participant.

The analysis was performed using the R package *lme4* (Bates et al., 2015) for the binomial, count, and continuous response variables. We used the "glmer()" command for binomial responses, which essentially performs a logistical regression contingent on random effects, and the "lmer()" command for continuous responses, which essentially performs a linear regression contingent on random effects. Using the ten response variables, we built 10 global models that included the following variables as part of the explanatory variable: country of origin, object difficulty (obj_diff), singelis, age, gender, and years of education (yoe) (see Table 4.1). The variables described collectively are believed to provide insight into the three objectives mentioned in the introduction.

Table 4.1. Global models created to predict participants' responses to the Silouettes subtest. All models take the form: response variable ~ explanatory variables + (1|random effects). In addition to the variables shown below, all models contain the following explanatory variables and random effects: age+gender+yoe+(1|participant)+(1|picture).

Response Variables	Global Models	Distribution
Accuracy	country *[1] obj_diff + singelis * obj_diff	Binomial
Reaction Time[2]	country * obj_diff + singelis * obj_diff + accuracy	Normal
Fixation Count	country * obj_diff + singelis * obj_diff + accuracy + rt	Negative Binomial
Average Fixation Duration[2]	country * obj_diff + singelis * obj_diff + accuracy + rt	Normal
Saccade Count	country * obj_diff + singelis * obj_diff + accuracy + rt	Negative Binomial
Saccade Duration[2]	country * obj_diff + singelis * obj_diff + accuracy + rt	Normal
Saccade Amplitude[2]	country * obj_diff + singelis * obj_diff + accuracy + rt	Normal
Saccade Velocity	country * obj_diff + singelis * obj_diff + accuracy + rt	Normal
Saccade Angle	country * obj_diff + singelis * obj_diff + accuracy + rt	Normal
Mean Pupil Size	country * obj_diff + singelis * obj_diff + accuracy + rt	Normal

[1] "*": Denotes both the interactive and the additive effect

[2] The following tranformation was made on the response variable: log(y)

Object difficulty was defined using the percentage of individuals in the original normative data set who correctly identified the object. This was how the creators of this test had determined the difficulty level of each image. We systematically eliminated non-influential variables from the global model until we identified the simplest model that best explained the data (the most parsimonious model), and we based our conclusions on this best-fit model. Specifically, to systematically reduce variables from the global model, the *drop1* command was used to identify variables that did not explain a significant amount of variation in the response. We evaluated these variables one-by-one, starting with the least influential one, by comparing the global model to a reduced model that excluded the variable. If a likelihood ratio test indicated no significant difference between the two nested models, the simpler model was then selected and the process of using the *drop1* command and likelihood ratio test was repeated until a significant difference was found between models, indicating that continuing to drop variables would represent a significant loss of explanatory power. At this point, the Akaike information criterion (AIC)—a measure that estimates the quality of each model relative to each other—for the two models was compared to determine which model was the better fit. This process continued until the more complex of the two models was considered to be the best-fit model, and we based our conclusions upon this best-fit model. All best fit models were also tested against the null hypothesis as further confirmation. The variables included in all best-fit models are considered significant at $P < 0.05$. All variables excluded was due to non-significance at $P > 0.05$.

All best fit models for which a poisson distribution and a binomial distribution were selected, goodness of fit was accessed by confirming that the ratio of residual variance and degrees of freedom approached 1. For both fixation count and saccade count, the data were accessed to be over-dispersed which was then corrected for by using a negative binomial distribution.

For all best fit models for which a normal distribution was selected (Table 4.1) it was confirmed graphically that the distribution of the residuals matched our selected distribution using a qqplot. The data for reaction time, average fixation duration, average saccade duration, saccade amplitude, and average pupil size were assessed to be over-dispersed which were corrected for by performing a log transformation.

Response variables presented in all graphs on the y-axis are predicted values derived from best fit models. In other words, graphs are not depictions of the raw data, but rather are depictions of the expected behavior based on the based fit model.

Results

In this study, we investigated whether the difference in performance on the Silhouettes Subtest of the VOSP could be explained by a difference in eye movement patterns. The eye movement measures taken included 8 different variable. In addition, Singelis, Reaction Time, and Accuracy were also investigated. Best fit models for these variables are shown in Table 4.2. In addition to these variables, self-contrual was also measured using the Singelis Self-Construal Scale.

Table 4.2. Best fit models for participants' responses in the Silouettes Subtest. All models contains the random effects: (1|participant)+(1|picture).

Response Variables	Global Models
Accuracy	country *[1] difficulty_level
Reaction Time[2]	accuracy
Fixation Count	accuracy + rt
Average Fixation Duration[2]	accuracy + rt
Saccade Count	accuracy + rt
Saccade Duration[2]	rt
Saccade Amplitude[2]	country + rt
Saccade Velocity	country + rt
Saccade Angle	rt
Mean Pupil Size	rt

[1] "*": Denotes both the interactive and the additive effect.

[2] The following tranformation was made on the response variable: log(y).

First-level descriptive statistics were also done to compare Indian and British groups in order to understand where potential differences in perception may lie (Table 4.3).

Table 4.3. Means of response variables measured in Sihouettes subtest. Format of data is: Mean (SE).

Response Variables	India	UK
Accuracy*	15.71 (0.48)	17.21 (0.57)
Reaction Time (sec)	6.97 (0.59)	7.91 (0.72)
Singelis	-8.71(0.09)	-3.91(0.62)
Fixation Count	20.25 (1.56)	22.46 (2.01)
Average Fixation Duration (sec)	0.29 (0.008)	0.29 (0.008)
Saccade Count	19.43 (1.56)	21.62 (2.07)
Saccade Duration (sec)	0.05 (0.003)	0.05 (0.004)
Saccade Amplitude	3.17 (0.06)	3.62 (0.01)
Saccade Velocity	84.53 (1.83)	89.85 (2.08)
Saccade Angle	7.54 (1.31)	4.51 (1.32)
Mean Pupil Size	1146.89 (55.43)	1103.98 (48.46)

*Average Score out of 30

Accuracy and reaction time, as explanatory variables, were seen to explain most of the variance seen in the response variables (Table 4.2) while age, yoe, and gender, were seen to not influence any of our response variables. Country of origin was seen to influence accuracy, saccade amplitude, and saccade velocity, however, despite our predictions, Singelis was not a significant predictor for any of our response variables measured (Table 4.2).

Singelis - Collectivism vs Individualism

The Singelis scores of India and British participants were not significantly different due to the high variance in the British sample (M_{India} = -8.71(0.09), M_{UK} = -3.91(0.62); p = 0.18, d = 0.34).

Accuracy and Reaction Time

Overall, the British were more accurate than the Indians in identifying the silhouetted objects; however the difference in performance alone did not reach significance (Table 4.3). Our best fit model for accuracy showed a significant interactive effect of country of origin and object difficulty level (Table 4.2). Object difficulty had a negative relationship with predicted accuracy. In other words, the performance of all participants predictably continued to drop as the objects became more difficult; however, this relationship showed to be stronger for the British than for the Indian; as expected, the British were more sensitive to object difficulty than the Indians-the British performed better than the Indian on the easy objects but worse than the Indians on the difficult objects (Figure 4.1).

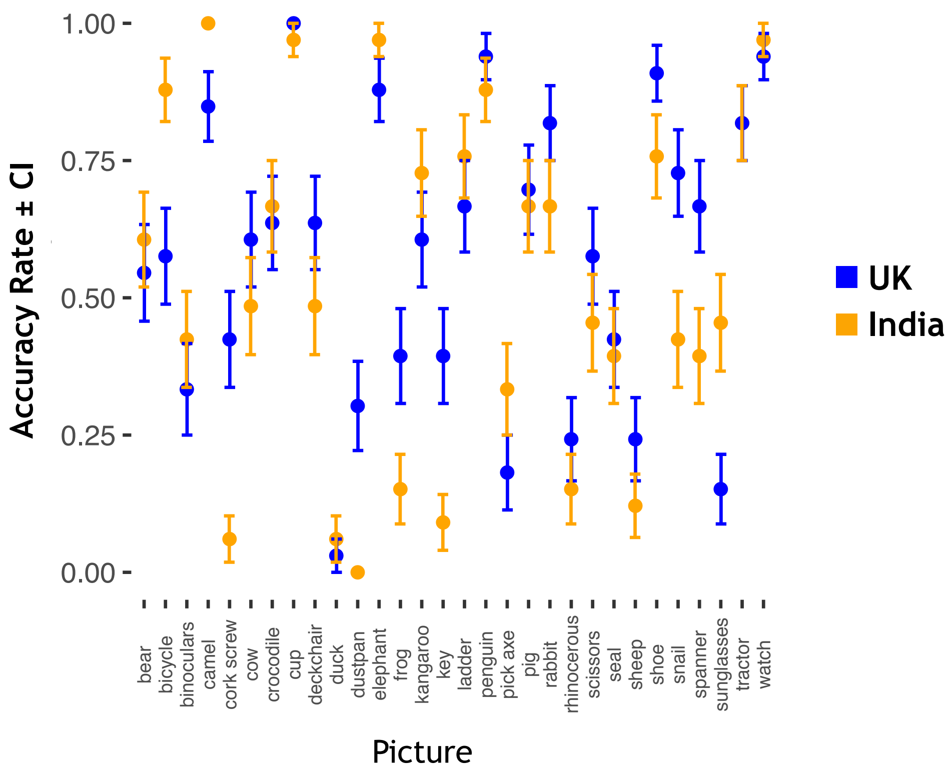

Figure 4.1. Predicted accuracy rates from the Silhouettes Subtest. Data shown refer to the predicted accuracy with which Indians and the British are able to correctly identify the silhouetted objects across different difficulty levels. Predicted values were derived from the best fit model for accuracy.

Of the 30 images in the set, six images showed a considerable difference in performance between the two cultures: Bicycle, Corkscrew, Frog, Key, Snail, Spanner. Of these six images, Indian participants out-performed the UK participants only on the Bicycle (Figure 4.2).

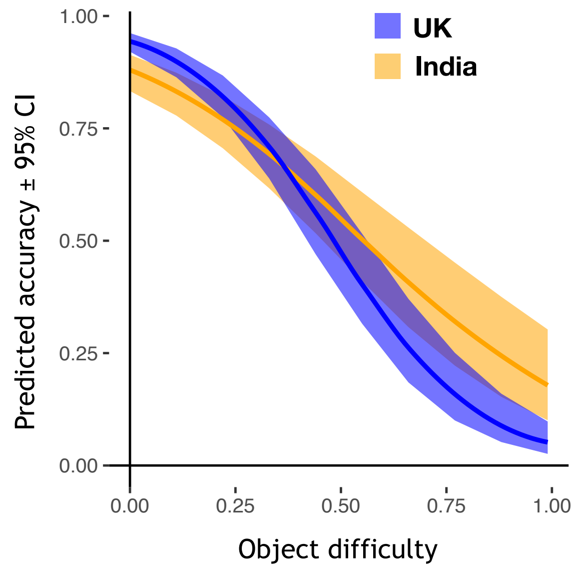

Figure 4.2. Accuracy rates of each picture from the Silhouettes Subtest. Data shown refer to the accuracy rates with which Indians and the British were able to correctly identify the silhouetted objects. Values were derived from the raw data for accuracy, and error bars refer to standard error.

Our best fit model for reaction time suggested that culture did not explain a significant amount of the variance in reaction time. Rather the only variable retained was accuracy which was negatively correlated with reaction time—participants reacted slower to questions they answered incorrectly.

Eye Movement Data

Of the eight different eye movement measurements taken, only models for saccade amplitude and saccade velocity showed an effect of country of origin—reaction time was also a significant predictor in these two models (Table 4.2). Best fit models for both variables predicted that across all participants, saccade amplitude and saccade velocity decreased as reaction time increased, with both being greater for the British than for the Indians (Figure 3a and 3b).

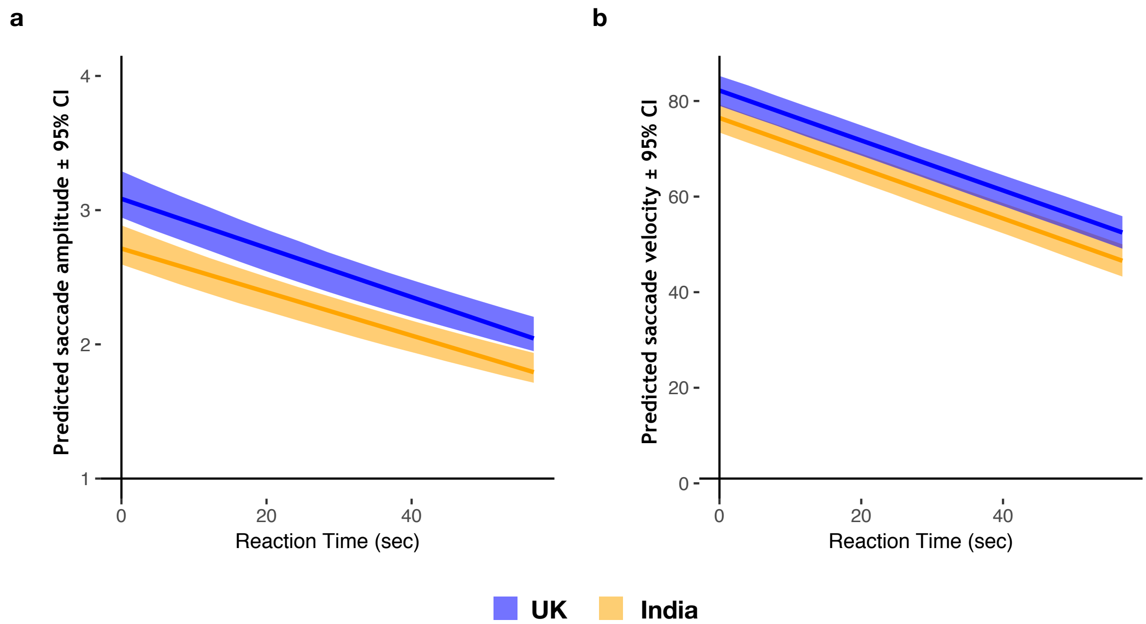

Figure 4.3. Predicted saccade amplitude (a) and predicted saccade velocity (b) from the Silhouettes Subtest. Data refers to the predicted saccade amplitude (a) and predicted saccade velocity (b) of Indians and the British across reaction times. Predicted values were derived from the best fit models for saccade amplitude and saccade velocity.

Our best fit models for fixation count, average fixation duration, and saccade count, suggested that only accuracy and reaction time explained a significant amount of the variance, such that all variables were negatively correlated with accuracy but positively correlated with reaction time—the longer participants looked at any given point, the longer it took for participants to react, and it also decreased the chances of answering correctly. Average fixation duration refers to the average length of time spent on any given fixation.

Our best fit models for average saccade duration, saccade angle, and average pupil size, suggested that only reaction time explained a significant amount of the variance such that both saccade duration and average pupil size were positively correlated with reaction time, however saccade angle was negatively correlated with reaction time—participants' had longer saccades and larger pupils when they took longer to react however the angle of their saccades increased the quicker they responded. Average saccade duration refers to the average length of time spent on any given saccade.

Discussion

The present study examined cultural differences in patterns of eye movement between Indian and British sample groups during the Silhouettes Subtest of the VOSP. In addition to examining country of origin, participants were asked to fill out a Singelis Self Construal Scale in order to investigate if variations in behavior could be explained by a social values scale. Our findings showed that Indians rated themselves as more collectivist than British participants with medium effect size though the difference was not statistically significant. It should be noted that the standard error of the British participants' Singelis score was very high making it unclear as to whether this finding is a true representation of the population. As discussed in the previous chapter, it is possible that self-construal as collectivist/ individualist is not a consistent feature of British culture, whereas self-construal as collectivist is a more consistent feature of Indian culture. Hofstede's scores of cultural dimensions for the UK were found to be very similar to the scores of the United States. For example, the cultural dimension with the highest rating for both countries was found to be individualism (UK: 89, US: 91); however, parts of the UK, Scotland and Wales in particular, have adopted more collectivist values into their social policies (Birrell, 2009). Recent political events including Brexit, Scottish and Catalonian independence, etc. have also brought light to a change in social ideology in continental Europe (Gobel, Benet-Martinez, Mesquita, & Uskul, 2018). Put together, the UK may not be so easily classified as one or the other in the collectivist-individualist dichotomy. The Singelis Self-Contrual Scale was specifically tailored to capture characteristics of collectivism and individualism hypothesized by Markus and Kitayama (1991). This scale has been widely used to study the relationship between self-construal and cultural difference in cognition, emotion, and motivation (Gudykunst & Lee, 2003), and has been used across different cultures (Besta, 2018; Dardara, 2018; D'Amico & Scrima, 2016). However, it has not been validated in India; no scales of self-contrual have been validated for both Indian and the UK, or have any scales been validates for India alone. Future research should consider validating this scale or any other widely used scales, like the Gudykunst et al. (1996) Self-Construal Scale or the Swartz Value Scale, in the cultures being explored. A different option would be to include an ethnographic evaluation of self-construal, and implement a mixed methods approach, i.e. use but qualitative and quantitative research methods, as oppose to relying solely on quantitative measures that can be too reductionist or basing assumptions purely on historical knowledge.

Self-construal did not have a significant effect on accuracy, reaction time, or any of the eye movement data; however, country of origin, did have an effect on accuracy, saccade amplitude, and saccade velocity. The overall performance of the UK participants was better than the Indian participants in terms of accuracy even though the difference did not reach significance. As expected, performance decreased as the difficulty level of the picture increased, however, the British were more affected by the difficulty levels. Meaning that the drop in performance as the objects became more difficult was greater than that seen by the Indians. This may be because the test was created based on the UK population, therefore, British participants may be more sensitive to the difficulty level of the object. When broken down picture-by-picture, we see that Indians significantly out performed the British on the Bicycle picture. This may be because bicycles, motorbikes, scooters, etc. are more of a staple mode of transportation within India than in the UK and, therefore, may be more prone to interpreting the image to be as such rather than a pogo stick or pneumatic drill, common answers made by British participants. The images in which the British significantly out-performed Indians included the Cork Screw, Spanner, Snail, Frog, and the Key. These differences in performance can, in part, be explained through cultural familiarity since a cork screw is an extremely uncommon tool in an Indian home. This may be because of high import taxes placed on alcohol that then reserve the use of a cork screw for those who can afford to buy alcohol that require one. Similarly, a spanner may not be very commonly used by everyone since the use of tools, in general, is typically done more often by those in the working class in India. Though this argument can also be made for those living in this UK, this trend tends to be more exaggerated in India because of its cheap labor costs compared to that in the UK. It should be noted that “bone” was a common answer for “spanner” which might have been due to the fact that participants recruited in India were mainly working in the medical field (doctors, psychologist, PhD candidates in the neuro field, etc.) and so responses could have been biased accordingly. However, justifying the remaining items in terms of unfamiliarity is less likely since all three items are commonly seen and used in India. In Dutt et al., (2016)’s study, the authors had asked their Indian participants if they were familiar with each object as a yes/no question; a factor that was not evaluated in this study. Their participants largely chose “yes” for each object suggesting that familiarity was not driving the low performance of their Indian participants. However, this could be a matter of “degree of familiarity” as opposed to the dichotomous question of familiar vs unfamiliar. Future research should consider investigating the nuances of familiarity, looking into whether the answers given relate to the individual’s greater familiarity with their response as oppose to the “correct” answer. This also raises the question of whether this is an issue of perception or of decision making. Future research should also consider investigating whether the “correct” answer featured as a part of participants’ decision-making process or not. It is also worth noting that according to the Silhouettes Subtest’s scoring guidelines based on the UK normative data, the expected average score of British people is 23/30 with a cutoff of 15/30. In this study, British participants scored well below the expected average raising the question of whether a performance difference exists between English and Scottish people since a majority of participants taken in the UK sample were from Scotland. This may be a result of the normative sample collected during the creation of the subtest being heavily biases towards a specific subsection of the British population that did not capture the subsection of the British population that was sampled in this study. It could also be possible that the prevalence and/or the representation of certain items in British society has changed since 1991 when the subtest was first created (Warrington & James, 1991) and thus, features that would have been considered diagnostic for accurate identification may have changed leading to a drop in overall performance. Future research should consider not only re-evaluating the subtest for the UK population, but also consider investigating what is considered to be diagnostic, and whether those diagnostic features are different between cultures. One possible way of exploring this may be through the use of the Bubbles technique, a technique used in face perception to determine which facial features are being used for facial recognition (Gosselin & Schyns, 2001; Saumure et al., 2018). It should also be noted that the administration of the objects in this study was in random order. This is contrary to how the assessment is given where the objects are shown in the same order to all patients, according to category-objects and animals-and the patients are prompted as to which category the silhouette belongs to. For example, “what animal is this?”. This was done to isolate whether or not a difference in perception of the specific object was contributing to the difference in performance. Future research can consider whether a difference in test administration affects test performance.

Along with accuracy, country of origin was seen to significantly influence saccade amplitude and saccade velocity, but not any other type of eye movement measurements. Saccadic eye movements have been demonstrated to be linked with attention, showing that attentional shifts strongly influence the direction of voluntary saccadic movements (Hoffman & Subramaniam, 1995, Zhao et al., 2012). Saccadic amplitude as been shown to indicate peripheral or central attention allocation with shorter amplitudes indicating more central focus and larger amplitudes indicating more peripheral focus (Cajar et al, 2016). Here we see that the British participants had significantly larger saccadic amplitudes than Indians implying that British participants focused more on the periphery, or the outline, of the silhouettes relative to the Indians. This would also explain why the British were shown to have a greater saccade velocity since a greater distance was being covered in about the same amount of time as the Indians (this is being assumed from rt between the two cultural groups being not significantly different). Perhaps this is why British participants were able to perform better since shadows provide very little detail and identification is more reliant on the outer shape.

This study, however, had several limitations. Participants recruited in India were all staff members or PhD candidates at NIMHANS and were therefore all in the medical field in some form. This may have biased certain answers. Furthermore, many participants were not able to come participate during working hours and so for many, data were collected in the early evening. Thus, cognitive functioning may have been hampered which could have contributed to the reduction in performance in Indians. Furthermore, although all participants were all fluent in speak English, the study was not conducted in the native language of the Indian participants, making it unclear if any incorrect answers were a result of a loss in translation - participants may have known the word for the object in their native language but not the correct word in English. An example of this is described in the Discussion section of the next chapter. There were also some challenges in calibrating the eye movement of Indian participants in part it because some participants did not maintain a fixation long enough on any given calibration fixation point before and during the task. Furthermore, after the initial calibration, participants are required to keep their heads as still as possible which proved to be difficult for Indian participants because of a characteristic, side-to-side, Indian head nod that was continuous made in response to any form of conversation. Calibration accuracy was therefore reduced, thus affecting the quality of the eye movement measurements taken.

Beyond the limitations mentioned above, certain factors taken could have been expanded upon to further understand which aspect of culture may have played a role in performance. For example, though years of education was recorded, quality of early education was overlooked, a factor that has been shown to influence cognitive development later in life (Sisco et al., 2015). Further research can look deeper into demographic information in order to gain a better understand of more specific factors that could be influencing performance on the Silhouettes subtest.

In conclusion, a difference in performance between Indians and the British can be seen across difficulty levels in the Silhouettes Subtest of the VOSP which is not driven by an adherence to any value system (individualism vs. collectivism). This difference may in part be explained by cultural familiarity and a difference in attention allocation to the periphery of each image between the two cultural groups, however further investigation is required to be able to make more definitive conclusions on these findings. In the next chapter, I extended this study by taking a different Indian sample-Kolkata-to bring more power to this current dataset, explore if a difference in performance existed between individuals from

Bangalore and Kolkata-despite both being Indian cultures, both represent two starkly different subsections of the Indian culture. In addition, I explore familiarity and perceived attention as potential driving factors.

5. The Influence of Familiarity on the Performance of Indian and British Participants on the Silhouettes Subtest of the Visual Object and Space Perception Battery.

Abstract

Objectives: Clinical neuropsychological tests evaluate conscious behavioral responses on tests that target specific cognitive domains. These standardized tests, mostly created in the U.S.A and Europe, show noticeably varied test responses when presented to individuals from other culturally distinct countries, making evaluations more uncertain. One such test is the Silhouettes Subtest of the Visual Object Space Perception Battery (VOSP). Dutt et al. (2016) showed that Indians performed significantly below their Spanish, Greek, and American counterparts, despite their comparable cognitive abilities. The specific explanation for this disparity remains unclear. We present two studies investigating whether eye movement, object familiarity, cultural relevance, and/or self-construal (the degree to which a person adheres to individualist or collectivist values), might account for any performance differences.

Methods: A further 33 British and 34 Indian participants completed the Silhouettes test along with object familiarity questionnaires. The performance data of this study was combines with that of the previous study for analysis. Object features that participants reported they had specifically attended to during the identification process were also recorded.

Results: The combined total Silhouettes subtest score between Indian and British participants was not significantly different, though the effect size was medium-large (d=0.66). At the level of individual objects, the proportion of correct identifications was significantly different for 13 objects. The British outperformed Indian participants on 11 objects whilst the Indians outperformed the British on 2 objects. Both the Indian and British samples showed a substantially lower performance than the original UK normative sample. Indians and British largely

overlapped in object features they reported they were attending to during identification. Familiarity with the objects did not explain the Indians' poorer performance, nor was self-construal as collectivist/individualist an influential variable in predicting performance or eye movements.

Conclusions: We found no evidence that self-construal or object familiarity explain the performance difference between Indians and the British on the objects in the Silhouettes Subtest of the VOSP. Although there was no difference in ratings of familiarity with the real objects represented by the silhouettes, one possible explanation for differences in ability to identify some objects is that there are differences in degree of cultural relevance of the objects, and in the ways in which the objects are most commonly depicted within each culture.

Introduction

Alexander Romanovich Luria is accredited for his pioneering work in understanding cognition, neuropsychological test development (Luria, 1987), and for his work in bringing necessary attention to the influence of "culture" on cognition. Luria's interest in the coordinated dance between culture and cognition are rooted in work carried out in Uzbekistan in 1931 and 1932, in association with Lev Vygotsky. Luria's work was able to demonstrate that level of global exposure and schooling were determinants of performance on various cognitive tests that were used in his home country. In other words, illiterate Ichkari women living in remote villages that were disconnected from modern social activities performed vastly different than women who were exposed to greater socialization and were students of a teaching course (for review of Luria's time in Uzbekistan, see Nell 1999). Luria's observations were not limited to Uzbekistan, very similar results were also seen in a study done by Gilbert (1996) in South Africa. Even today, we see that not only length of education and global exposure, but quality of early education can also determine our cognitive abilities (Sisco, 2015). Though the work of Luria is iconic in the field of cultural neuropsychology, attention to the subject didn't gain much traction until the turn of the century (Puente & Agranovich, 2013).

A majority of neuropsychological assessments have been created in countries that have historically been considered part of the “Western World”. As a result, cognitive tests were shaped to mimic the cognitive styles of the people who resided within this world. These assessments were globally standardized under the assumption that there existed a universalism in cognition and conscious behavior (Sperry, 1965). However, many studies have since shown that cognition is significantly influenced by the many factors that make up one’s environment (Tavassoli, 2002; Norenzayan, Smith, Kim, Nisbett, 2002; Hedden et al. 2002) and can lead to performance disparities in neuropsychological assessments (Arnold, Montgomery, Castañeda, Welsh et al., 1995; Teng et al., 2002; Patton, Duff, Schoenberg, Mold, Scott, & Adams, 2003; Oliveira, Salter, & Tomaz, 2012). One such assessment that has shown cultural differences in performance is the Visual Object Space Perception Battery (VOSP).

The VOSP was created in 1991 by Elizabeth Warrington and Merle James in order to assess visual impairment as a result of cortical damage. It consists of 8 subtests (4 for object perception and 4 for space perception) that were designed to evaluate different distinct aspects of object and space perception. The object perception subtests were based on a model which proposes three subtypes of impaired object recognition: disorders of visual sensory discrimination—inability to process certain sensory information including acuity, shape, and color discrimination; apperceptive agnosia— impaired object perception; and associative agnosia—inability to derive meaning of an object despite having normal perceptual and sensory abilities (McCarthy & Warrington, 1990). Thus, it was inferred that object perception is, “a requisite to object recognition, which represents the successful integration of sensory, perceptual, and representational information,” (Rapport, Millis & Bonello, 1998).

When this battery was created, residents of the UK were used in the collection of normative data. Thus, stimuli were created around what was expected of British people. A small number of studies have investigated the effects of culture on performance on these subtests (Casals-Coll, 2013; Kosmidis, Tsotsi, Karambela, Takou, & Vlahou., 2010; Herrera-Guzman, Peña-casanova, Lara, Gudayol-Ferré, & Böhm, 2004; Bonello, Rapport, Millis, 1997). A recent study by Dutt et al., (2016) demonstrated a performance disparity between Indians residing in Kolkata and individuals originating from Spain, Greece, and the United States on the object perception subtests of the VOSP, thus begging the question of what factors could be contributing to their results.

Many studies have reported differences in eye movements, measured using eye-tracking technology, between people from different cultures in scene perception (Chua, Boland, & Nisbett, 2005; Masuda, Ishii, & Kimura, 2016; Duan, Wang, & Hong, 2016), with differences attributed to social structures categorized as collectivist or individualist. In Chapter 4, I conducted a study that explored the possibility of different eye movement patterns as a contributing factor to the performance difference between individuals from India and the UK—cultures historically perceived to be collectivistic and individualistic respectively—on the Silhouettes Subtest from the VOSP. Results showed little evidence that a difference in eye movements existed. Furthermore, the study showed that Indians and British participants did not significantly differ in their self-construal. In relation to accuracy in identifying silhouettes, there was not an overall significant difference in total score, but there were significant discrepancies on a number of individual objects in the test.

In relation to eye-movements, it is possible that what participants were looking at may not have been what was being consciously attended to when viewing the silhouetted objects (Palmer, 1999). It is also possible that participants considered the correct answer as part of their decision-making process to identify the object but then selected an alternative answer. Furthermore, Dutt et al., (2016) had explored level of familiarity with the objects as a way to potentially explain differences in performance on the Silhouettes Subtest and found no evidence that familiarity discrepancies explained the poorer performance of their Indian participants; however since familiarity was investigated in a dichotomous framework— yes vs. no —participants in the study reported a high level of familiarity because a majority of participants selected “yes” when asked whether or not they were familiar with the objects in the test. Therefore, the aim of this study was to investigate the degree of familiarity of the Silhouettes Subtest objects compared to common alternative responses that were given in our previous study (see chapter 4). Furthermore, this study aimed to investigate whether the correct answer was considered by participants when presented with the images (before giving an incorrect answer), and whether a cultural difference is seen in the areas of the silhouetted images the participant felt had caught their attention when presented with the image. In addition, the Singelis Self-Construal Scale was also administered in order to supplement our previous data set and add power to our findings. This study was conducted in Kolkata, India and performance data on the Silhouettes Subtest was combined with the data we collected in Bangalore, India, thus allowing for greater power to our performance/accuracy data, and also adding an additional dimension of investigation of possible intra-cultural differences. India, being very culturally diverse, is more starkly contrasted between North and South India. Therefore, potential differences in performance between our Bangalore and Kolkata samples may also be present.

Based on our aims, we tested the following hypotheses that:

1) a difference in performance/accuracy on the identification of the silhouetted objects will be seen between Indians and the British.
2) a difference in performance will be seen between individuals residing in Kolkata vs. Bangalore.
3) the chance of correctly identifying an object will be influenced by how familiar the participant is with the object. The influence the degree of familiarity will have on accurately identifying the shadowed objects will differ between Indians and the British.
4) areas of the silhouetted images that participants felt they attended to will differ between Indians and the British.
5) performance differences will partially be explained by participants thinking of the correct object but then dismissing it in favor of a different object as their answer.

Methodology

Participants and Recruitment

Thirty-three British participants were recruited at the University of Glasgow (16:17 female:male, mean age: 30, mean years of education: 15) and 34 Indian participants were recruited at the Duttanagar Mental Health Center, Kolkata (17:17 female:male, mean age: 28, mean years of education: 18). A sample of ~33/cultural group is in accordance with what has been recommended for this type of analysis (Simmons, Nelson, & Simonsohn, 2011). The study conducted by Dutt et al. (2016) found a very significant difference in performance between their Indian participants and their European and American counterparts (effect sizes ranging from 0.64 - 1.87). However, in our previous study, we found the difference in performance to not reach significance. We determined the sample size based on this, powering the study to be able to detect an effect size of 0.7 with an $\alpha = 0.05$ and power = 0.8, leading to the requirement for a sample size of 33 in each participant group (Faul, Erdfelder, Lang, & Buchner, 2007; Faul, Erdfelder, Buchner, & Lang, 2009). All Indian and British participants were born and raised in India and the UK respectively. For the purposes of comparing performance on the Silhouettes Subtest between the two groups and Singelis Self-Construal Scale scores, the data collected for this study were combined with our previous data collected (see Chapter 4) to give a total of 66 participants per cultural group, and thus increasing the power of the analysis, so that it would be possible to detect an effect size of $d=0.49$.

Participants in the UK were recruited via online ads placed on community forums (e.g., The Student Voice), and social media (e.g., Facebook, Twitter). Additionally, individuals registered with the University of Glasgow Subject Pool, maintained by the Psychology Department, were emailed an advert for the study. Volunteers were paid £6/hr for their participation in the study.

Participants in India were recruited through known associates in coordination with staff members at the Duttanagar Mental Health Centre. Participants were provided with tea or water and biscuits, and any travel expenses were covered. Participants were not paid for participating as this was not normal practice at the Institute.

Ethics Approval

All procedures and materials used were approved by the Review Boards of both the University of Glasgow College of Medical, Veterinary and Life Sciences, and the DMHC, Kolkata. All participants who passed the initial screening gave written informed consent before proceeding.

Screening

All participants were asked to fill out a demographic form where they were asked about their age, gender, years of education, where they have lived and for how long. They were also asked to self-identify their ethnicity, and the ethnicity of their parents and grandparents (both maternal and paternal). Participants were also asked if they had a history of brain injury or cognitive disfunction and were excluded if they did. Anyone who was under the age of 18 or who did not self-identify themselves or their family members as solely one of the British or Indian ethnic groups were excluded. Those who passed this initial screening then proceeded to the experimental tasks.

Materials and Procedure

All procedures were conducted in English for all participants in the UK, and in either English or Bengali with the participants India, depending on which language the participants felt most comfortable speaking. The study was conducted by the same researcher, who is well versed in both English and Bengali, for all participants in both the UK and in India.

In the test phase, the thirty images of the Silhouettes Subtest (15 animate, 15 inanimate) were presented one-by-one in random order to each participant. The participants were asked to identify the real object that each shadow represented.

The participants were reassured that the shadowed images were of real objects and that, “I don’t know” was a valid response. There was also no time limit given.

After presenting all 30 images, the researcher moved onto the second phase of the study. The same 30 images were presented in the same order to the participants again, this time asking the participants to describe their thought process when identifying the object. More specifically, they were asked if any other objects had come to mind when they saw each image of the silhouette:

“when you looked at this picture, did any other objects come to mind?”

Furthermore, the researcher asked the participants to point to the parts of each image that had caught their attention when they looked at each image. Parts that were indicated by the participants were circled by the researcher.

Based on our previous study (see Chapter 4) conducted at the University of Glasgow and at the National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore, objects that less than 80% of participants were able to accurately identify were noted along with the incorrect answers—this evaluation was done separately for the UK and Indian sample groups. This was considered to be a reasonable cut-off by the researcher. Each of those objects were made into individual categories, and each of those categories consisted of the incorrect guesses made by the participants for that object—the first object listed in each category was the correct silhouetted object. After completing the tasks described above, participants were then presented with a questionnaire that contained the categories as previously mentioned. Participants were then asked to first rate how familiar they felt they were with each object listed in each category on a scale of 1 (no familiarity) to 10—extremely familiar. Familiarity was described as how often one sees the object in everyday life, interacts with the object, sees the object in media such as in movies, television, books, magazines, social media content, etc., and how pervasive the object is in their cultural atmosphere such as in mythological or culturally iconic stories and symbolisms, religion, etc. After completing this questionnaire, participants were presented with a second questionnaire that was exactly the same as the first questionnaire, but this time, participants were asked to imagine their understanding of an average British/Indian person (ie. Britons were asked about an average British person and Indians about the average Indian person) and then rate the objects according to their assumptions of how familiar that person would be with the objects.

The last task that the participants was asked to complete was the Singelis Self Construal Scale (Singelis, 1994). This scale consists of 30 statements regarding social situations, 15 of which describe situation that are more characteristic of individualism and the other 15 are more characteristic of collectivism. Participants were asked to rate how much they agreed for disagreed with the statement on a 1-7 Likert Scale. The scores of the 15 individualistic statements and 15 collectivist statements are added up separately and a score is calculated using the following formula: Total Score Individualism - Total Score Collectivism. A more negative score is indicative of greater collectivism and vice versa.

Data Analysis

We used generalized linear mixed models (GLMMs) to determine if there were cultural differences in participants' responses to the Silhouette subtest. We chose accuracy as our response variable and created three global models that included the following variables: country of origin (country), location (Kolkata, Bangalore, or the UK), object difficulty (obj_diff), singelis, age, gender, years of education (yoe), and MMSE (see Table 5.1). Object difficulty was defined using the percentage of individuals in the original normative data set who correctly identified the object. This was how the creators of this test had determined the difficulty level of each image.

We systematically eliminated non-influential variables from the global model until we identified the simplest model that best explained the data (the most parsimonious model), and we based our conclusions on this best-fit model. For greater detail on GLMMs and how best fit models are obtained, refer to the data analysis of the methodology section in chapters 3 and 4.

Table 5.1. Global models created to predict participants' responses to the Silouettes subtest. All models take the form: response variable ~ explanatory variables + (1|random effects). In addition to the variables shown below, all models contain the following explanatory variables and random effects: age+gender+yoe+mmse+(1|participant)+(1|picture).

Response Variables	Global Models	Distribution
Accuracy	country *[1] obj_diff + singelis * obj_diff	Binomial
Accuracy	location * obj_diff + singelis * obj_diff	Binomial
Accuracy	country * familiarity + singelis * familiarity	Binomial

[1] "*": Denotes both the interactive and the additive effect

All best fit models were also tested against the null hypothesis as further confirmation. The variables included in all best-fit models are considered significant at P <0.05. All variables excluded was due to non-significance at P >0.05.

A binomial distribution was selected for all best fit models, and so goodness of fit was accessed by confirming that the ratio of residual variance and degrees of freedom approached 1. Response variables presented in all graphs on the y-axis are predicted values derived from best fit models.

When participants were asked about other objects that came to mind when evaluating the shadowed image, all alternative answers were recorded. For objects that were incorrectly identified, if the correct answer was mentioned as part of the participants' thought process, a notation was made and the proportion of objects which were correctly identified but was ultimately dismissed out of all incorrect answers was calculated for people from India and from the UK.

Features of each shadowed object that participants indicated had caught their attention when viewing them were noted and given a specific code. Commonly indicated features were tallied and features that at least 30% of participants had pointed towards were extracted. The researcher determined that extracting the features that at about 1/3 of the participants indicated as grabbing their attention was a reasonable cut-off. This was evaluated separately between Indians and the British and were then compared to each other to see how much overlap there was between the two cultures.

Results

In this study, country of origin (India or the UK), location (Kolkata, Bangalore, or the UK), and familiarity were tested as a function of accuracy. Best fit models are shown in Table 5.2. In addition to these variables, self-contrual was also measured using the Singelis Self-Construal Scale.

Table 5.2. Best fit models for participants' responses in the Silouettes Subtest. All models contains the random effects: (1|participant)+(1|picture).

Response Variables	**Best Fit Models**
Accuracy	country *[1] obj_diff
Accuracy	location * obj_diff
Accuracy	country * familiarity

[1] "*": Denotes both the interactive and the additive effect.

First-level descriptive statistics were done to compare Indian and British groups on their overall performance and Singelis scores (Table 5.3).

Table 5.3. Means of response variables measured in Sihouettes subtest. Format of data is: Mean (SE).

Response Variables	India	UK
Accuracy*	15.91 (0.40)	18.06 (0.46)
Singelis	-2.63(1.33)	-1.58(2.99)

*Average Score out of 30

Singelis - Collectivism vs Individualism

As reported in the previous chapter, the Singelis scores of the Bangalore and UK samples of the previous study were not significantly different ($M_{Bangalore}$ = -8.71(0.09), M_{UK} = -3.91(0.62); p = 0.18, d = 0.34). Looking at the Singelis scores of the Kolkata and UK samples taken for this study, the Singelis scores were also not significantly different (($M_{Kolkata}$ = 3.26(2.14), M_{UK} = 3.53(5.84); p = 0.96, d = 0.055) Thus, the overall Singelis scores of Indians (both Bangalore and Kolkata samples combined) and British participants were also not significantly different (M_{India} = -2.63(1.33), M_{UK} = -1.58(2.99); $p = 0.75$, $d = 0.07$) (Table 1).

Accuracy — India vs. UK

This analysis looked at the combined data sets as a whole. Though the overall performance of the British was greater than the Indians, the difference in performance alone did not reach significance (Table 5.3). Our best fit model for accuracy showed a significant interactive effect of country of origin and object difficulty level (Table 5.2). Object difficulty had a negative relationship with predicted accuracy. In other words, the performance of all participants predictably continued to drop as the objects became more difficult. This relationship, once again predictably, showed to be stronger for the British than for the Indians, i.e. the British were more sensitive to object difficulty than the Indians in that the British performed better than the Indians on the easy objects but worse than the Indians on the difficult objects (Figure 5.1).

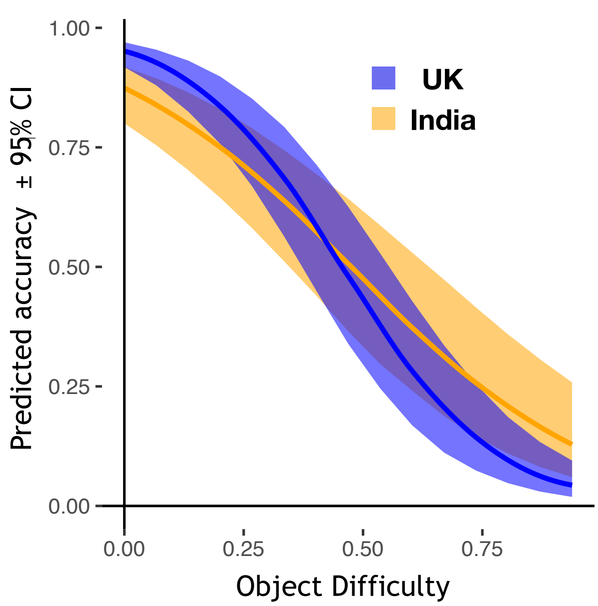

Figure 5.1. Predicted accuracy rates from the Silhouettes Subtest. Data shown refer to the predicted accuracy with which Indians and the British are able to correctly identify the silhouetted objects across different difficulty levels. Predicted values were derived from the best fit model for accuracy.

Accuracy — Location: Bangalore vs. Kolkata vs. UK

Our best fit model for accuracy showed a significant interactive effect of location and object difficulty level (Table 5.2). Object difficulty had a negative relationship with predicted accuracy and followed the same pattern as described above (Figure 5.2). Furthermore, Indians from Bangalore and Kolkata performed very similar to each other.

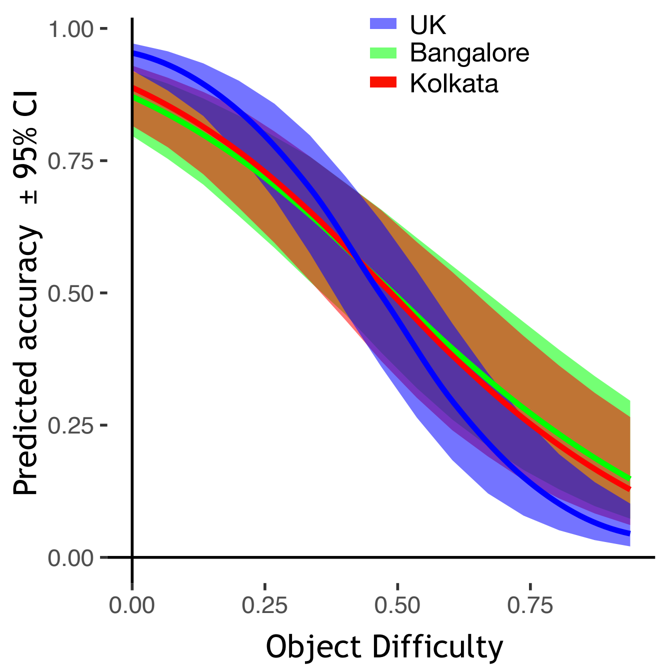

Figure 5.2. Predicted accuracy rates from the Silhouettes Subtest. Data shown refer to the predicted accuracy with which individuals from Kolkata, Bangalore, and the UK are able to correctly identify the silhouetted objects across different difficulty levels. Predicted values were derived from the best fit model for accuracy.

Accuracy - Familiarity

Our best fit model for accuracy showed a significant interactive effect of country of origin and familiarity (Table 5.2). The data used for this analysis only included the Kolkata and UK sample from this study as familiarity was not taken as a measure in the previous study. Familiarity had a positive relationship with predicted accuracy;

however, this relationship was stronger for the British than for the Indians. In other words, the probability of a British individual correctly identifying one of the silhouettes increased as their familiarity with the object increased; however, the probability of an Indian to correctly identify one of the shadowed images was unaffected by how familiar they were with objects. These results were seen for both the participants' rating of their personal familiarity with the objects, and with the participants' rating of their perception of an average person from their country's familiarity with the objects (Figure 5.3)

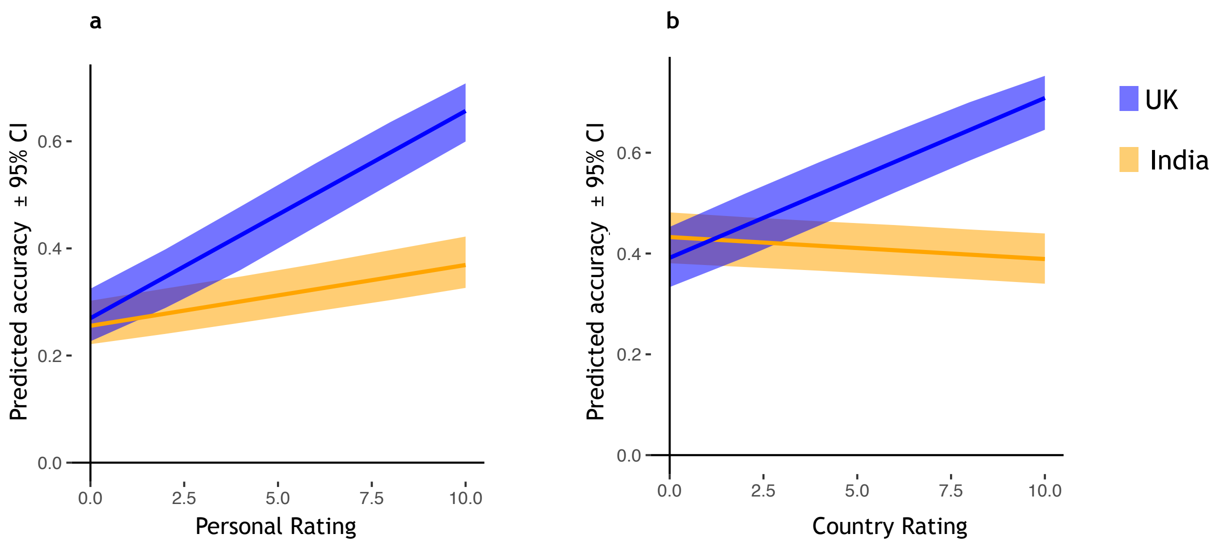

Figure 5.3. Predicted accuracy rates from the Silhouettes Subtest. Data shown refer to the predicted accuracy with which individuals from India and the UK are able to correctly identify the silhouetted objects relative to how familiar they are to the shadowed object (a) and how familiar the participants' perception of the average person from their respective countries are to the shadowed objects (b). Predicted values were derived from the best fit model for accuracy.

Object Evaluation

For 13% (261/2010) of the incorrect answers made by the Kolkata sample, it was reported that the correct answer was something the participant had thought about whilst attempting to identify the object from the silhouettes. In other words, for 13% of all the incorrect answers given across all the participants in the Kolkata sample, the correct answer had occurred to the participant, but the participant decided to provide a different object as their final answer. In some cases, upon looking at the image a second time, participants were able to perceive the correct object—it had not occurred to them previously in the test phase. This, however, only occurred for 3% (60/2010) of all the incorrect answers given by the Kolkata sample.

For 18% (356/1980) of the incorrect answers made by the UK sample, it was reported that the correct answer was something they had thought about whilst attempting to identify the object from the silhouettes. In other words, for 18% of all the incorrect answers given across all the participants in the UK sample, the correct answer had occurred to the participant, but the participant decided to provide a different object as their final answer. For 10% (198/1980) of all the incorrect answers, participants were able to perceive the correct object when looking at the image for the second time during the discussion phase although it had not occurred to them previously in the test phase.

Attended Object Features

The objects in which accuracy differed between Indians and British participants by greater than 10% include: Corkscrew, Dustpan, Key, Frog, Deckchair, Binoculars, Rabbit, Spanner, Snail, Bear, Bicycle, and Sunglasses. Of these objects, the Bicycle and the Sunglasses were the only two objects in which the Indians outperformed the British. It is also worth noting that the performance of many of these by both the Indians and the British participants greatly differed from the normative data. Objects for which the performance of both Indians and the British differed from the norm by greater than 10% include: Cork Screw, Dustpan, Pig, Cow, Key, Frog, Kangaroo, Deckchair, Rhinoceros, Sheep, Pick Axe, Seal, Watch, and Duck (Table 5.4).

Table 5.4. Accuracy rates for participants from India, the UK, and from the UK normative data for each picture in the Silhouettes subtest of the VOSP.

Picture	Accuracy Rates (%)		
	UK Norm	UK Sample	India Sample
Camel	100	90	97
Cup	100	100	97
Elephant	100	90	97
Penguin	99	96	93
Corkscrew	93	48	10
Dustpan	93	38	6
Pig	93	69	60
Bicycle	85	52	80
Shoe	85	82	90
Cow	84	63	57
Rabbit	83	85	57
Ladder	82	67	74
Spanner	81	73	48
Snail	80	73	40
Crocodile	79	69	72
Tractor	79	83	75
Key	78	46	19
Bear	77	67	55
Frog	77	65	58
Kangaroo	77	65	58
Deckchair	76	63	48
Rhinoceros	68	27	16
Sheep	67	29	25
Scissors	65	64	61
Pick Axe	59	19	28
Seal	57	44	39
Watch	54	90	88
Binoculars	45	29	40
Sunglasses	36	29	48
Duck	15	4	4

In looking at which features of the objects participants felt had caught their attention, many of the features largely overlapped between the Indians and the British. Figure 5.4 depicts the 3 animal and 3 object silhouettes with the largest performance disparity between the Indians and the British.

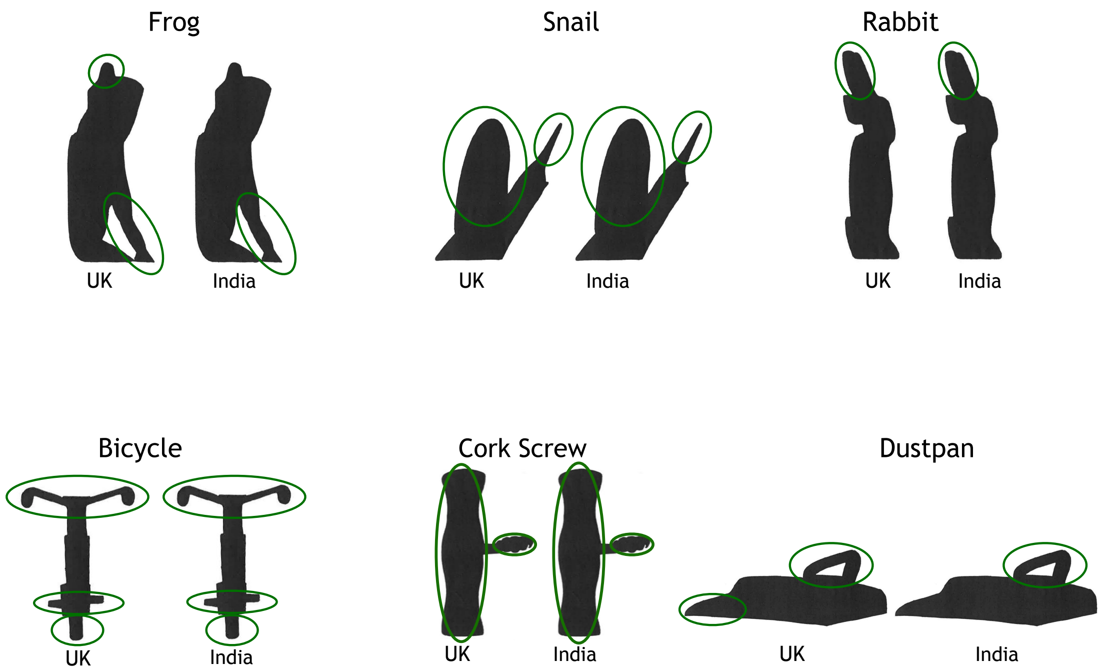

Figure 5.4. Features that have been indicated by at least 30% of participants when asked which features of each object caught their attention when they looking at the image.

Discussion

This study aimed to investigate degree of familiarity, decision-making, and focal features as potential factors driving the difference in performance between Indians and British on items in the Silhouettes Subtest of the VOSP. In addition to examining these factors, participants were asked to fill out a Singelis Self Construal Scale in order to investigate if variations in behavior could be explained by a social values scale. Our findings showed that though Indians, overall, rated themselves as more collectivist than British participants, there was a difference in how individuals scored between the two studies-people from Kolkata rated themselves as more individualistic than individuals from Bangalore. Similarly, the British sample from this study rated themselves as being more individualistic than the British participants of this study. However, the standard errors of both British samples were very high making conclusions on collectivism and individualism unclear. Though the UK and India are considered to be individualistic and collectivistic cultures respectively (Hofstede Insights, 2018), the high variation within each culture, particularly the British culture, does not allow for the Singelis Scale to clearly classify the two cultures along a collectivism-individualism scale. The high variation could be due to globalization, exposing each other to different global perspectives, thus shifting values within each culture towards a more amalgamated global view (Shah, 2009; Majima & Savage, 2007). The two cultures may currently be in a state of cultural transition thus leading to the large variations seen on the Singelis Self-Construal Scale.

Self-construal did not have a significant effect on accuracy; however country of origin and familiarity both did have an effect. In conjunction with our previous study, the overall performance of the UK participants was better than the Indian participants, but did not reach significance. Furthermore, performance decreased as the difficulty level of the picture increased. Just as we saw in our previous study, the British were more sensitive to difficulty level in that the drop in performance as the objects became more difficult was greater than that seen by the Indians. In addition to comparing Indians and British, we were able to investigate cultural differences present within the Indian culture. Kolkata and Bangalore are considered to be considerably different from one another. For example, the language mainly spoken by those who reside in Kolkata is Bengali, a Sanskrit based language, whereas people living in Bangalore mainly speak Kannada, a Dravidian based language. This lends itself to potential performance differences on the Silhouettes Subtest; however the performance of participants from Bangalore and Kolkata was virtually the same, indicating that the overall lower performance of Indians, though marginally significant, may have more to do with unifying characteristics of "Indian" as oppose to the differences. It is important to note, however, that India possesses far more cultures than that seen in Bangalore and Kolkata, and that the results seen in this study should be generalized with caution. Future research can benefit from continuing to compare performances from other Indian cultures in order to gain a more complete picture. Our results also showed a discrepancy between the performance of our UK participants and the UK normative data that was originally used during the creation of the Silhouettes Subtest on at least half the objects, bringing into question whether the subtest has cultural variations within the UK. Though the lower cut-off for healthy individuals in this age group is

15, the expected performance is 23. Considering this, only two British participants scored above this—they both had a score of 24 and were the highest score amongst all the participants—and the rest all scored below 23. The participants in this study were all residents of Glasgow, Scotland and the subtest was created using denizens of London as the normative data. This is not necessarily representative of the British people since the UK consists of four different countries. The difference in performance within the UK culture could also be a result of a change in representation of these objects over time thus rendering the shadowed objects of the subtest less recognizable. Future research should also consider administering this subtest in different parts of the UK to see if the difference in performance persists. It should also be noted that the administration of the objects in this study was in random order. This is contrary to how the assessment is given where the objects are shown in the same order to all patients, according to category-objects and animals-and the patients are prompted as to which category the silhouette belongs to. For example, “what animal is this?”. Future research can consider whether this should be considered when design their studies.

One potential factor that was thought to influence the difference in performance between Indians and British was familiarity with the objects themselves. In the study undertaken by Dutt et al., (2016), participants were asked whether or not they were familiar with the objects in the Silhouettes Subtest. A majority of their participants claimed to be familiar with the objects. However, we speculated that perhaps degree of familiarity was influencing participants’ answers. In other words, though participants were familiar with the objects themselves, because they were relatively more familiar with a different object that could be represented by the silouette, they were more likely to answer with the object of dominant familiarity. Our results showed that only the British were more likely to provide a correct answer if they had a higher familiarity with the object but Indians did not appear to be significantly affected by self-rated familiarity. The same pattern was also seen when rating objects based on the individual’s perception of an average person from their country’s familiarity with the objects. This was indicative that relative familiarity with the object may not be what is driving the performance differences, not only for the participants themselves but equally at a societal level since Indians felt the prevalence of these objects to have a similar pattern as themselves at a societal level. This is limited, of course, because the judgement of familiarity to the individual's culture as a whole is still based on the person's understanding of their society which can be tied to personal identity. It is perhaps not surprising that individuals would rate familiarity with an object at a societal level similar to their personal level. In other words, this is not, necessarily, an accurate representation of the whole culture, but it does give insight into individuals' understanding of their own culture. In India, surveys, particularly customer service surveys, have come into greater popularity in recent years with the rise of certain services, like home deliveries, and Whatsapp through which customers are sent these surveys. These questionnaires usually rate on a scale of 1-5. Since the questionnaires of this study were on a scale of 1-10, the researcher for this study faced some difficulty in explaining the concept to the participants in Kolkata, a difficulty that was not faced with the UK participants. It should be emphasized that making judgements of subjectivity along a more concrete, numeric scale may not be considered intuitive to how such judgments are generally made by people living in Kolkata. This may mean that the familiarity data for the Indians may not be reliable and thus, familiarity as a driving factor should be investigated further.

Our results also showed that participants generally did not think of the correct object during their conscious process of identifying the shadowed objects, which would suggest that the difference in performance is not due to individuals deciding to choose a different object as their final identification of the shadowed objects. Participants also largely overlapped in features that they felt had caught their attention when looking at the images. This would suggest that participants from both cultures find, for the most part, attend to the same features when looking at objects for identification; however, despite this, Indians and the British are still ultimately coming to different conclusions.

This study has several limitations that should be addressed. One limitation is that the conditions in which the participants in the UK were given the various tasks of this study were very different from those in Kolkata. UK participants sat in a quiet room with no distractions while in Kolkata, the study was conducted in various environments including different home settings, libraries, and labs. Because of the general rhythm of the Indian culture, access to a private space with no interruptions was a near impossibility. Other interruptions, such as the answering of phone calls, conversations being started with other members present within the same space, etc. were very prevalent in Kolkata. The researcher-participant dynamic also played a major factor. Many participants insisted on speaking in English despite having poor fluency in English, and the researcher persisting to speak in the native language of the participant. This study was also limited in that the demographic factors that were controlled for in the UK did not necessarily translate in India. For example, the concept of defining one's ethnicity, a question that was asked of the UK participants, was something that did not make sense to the Indian participants—instead, participants were asked to define their Indian-ness as the closest alternative to the original question. Similarly, certain demographic factors in India that could have played a factor in performance are not factors that exist in the UK. For example, the caste system strongly influences an individual's access to education (Borooah & Iyer, 2004). Furthermore, education is widely varied in the language in which students are taught and the standardized curriculum they follow. The quality of education varies widely in India, which has been shown to influence cognition later in life (Sisco et al., 2015). Future research should consider doing a critical analysis of what would be considered to be demographic information in different cultures, and how these factors may contribute to cognitive differences seen between Indians and the British.

In conclusion, features that are consciously attended to largely overlap indicating that features that are being attended to are more-or-less the same between cultures. This would mean that the same features lead to different conclusions between Indians and the British, resulting in Indians performing worse than the British for certain items. The wrong conclusions made by the Indians can not be explained by how familiar they are with the object, nor does it appear to be part of their conscious thought process when identifying the shadowed objects. Our previous study did not show any differences in eye movement when Indians and the British were looking at the silhouetted objects which would suggest that the difference in performance is not due to a difference in perceptual information gathered. However, future research should explore this further since no other study has been done that has investigated cultural differences in eye movement and perception for single objects.

General Conclusion

Overview

The main purpose of this thesis was to explore the influence of culture on visual perception. Specifically, this thesis focused on whether eye movement patterns observed in scene perception studies would reveal perceptual differences between Indians and British participants, and whether these differences in eye movements could be used to explain performance differences seen between Indians and the British on the Silhouettes Subtest of the VOSP—a widely used visual perceptual neuropsychological assessment battery. First, a systematic review was conducted to examine how technologies including eye-tracking, EEG, and fMRI have been used to detect cultural differences during scene or object perception. In addition to this, the review explored the lens through which culture was defined to explain perceptual differences observed, and also the specific cultural groups used to exemplify the lens used. This gave insight as to how cultural differences could potentially manifest during scene or object perception, thus providing the framework for the studies conducted in this thesis. The systematic review revealed that a majority of studies explored culture through the East-West dichotomy, linking this paradigm to concepts of Individualism and Collectivism. They suggested that since cultures of the East practice a more collectivist social structure, more holistic thinking would be expected, and thus, a cognitive strategy involving relations between objects or context dependency would predominate. Complimentary to this, the studies suggested that since cultures of the West practice individualism in their societies, more analytical thinking would be expected, and this is reflected in a cognitive strategy that is more absolute or independent of contextual information. However, the cultures used by the majority of the studies to illustrate the two categories were individuals of Chinese heritage to represent “Eastern” and Americans to represent “Western”. Furthermore, the classification of these cultural groups was mostly done based on what is generally understood about these cultures. A majority of studies did not corroborate whether the assumptions made about the East and West in relation to individualism and collectivism were truly exhibited by their participant groups. The review also revealed that only one study explored cultural differences in single object perception, i.e. with no background (Paige, Ksander, Johndro, & Gutchess, 2017) and all other studies had explored scene perception. Furthermore, eye-tracking during scene perception was, by far, the technology and paradigm most used to explore visual perceptual differences between cultures. Though these studies did suggest differences in eye movements that mimicked patterns predicted for Eastern-Western/Collectivist-Individualist individuals, there were some inconsistencies across studies (Rayner, Li, Williams, Cave, & Well, 2007; Evans, Rotello, Li, & Rayner, 2009; Rayner, Castelhano, & Yang; 2009; Millet, Zhou, He, Rodger, & Caldera, 2010). In addition, if the scene perception paradigm could detect cultural differences in eye movement, it still remained unclear if the patterns shown in previous studies would exhibit in other cultures that are historically considered to be part of the "East" and "West" and have been generally assumed to have collectivist or individualist social structures.

Taking what was understood from the systematic review, the scene perception study first conducted by Chua, Boland, & Nisbett, (2005), was replicated using individuals who are of UK and Indian origin and have only resided in either the UK or India, respectively, their whole life. These two cultures are historically considered to be part of the "East"—India—and "West"—UK. Moreover, India is thought to incorporate collectivism into their lifestyle, and UK lifestyle is thought to largely have individualistic characteristics; however, with current shifts in cultures due to factors like globalization, such a clear division in social values may no longer be apparent, even if it was previously. Chua, Boland, & Nisbett, (2005)'s study was also repeated to add to the repertoire of studies that have already been undertaken using this paradigm with the aim of bringing greater clarity to the association between culture and eye movement during scene perception. This first study incorporated the generalized linear mixed models statistical method to analyze the data which revealed the pattern of eye movement on the background of the scene did not differ between Indians and the British, but did differ in the focal object. When participants made shorter fixations, the number of fixations made by both the Indians and the British were comparable, however, as each fixation increased in duration, the number of fixations made by the Indians remained unchanged however the British made far few fixations. This would suggest that Indians spent a shorter time in between each long fixation than the British. In other words, this would suggest that the British spend more time scanning the focal object in between long fixations. Scanning as oppose to focusing on any one point is more characteristic of holistic thinking, therefore, this could indicate that the British take a more holistic approach when looking at the focal object whereas the Indians take a more analytical approach. This doesn't necessarily follow the overall pattern of eye movement in previous studies that suggest holistic and analytic perceptual approaches on based on the whole image. Furthermore, Indians and British did not significantly differ in self construal. This would suggest that the difference in eye movement may not be related to concepts of collectivism or individualism.

The second study explored whether or not the differences in eye movement could explain the performance difference demonstrated in the Dutt et al. (2016) study on the Silhouettes subtest. Individuals were presented with the Silhouettes Subtest of the VOSP which consists of 30 images of silhouetted objects (15 animate, 15 inanimate). The pictures were presented in random order and participants' eyes were tracked. Since differences in eye movement between Indians and the British were only seen in the focal object of the scenes, we expected to see a similar difference for the silhouetted objects even though these images didn't have any background. Using the generalized linear mixed models statistical method, our results were contrary to what was expected. Performance, alone, was not significantly different between Indians and the British; significance in performance was only seen with an interactive effect with object difficulty. Furthermore, self construal did not explain a significant amount of the variance for any variable and very little difference was seen between the Indians the British in eye movement patterns. Differences between the Indians and the British were only seen in saccade amplitude and in saccade velocity in a manner that would suggest that the British allocated more attention to the periphery of the shadowed images compared to the Indians. This may be enough to drive the difference in performance examined across object difficulty, between the Indians and the British but it was also important explore certain other factors, such as cultural relevance and decision making, as potential factors. Though familiarity was examined in Dutt et al., (2016)'s study it was explored on a yes/no basis which did not tap into how familiar individuals were with the objects in the Silhouettes subtest. Thus in the third study, degree of familiarity with the object, and whether participants were able to perceive the correct object but then decided to settle for a different object were tested. Participants were, once again, presented with the Silhouettes Subtest in random order. After being presented with all the images, participants were asked if any other objects had come to mind when looking at the image, and which features of the image had caught their attention. After this discussion, participants were asked to rate and rank a list of objects in categories specific to particular silhouetted objects. Each category contained the actual silhouetted object the category was based on. It is important to note that the Indians from the first two studies were residents of Bangalore, India, and the Indians in the third study were residents of Kolkata. This is important, given the diversity that exists within India, particularly between a North Indian culture—Kolkata—and a South Indian culture—Bangalore. The third study allowed for the added dimension of investigating potential intra-cultural differences. Our results revealed that Indians from Bangalore and Kolkata showed very little difference in performance from each other, and that the performance of Indians overall was lower, but not significantly,than the British. Furthermore, the performance of both Indians and UK participants showed a disparity on many of the items in comparison to the expected performance level—based on the normative data. Our results also revealed that only a small portion of the incorrect answers could be explained by decision making —participants had named the correct answer as being part of their thought process for only a small proportion of all the incorrect answers—suggesting that participants considering the true object, but then dismissing it favor of a different object is not a strong explanation for the performance difference seen between Indians and the British on items in the Silhouettes Subtest. Furthermore, features of each image that participants felt that they were commonly attended to when viewing each image largely overlapped between the two cultural groups suggesting that individuals from both cultural groups were attending to similar features. In looking at how participants rated and ranked their level of familiarity to the silhouetted objects, our results showed that the performance of the British depended on how familiar they were with the objects, but Indians were not influenced by familiarity.

This would suggest that the sensitivity of the British individuals to object familiarity might explain differences in their performance compared to the normative data—cultural relevance to some of these items may have changed within the UK from the time in which the subtest was first created; however object familiarity does not appear to largely explain the performance difference between the British and the Indians.

Implications and Future Research

Cross-cultural research has proposed different theories to explain the mechanism by which culture influences visual perception. These theories suggest various factors that include traditional philosophies as a result of geography (Nisbett, 2003), social organization exhibited as individualistic or collectivistic (Markus and Kitayama 1991), self-construal as a result of the social organization (Han et al. 2013), sense of personal control (Zhao, Gersch, Schnitzer, Dosher, & Kowler, 2012), language (Senzaki, Masuda, & Ishii, 2014; Papafragou, Hulbert, & Trueswell, 2008), and structure of physical environment (Caparos, Ahmed, Bremner, de Fockert, Linnell, & Davidoff, 2012; Miyamoto, Nisbett, & Masuda, 2006; Ueda & Komiya, 2012). Though these theories are all partially supported by existing evidence, the lack of consistency and the possible interactions among them remain unclear. Though credence can be given to social and physical environments directing cognition styles, the systematic review shows us that the holistic cognitive style of collectivism is mainly seen in Chinese participants and thus may be more characteristic of the Chinese culture. Likewise analytical cognitive style of individualism is mainly characteristic of the American culture. Therefore extending these concepts to the “East” and “West” lends itself to over generalizations. This is demonstrated in our subsequent studies in which collectivism and individualism were measured in the Indian and British groups but did not show a clear division between the two cultures. Despite this, differences in eye movements were seen in the scene perception task, though these differences did not necessarily align with what would have been expected assuming the UK to be an archetype of the individualistic “West” and India to be an archetype of the collectivist “East”. This would suggest that the differences are being driven by a factor(s) that can not be strongly attributed to this specific concept of social organization. Previous studies that have utilized eye-tracking to measure cultural differences in eye movement during scene perception have shown more consistent and clearer differences in tasks that require more top-down processing like the use of native language to maneuver perception (Senzaki, Masuda, & Ishii, 2014; Masuda, Ishii, & Kimura, 2016). Though cultural differences in our scene perception study were present, future research should investigate whether these differences continue to persist in different scene perception tasks that require different levels of attention. Similarly, with varying complexities of scenes—one focal object vs multiple focal objects. Differences in eye movements did not translate to the Silhouettes Subtest nor did differences appear in the features to which the participants felt they were attending. It is important to note that no previous study has investigated how eye movements differ between cultures when viewing objects with no background. Therefore eye movement data on the overall image were analyzed; there was no previous framework to base potential focal points on the silhouetted objects. Future research should look into whether cultural differences in eye movement become more apparent given different focal points and whether this differs in what participants feel they are attending to. Furthermore, it would also be important to investigate whether features that are considered to be diagnostic on a fully detailed image of the objects differ between cultures, and whether the loss in those features in the shadowed objects are contributing to the difference in performance. Alternatively, since differences in performance on the subtest between the Indians and the British can not be explained by eye movements, attention, or familiarity, from our results, this could imply that the driving factor may not have anything to do with over all differences in perception but rather differences specific to particular items. For example, a cork screw is not a culturally relevant object in India, therefore the low accuracy rate on that object would be expected. Similarly, Indians performed poorly on all of the four-legged animals compared to the norm: Bear, Rhinoceros, Sheep, and Cow. This might have more to do with the great diversity of four-legged animals that exist in India and therefore the silhouetted objects may not have been distinct enough for Indians to identify them correctly. It should be noted that British participants also performed poorly on the four-legged animals compared to the norm—the Indians and the

British performed comparably only on for the Sheep and the Cow—which might suggest that the general representation of these items may be out dated. Nonetheless, future research should conduct a more item-wise study and analysis, or consider aspects of stimulus saliency, e.g. frequency of exposure, as part of their experimental design. As discussed earlier, it may be that simple measures of familiarity are insufficient to detect differences in exposure to objects or differences in exposure to different representations of objects, across cultures. Therefore more detailed or sophisticated assessment of the salience of particular representations of objects may be required.

Beyond just the studies conducted in this thesis, it would be important to acknowledge certain methodological gaps. When conducting scientific work, we aim to control for potentially influential factors so that we are able to make fair comparisons between data points. The better we are able to control for these factors, the better we are able to create models that allow us to make more precise predictions at a population level. The less standard these factors are, the more difficult it becomes to control for them. Countries categorized as developed, like the UK, are characterized as such because they possess technological advancements that place the country in a post-industrial period where as, developing nations, like India, are either in a pre-industrial or industrial era where the economy is more dependent on agriculture (Bell & Pavitt, 1997). Currently, developed nations tend to possess greater overall infrastructure and therefore tend to have greater order. This "order", so to speak, allows for a more controlled environment and therefore factors like education, socioeconomic status, etc. are less varied than that seen in developing nations. In the case of this study, many factors that were unexpected that potentially could have influence performance were not accounted for. For examples, the inability of the researcher to conduct the studies in a quiet environment or even in the same environment in India—the researcher had to travel to various parts of Kolkata to meet participants, behavioral challenges that come with the researcher-participant dynamic, a relationship that is accentuated in India, inability of the researcher to consistently conduct the studies during business hours, and other behaviors that are part of the cultural norm in India. For example, many participants would divert from the study task to engage in personal conversation. This would be considered normal in India as individuals feel more comfortable when they are able to connect with the people they are interacting with in any way. Certain other factors that were not accounted for include quality of education, caste, socioeconomic status, number of languages spoken by participants—people in India are typically multilingual and knowing between 3-6 different languages is not uncommon—language in which participants were taught, and standardized education curriculum taught to participants. As one can see, in some cases, factors controlled for in one environment may not necessarily apply in a different environment, and for other cases the method of controlling for certain factors may have to be adapted to the environments. Future research would benefit greatly in evaluating the research method itself when conducting cultural studies in two or more different environments. Similarly, care should be taken in cultural studies that are conducted in the same environment, e.g. comparing British individuals to Chinese individuals who have been residing in the UK for less than a year, in recognizing that results do not represent what might be seen if the studies were conducted in the respective countries of origin.

Identifying the most appropriate sample size for studies in this area of research is challenging given the wide range of effect sizes apparent in previous research and a lack of clarity with regard to exactly what factors are driving differences between studies. Future studies might consider whether it is feasible for studies to estimate sample sizes required on the basis of recommendations regarding the minimal effect sizes that have practical significance. For example, Ferguson (2009) suggested that for social science data an effect size of $d=0.41$ reflects a minimal practically significant effect. This will lead to the need for a much larger sample size (e.g. a comparison between two groups would require a sample size of 190 participants), which may not be easy to achieve.

It is also important to note that the approach used in this thesis and in previous studies have been through the quantitative lens. Though very important, quantitative methods do not capture social nuances that may actually explain the “culture” portion of such cognitive work. In other words, understanding which aspect(s) of culture are contributing to differences in performance on visual perceptual neuropsychological tests may be more fruitfully understood by implementing qualitative research methods. For example, conducting an ethnography in order to better understand social structures and interactions. This method would not only more accurately grasp telling characteristics of a culture, but will also allow space for capturing the smaller details that are lost in quantitative analysis. For example, it was common for family members or friends to be present in the room when the studies described above were conducted. This was not meant as a point of supervision, but rather a common mode of social interaction in India, mainly driven by curiosity. The presence of the family member/friend, however, meant that from time to time, they would prompt the participant towards a particular answer. Though this might lead one to think that that data point is compromised, it is also the very thing that may be contributing to the "culture" portion of the study. Similarly, qualitative and quantitative methods can be used to understand how language can influence performances. For example, one could explore if performance would change if participants were administered the study in their first versus their second language verse the option to all known languages. Future studies should consider a more mixed methods approach in their experimental design.

Overall, the findings of this thesis has added dimension to the understanding of how eye movements can differ between two cultural groups during scene perception. Furthermore, this thesis is the first to explore how eye-movements may differ on standardized visual perceptual tasks that consist of single objects. In addition, this thesis has provided an avenue to further explore the driving factors behind the performance differences on Silhouettes Subtest of the VOSP, thus potentially stimulating new research that may allow for the adaptation or development of a new, more culturally compatible visual perceptual neuropsychological assessment. It is important to recognize that when deciding whether adapting a neuropsychological assessment can be sufficient done by simply collecting local normative data, we must be conscious of the fact that in a different context, the test may engage different cognitive domains outside of the domain it is intended for. For example, the VOSP was created for the purpose of testing an individuals object and space perceptual abilities; However, this was created within the British context. Therefore, though it may it may have been validated has an effective tool for detecting object/space perceptual impairment in the UK, when used in the Indian context, it is unclear what are driving performance differences and thus casting doubt onto whether the assessment is still testing for the same cognitive domain. It could be that performing the test uses different cognitive processes between cultures, thus what the test is actually assessing is different. It is, therefore, important to examine the validity of the test to properly understand what it is assessing and the extent to which it is sensitive to impairments it is intended to detect. This may involve first understanding the construct of interest, e.g. perception, within the new context in order to know how to measure it and thus develop a test that is suitable. This approach, hopefully, will not only improve an important health service, but Neuropsychology as a whole.

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Appendix

Article Search Results

Key Terms	Total Number in Search Results Web of Science	Ebscohost
Cultur* AND “visual percept*” AND “eye” AND “movement”	3	49
Cultur* AND “visual percept*” AND “eye movement”	2	37
Cultur* AND “eye movement”	133	369
Cross cultur* AND “eye movement”	17	47
Cross cultur* AND eye movement	54	132
Cultur* AND "cognitive style*" AND "eye movement"	1	2
Cultur* AND cognitive style* AND eye movement	7	4
Cultur* AND “visual search” AND “eye movement”	8	7
Cultur* AND visual search AND eye movement	39	15
Cultur* AND perception AND eye movement	210	210
Cultur* AND “eye movement*”	519	681
Cultur* AND percept* AND “eye track*”	85	107
Cultur* AND cognit* AND “eye track*”	54	104
Cultur* AND cognit* AND “eye movement*”	138	245
Cross cultur* AND “eye track*”	39	36
Cultur* AND “visual search” AND “eye track*”	7	6
Cultur* AND “visual percept*” AND fixation	14	93
Cultur* AND “visual percept*” AND “fix* pattern*”	3	5
Cultur* AND “visual*” AND “fix* pattern*”	12	11
Cultur* AND attention* AND “eye movement”	55	42
Cultur* AND attent* AND “eye movement”	55	42
Cultur* AND attent* AND “eye track*”	84	99
Cultur* AND “eye track*”	176	217
Cultur* AND “eye fix*”	18	113
Cultur* AND “fixation pattern*”	27	12
Cultur* AND saccade*	68	85
Cultur* AND “free search”	6	4
Cultur* AND "free search" AND "eye track*"	0	1
Cultur* AND "search task" AND "eye track*"	2	2
Cultur* AND "search task" AND "eye movement*"	5	8
Cultur* AND "percept* process*" AND "eye movement*"	8	4
Cultur* AND "percept* process*" AND "eye track*"	4	1
Cultur* AND percept* process* AND "eye track*"	49	5
Cultur* AND “information process*” AND “eye movement*”	7	9
Cultur* AND “information process*” AND “eye track”	0	2
Cultur* AND information process* AND eye track	59	2
Cultur* AND “information process*” AND “fix* pattern*”	0	2
Cultur* AND information process* AND fix* pattern*	142	1
Cultur* AND “information process*” AND saccade*	2	2
Cultur* AND select* attent* AND “eye movement*”	17	3
Cultur* AND select* attent* AND “eye track*”	8	3
Cultur* AND select* attent* AND “fix* pattern*”	1	2
Cultur* AND select* attent* AND saccade*	7	2

	Total Number in Search Results	
Key Terms	Web of Science	Ebscohost
Cultur* AND “scene percept*”	20	12
Cultur* AND “object perception”	13	18
Cultur* AND “scan* path*”	11	11
Cultur* AND “visual scan*”	26	19
Cultur* AND percept* AND fMRI	168	184
Cultur* AND percept* AND functional magnetic resonance imag	109	169
Cultur* AND “visual percept*” AND neural	210	178
Cultur* AND “visual process*”	128	174
Cultur* AND “object process*”	19	7
“Self construal*” AND “eye movement*”	2	1
“Self construal*” AND “visual percept*”	7	12
“Self construal*” AND “visual atten*”	4	6
“Self construal*” AND “visual search*”	0	2828
“Self construal*” AND “visual scan*”	0	2690
“Self construal*” AND “visual processing*”	2	1
“Self construal” AND “visual”	24	29
Cultur* AND percept* AND EEG	77	92
Interdepend* AND independ* AND “visual attent*”	10	11
Holistic* AND analytic* AND “visual percept*”	66	160
Holistic* AND analytic* AND “visual attent*”	13	14
Interdepend* AND independ* AND “visual percept*”	27	45
Priming AND “visual percept*” AND “eye movement*”	115	194
Ethnic* AND "visual percept*" AND "eye movement*"	4	25
Ethnic* AND "visual percept*"	161	556
Ethnic* AND "visual attent*"	31	38
Cultur* AND “categor* percept*”	76	80
Cultur* AND “event related potential” AND percept*	52	36
Cultur* AND global AND local AND “eye movement*”	7	3
Cultur* AND “event related potential” AND “visual attent*”	1	1
Cultur* AND “visual* illusion” AND “eye move*”	1	1
Cultur* AND “visual* illusion*”	29	21
Cultur* AND “geometric* pattern*” AND “fMRI”	0	2
Cultur* AND “geometric* pattern*” AND “MRI”	2	1
Cultur* AND “geometric* pattern*” AND “eye track*”	0	2
Cultur* AND “geometric* pattern*” AND “eye movement*”	0	2
Cultur* AND “geometric* pattern*” AND “EEG”	2	0
Total	3562	10446
		Number of Articles Excluded
Total Searches	14008	
After Duplicate Removal	4718	
Tittle Selection	307	4411
Abstract Selection	124	183
Full Paper Selection	38	86

Articles Excluded

Criteria

1 Must be written in English.
2 Be reported in studies with participants who are 18 years and above
3 Must pertain to scene and object visual perception but not the
4 Studies must be quantitative
5 Must include more than one cultural groups/environment.
6 Sample must be healthy
7 Study must include technological evidence in conjunction with the behavioral evidence (use of an eye-tracker, fMRI, EEG, ERP, etc.)
8 Paper must be a pubished article and not a book, conference abstract, dissertation, etc.

Article	Criteria Not Fullfilled
Jiang et al. 2019	3,7
Martin et al. 2019	3
Fung et al. 2018	3
Li et al. 2018	3
Steinmetz et al. 2018	7
Ksander et al. 2018	7
Wong et al. 2018	7
Tang et al. 2018	3
Shabalina et al. 2018	1
Wang et al. 2017	3
Alsaffar et al. 2017	3
Hakim et al. 2017	7
Golubickis et al. 2017	5,7
Liddell et al. 2017	3
Varnum et al. 2017	3
Masuda et al. 2017	7
Kardan et al. 2017	3
Muehlenbeck et al. 2017	2
Rozin et al. 2016	7
Lee et al. 2016	8
Chizari et al. 2016	8
Choi et al. 2016	7
Muehlenbeck et al. 2016	2
Rhode et al. 2016	7
Cramer et al. 2016	7
Saner et al. 2015	8
Duan et al. 2015	8
Goeke et al. 2015	7
Sohn et al. 2014	1
Yoon et al. 2014	7
Luliucci et al. 2014	3
Han et al. 2014	2
Lim et al. 2013	3
Kincl et al. 2013	5
Shin et al. 2012	1
Yang et al. 2011	3
Matzen et al. 2011	4
Gutchess et al. 2011	4
Chokran et al. 2011	8
Adams et al. 2010	3
Kelly et al. 2010	3
Fung et al. 2010	3
Ames et al. 2010	4
Goh and Park 2009	4

Article	Criteria Not Fullfilled
Chiao et al. 2009	3
Dong et al. 2008	3
Zhou et al. 2008	7
Masuda et al. 2008	1
Davidoff et al. 2008*	7
Becker er al. 2008	3
Han and Northoff, 2008	4
Davidoff et al. 2008*	7
de Fockert et al. 2007	7
Takata 2007	1
Sui et al. 2007	3,7
Jain et al. 2007	5
Kobayashi et al. 2006	7
Hot et al. 2006	3
Gordon et al. 2006	3
Miyamoto et al. 2006	7
Masuda and Nisbett 2006	7
Nisbett et al. 2005	4
Zentall et al. 2005	4
Kozhevnikov et al. 2005	4,7
Gajewski and Henderson 2005	5
Byrd et al. 2004	7
Kuhnen and Hannover 2003	3,7
Sanoki et al. 2003	7
Hernandez and Iyengar 2001	4
Eme and Marquer 1998	7
Ardilla et al. 1995	4
Bertenthal et al. 1993	7
Goncharova 1991	0
Coren et al. 1989	7
Magaro and Moss 1989	5
Mayes et al. 1988	7
Hagen 1977	7
Bornstein 1975	4
Lockhead 1989	7
Coyle and Russel 1968	7
Deregowski 1968	7
Hudson 1967	7
Wober 1966	7
Woods and Toal 1957	7

*two different papers

Cultural Quotes

Article	Cultural Framework	Quote			
EYE-TRACKING					
Abed 1991	Language System	Several visual scanning studies with English and Hebrew readers have demonstrated the existence of cultural differences. Nachshon, Shefler, and Samocha (1977) stated that, "because lines of written scripts are scanned in every language in a specific irection, single words or even single letters have become stimuli with directional characteristics." These directional charateristic and acquired reading and writing habits account for the cultural differences.			
Chua et al. 2005	Westerners vs East Asians, North American vs. East Asian, Analytic vs. Holistic, Object vs Context	Westerners, in particular North Americans, tend to be more analytic than East Asians. That is, North Americans attend to focal objects more than do East Asians, analyzing their attributes and assigning them to categories. In contrast, East Asians have been held to be more holistic than Westerners and are more likely to attend to contextual information and make judgments based on relationships and similarities.	Causal attributions for events reflect these differences in analytic vs. holistic thought. For example, Westerners tend to explain events in terms that refer primarily or entirely to salient objects (including people), whereas East Asians are more in-clined to explain events in terms of contextual factorsIn contrast, East Asians have been held to be more holistic than Westerners and are more likely to attend to contextual information and make judgments based on relationships and similarities.	The difference in attending to objects vs. context also was shown in a perceptual judgment task, the Rod and Frame test.	
Rayner et al. 2007	Language System	Given this interesting finding, we compared the eye movements of native English speakers with no knowledge of Chinese to those of Chinese speakers with differing levels of knowledge of English.			
Papafragou et al. 2008	Language System	This cross-linguistic variation raises two interrelated questions. First, how do speakers of different languages manage to attend to different aspects of the visual world and integrate them into linguistic structures as they plan their speech?	These cross-linguistic issues raise two different ways in which language might guide attention during event perception.		
Evans et al. 2009	Americans vs. Chinese, Individualist vs. Collectivist, Analytic vs. Holistic, Object vs. Context	The general argument is that, because individualism is strongly emphasized in American culture, Americans attend to the scenes in a more analytical way, and therefore object memory is not affected by a change in the contexts. In contrast, Asian cultures stress the importance of collectivism, and thus people attend to the scenes more holistically. As a result, Chinese are more likely to reject old objects when they appear in different contexts.			

Goh et al. 2009	Westerners vs. Easterners, Westerners vs. East Asian Independence vs. Interdependence, Analytic vs. Holistic	Western cultures emphasize indepe dence, and individuals who come from these cultures tend to be more analytic and process visual stimuli with a focus on objects and their attributes. In contrast, East Asian cultures emphasize interdependence, which leads to more monitoring and holistic processing of contextual information [1–6].	In another study involving change-detection with complex pictures, East Asians noticed visual changes occurring in the background more frequently than Westerners [8]. These studies, amongst many others [9], point to differences between Westerners and East Asians in the attention to different elements within a visual scene.	Interestingly, Chua et al. [10] also observed that overall durations for both object and background fixations were longer for Americans than for Chinese, indicating that Americans' eye-movements were characterized by longer dwell times, perhaps to extract more visual details at each focal point. These eye-movement findings were consistent with a more analytic style of processing in the Americans as Westerners and a more holistic processing style in the Chinese as East Asians.	Due to the focus on objects, and the fact that the attentional system is geared toward detecting visual novelty, an onset of object change or novelty in a complex scene should capture attention in Westerners, as one would expect in any event of visual onset [23,29]. We expected that East Asians should show a similar attention to visual novelty. However, due to a parallel focus on holistic processing of the total scene, this effect may be dampened, resulting in a more equivalent response to object and background novelty, since any change in the visual scene would disrupt the holistic representation of the scene.
Rayner et al. 2009	Chinese vs American	Specifically, we asked Chinese and American participants to look at scenes that had a rather unusual or weird component to them. We reasoned that if cultural differences can influence where viewers look in a scene (and how quickly they look there), then there could be differences in how quickly Chinese viewers look at the unusual/weird parts of the scene. That is, if they truly are intent on looking more at the background information, it is likely that the unusual/weird object would not be as apparent to them as quickly as it would be for the American viewers.			

Miellet et al. 2010	Westerners vs. Easterners, Westerners vs. East Asian Independence vs. Interdependence, Analytic vs. Holistic, Individualist vs. Collectivist, Object vs. Context	Importantly, for the purpose of the present study, the fixations directed toward the center of gravity of faces by EA observers would suggest a more effective use of extrafoveal information for Easterners compared to Westerners.	In line with this explanation, Nisbett and Miyamoto (2005) suggested that a crucial question for future investigations is whether "the actual field of vision is wider for those from interdependent cultures than for those from independent cultures?" Indeed, one of the most influential, despite arguable, view in the cultural field assumes that the organization of the social systems, in which people develop and live, leads to the diversity in cultural perceptual strategies (for a review, see Nisbett & Masuda, 2003; Nisbett & Miyamoto, 2005). In this framework, Western societies are seen as individ-ualistic, which would favor the perception of focal objects in a context (Triandis, 1995). By contrast, Eastern societies are seen as collectivistic favoring perception biases toward the relationship between objects (but see Davidoff, Fonteneau, & Fagot, 2008).	These findings were interpreted as being consistent with a relative greater holistic perception of EA compared to WC observers. The core idea of the holistic-analytic theory of culture is that people in East Asian cultures focus more holistically on relationships and similarities among objects when organizing the environment (Nisbett & Miyamoto, 2005).
Amatya et al. 2011	Biological	The sparse literature to date suggests that ESMs are rare, and the expectation is that the production of ES, at least in any numbers, requires the use of the gap paradigm. The observation of a high proportion of ES in overlap conditions might therefore be indicative of oculomotor pathology and could provide a parameter-related tool for identifying such pathology. It is also generally assumed that the saccade system, particularly with respect to reflexive responses, is constructed in essentially the same way across the whole human population. However, we report here the observation that in a group of Chinese subjects, we encountered ESMs much more frequently than expected.		

Ueda et al. 2012	Westerners vs. East Asians, Chinese, Japanese vs. American, Analytic vs. Holistic, Physical Environment	A vast amount of literature has documented cultural differences in cognitive processing. East Asians such as the Chinese and Japanese are likely to holistically recognize an object, taking contextual information into account or judging a target from a relational perspective. On the other hand, Westerners, especially people from the United States, are more likely than East Asians to be analytical, tending to ignore contextual information to focus on the central object or to judge a target from a categorical perspective.	Miyamoto, Nisbett, and Masuda indicated another possibility: the physical environment of a given culture. Specifically, because the Japanese live in a visually complex environment in which objects frequently overlap and have borders that are too ambiguous for people to distinguish them from the background, the Japanese may have a greater tendency than the Americans do to distribute their attention and direct it to the background.	Although the findings of Miyamoto et al. suggest that absorbing one's physical environment influences holistic/ analytic cognitive processing, the study did not directly examine patterns of visual attention, that is, how people perceive cultural scenes. In this sense therefore, the link between people's perception of cultural scenes and their attention toward these scenes is missing. One explanation may be that seeing a cultural environment, especially complex Japanese scenes, prompts the eye to scan contextual information. If this is the case, particular cultural environments should generate common attentional patterns.	The purpose of the present study is to cohere the diverse possibilities afforded by physical environments and oculomotor control by investigating patterns of eye movements. If visual attention is fine-tuned by the visual environment, oculomotor control may be calibrated according to cultural scenes. Thus, repeated exposure to a cultural scene shapes in turn a specific style of attention control, such as holistic or analytic attention.
Petrova et al. 2013	Westerners vs East Asians, Analytic vs. Holistic, Object vs. Context	Westerners have been argued to process visual information in analytic fashion, focusing on salent objects independently of the context in which they appear, whereas East Asians have been assumed to process visual informa- tion in holistic fashion, attending to the entire visual field and the context in which the objects appear.	We were particularly interested in whether the saccade curvature effect typically observed in this task is modulated by the participants' cultural background (East Asian vs. Western).		

Senzeki et al. 2014	North American vs. East Asian, Analytic vs. Holistic, Language System	Research investigating cultural variation in attention provides some of the most important contributions to the field, showing that members of East Asian cultures tend to be more attentive to contextual information than members of North American cultures (e.g., Chua, Boland, & Nisbett, 2005; Kitayama, Duffy, Kawamura, & Larsen, 2003; Masuda & Nisbett, 2001, 2006). These researchers also maintain that such cultural variation in attention is likely a product of culturally shared thinking styles: East Asians' holistic thought and North Americans' analytic thought (Nisbett, 2003; Nisb- ett & Masuda, 2003; Nisbett, Peng, Choi, & Norenzayan, 2001).	Although previous cross-cultural studies have provided convincing evidence of the influence of culture on visual attention, it still remains unclear whether one's culturally unique patterns of attention are static across all situations or are more likely to be acti- vated under particular conditions—such as when people are required to construct narra- tives in social situations.	Jerome Bruner (1990) theorized the narrative perspective of culture and mind, maintaining that narrative is an essential part of human thought. According to Bruner, members of a given cultural community construct, maintain, and are influenced by cultural meaning systems through social exchange in the form of narratives.	To further examine the role of narratives on human attention and to demonstrate the existence of both culturally unique and culturally similar patterns of attention, we con- ducted two cross-cultural studies.

Knox et al. 2014	Biological, Theory of Basic Human Value	Gaps also encourage the production of a particular class of low-latency, visually-guided ''express'' saccade (ES). ES formed a distinct peak in saccade latency distributions in monkeys [18,19], but only occasionally did so in humans, leading to considerable controversy [20–23]. However, in the monkey, it was shown that they were critically dependant on the integrity of the superior colliculus [19] and occurred when a general reduction in inhibition allowed the visual (target onset) response burst in collicular saccade-related neurons to trigger saccades directly [24,25].	An alternative approach is represented by ''values theory'' [10,34,35]. Schwartz values theory derives a limited number of values that are claimed to be present in all human cultures because they are grounded in the needs of individuals as biological organisms, the requirements imposed by the need for coordinated social interaction, and the needs of the survival and welfare of groups.

Zhang et al. 2015	Westerners vs. Easterners, Westerners vs. East Asian, Independence vs. Interdependence, Analytic vs. Holistic, Obbject vs. Context	Generally, Western culture emphasizes independence while East Asian culture highlights interdependence (Chiu, 1972). Furthermore, Western people tend to look at visual stimuli more analytically, focusing on objects and their individual components, while East Asian people pay more attention to contextual information such as background.	A number of studies have shown cross-cultural variations between Western and Eastern countries in visual attention, although culture-induced variation in visual attention was not consistently observed in earlier studies.	Given previous research that Western people tend to focus more on the focal objects, while East Asians are likely to focus more on the surrounding background, it was hypothesized that North American participants would focus more attention on the food items (i.e., focal objects) themselves than would Chinese participants.	Nisbett and his colleagues (Nisbett, 2003; Nisbett & Masuda, 2003; Nisbett & Miyamoto, 2005; Nisbett et al., 2001; Peng & Nisbett, 1999) explained this cultural variation in visual attention under the rubric of ‘‘holistic’’ versus ‘‘analytic’’ epistemology. For exam- ple, East Asians tend to view the world (or respond to visual stim- uli) holistically, with a focus on the total relationships among individual objects and events (Masuda & Nisbett, 2006; Masuda, Wang, et al., 2012). By contrast, Westerners tend to view the world (or respond to visual stimuli) analytically, focusing mainly on the attributes of focal objects (Masuda & Nisbett, 2006; Masuda, Wang, et al., 2012). Our findings might be explained in this way under the rubric of ‘‘holistic’’ vs. ‘‘analytic’’ thought.
Masuda et al. 2016	Westerners vs. Easterners, Object vs. Context, Americans, Canadians, Western Europeans vs. Chinese, Japanese, Korean	For more than two decades, cultural psychologists have advocated the importance of culture in human psychological processes (Bruner, 1990; Miller, 1999; Shweder, 1990) and have demon- strated systematic cultural variations between people in Western societies and Eastern societies, even in fundamental psychological processes, notably attention.	Various researchers have speculated on the origin of cultural variation in attention. Nisbett and colleagues maintained that Westerners such as Americans, Canadians, and Western Europeans have historically developed the worldview that things exist independently from each other, and that each thing can be understood in terms of its own essential qualities. Accordingly, Westerners developed the object-oriented mode of attention, selectively attend- ing to the focal objects in a visual scene while paying little attention to the context or back- ground. By contrast, Easterners such as Chinese, Japanese, and Koreans have historically developed the worldview that things are interrelated and believe that the relationships among things are important for understanding a phenomenon. As a result, they have developed the context-oriented mode of attention, equally allocating their attention to both focal objects and context, while paying attention to the relationships among them			

Duan et al. 2016	Westerners vs. Easterners, Object vs. Contest, Individualist vs Collectivist	Based on the comparison of East and West, researchers conducting cross-culture studies on scene per- ception have different views. One perspective holds that Asians look at scenes differently from the way Western- ers do, with Asians paying more attention to the focal objects than the backgrounds and being more sensitive to contextual changes.	According to Nisbett and his colleagues (Nisbett & Miyamoto, 2005; Nisbett & Norenzayan, 2002), the answer would be yes, because Chinese and Africans share the cultural value of collectivism (Triandis, 1989; Triandis, Bontempo, Villareal, Asai, & Lucca, 1988); that is, people pay more attention to the group such as the family or the tribe than to the individual. Thus, when it comes to scene percep- tion, they would allocate more attention to background information than to the focal object. But there are also important differences between these two groups. First, Chinese have a higher score on collectivism than Afri- cans (Triandis, 1989). This may be because China is a socialist country with a high regard for Confucianism, the socio-cultural traditions that put groups' interests above an individual's. Second, Africa used to be a colony of the West, so Africans may be relatively more influenced than Chinese by the Western value of individualism.	In summary, due to historical, societal and economic reasons, Africans may have collectivistic societies, but with a relatively greater individualistic tendency when compared to East Asians.

Afsari et al. 2016	Language System	Here, we consider the effect of reading direction habits. Given the ever-present use of text in our daily lives, the systematic bias of reading direction might result not only in biases for written content, but also a general motor-priming effect.	Reading habits from right to left (RTL) have an influence in line bisection tasks, and whereas left-to- right (LTR) readers usually show a bias to the left when asked to bisect a line, RTL readers show an opposite effect of bias to the right.	
Wang et al. 2016	Physical Environment, Westerners vs. Chinese, Westerner vs. East Asians, Analytic vs. Holistic, Object vs Context	A theoretical foundation of contemporary anthropology is the nature–culture divide, in which culture is defined as a social entity and nature as a bio-physical entity. In Western society, nature and culture are conceptualized as separate and distinct entities. This divide is manifest in the environment (i.e., natural vs. built) and offers a basis for classifying tourism images/ activities. At the other extreme are constructed or built tourism attractions, such as theme parks, casinos, and museums. Tourist promotions reflect this differentiation between nature-based tourism and urban commercially oriented attractions of a purpose-built kind. This dichotomy is also present in theories of human–environment interaction (Ulrich et al. 1991), as well as studies of environmental aesthetics	Further, the Chinese often prefer passive activities such as going to the beach, lazily walking and sightseeing, and boating (Han 2006; Mohsin 2008), while Westerners appear to be more interested in active pursuits that entail elements of risk, such as hunting and riding.	Similarly, East Asians seem to possess a holistic cognitive style that processes a scene more globally than Westerners, who as analytical thinkers tend to detach objects from their wider context (Dong and Lee 2008; Nisbett 2003).

Hernandez et al. 2017	Language System	Furthermore, language writing and reading are also habitual. For example, the literature has documented significant habitual differences in information processing among individuals speaking dissimilar languages, based on different alphabets (Schmitt et al., 1994). In particular, there are significant differences in the reading direction of written languages (Smith and Elias, 2013). The focus of our study is the difference in reading direction. Toward this end, we classify languages as follows. The left-to-right (hereafter, LTR) language family includes most alphabetic languages (e.g. English, Spanish), and the modern versions of Far East languages (e.g. Chinese, Korean, Japanese). The right-to-left (hereafter, RTL) language family includes Arabic, Farsi, Hebrew, Urdu, Pashto and a few African languages.	A number of studies linked the directions of text reading and patterns of information processing, presumably based on language constraints (Rayner et al., 2005; Román et al., 2013). By extension, we think that the amount of visual information process ing oflogo in the bottom right corner ofa webpage, the "corner of death", depends on the bidirectionality of readers.	With the underlying fluency of reading from either side, bidirectional readers have a higher tendency for spatial attention than their unidirectional counterparts because of their bidirectional bias. On the contrary, unidirectional LTR readers have developed the directional habitat in visual information processing.
Knox et al. 2017	Theory of Basic Human Value, Biological	ES occur when the visual (target onset) response, combined with increased pre-target activity, is sufficient to trigger the brainstem gaze generating circuitry (Dorris et al. 1997; Edelman and Keller 1996; Sparks et al. 2000). When saccade latency distributions are plotted, ES may form a distinct, early mode in the distribution. This pattern, while observed in non-human primates (Fischer and Boch 1983; Schiller et al. 1987), was not always observed in human studies, leading to considerable controversy.		

Alotaibi et al. 2017	Individualist vs Collectivist, Analytic vs. Holistic, Westerners vs. Easterners, Independent vs. Interdependent	A robust finding appears to be in hierarchical perception, with different groups demonstrating a relative bias towards the global or local level of a stimulus or scene. In particular, it seems that people from an individualistic culture (i.e. one that focuses on the skills and achievements of the individual) demonstrate an analytical style, preferentially attending to focal parts of a visual scene. In contrast, people from a collectivist culture (i.e. one that focuses on group-based membership and collective achievement) appear to demonstrate a holistic style, attending more to the structure of a scene and the relationship between its parts (Chua et al., 2005; Masuda & Nisbett, 2001, 2006; Miyamoto, Nisbett, & Masuda, 2006; Nisbett & Miyamoto, 2005). Thinking styles tend to correspond to national cultures, with a bias towards individualism in Western countries, and towards collectivism in Eastern countries (Hofstede, 2001).	Based on an individualism-collectivism framework, individualistic cultures tend to emphasize personal goals, and encourage the desire to be different, whereas collectivist cultures emphasize the priority of group goals, and value obligations (Hofstede, 2001). Correspondingly, it has been argued that this dimension is reflected in the preferred cognitive styles of individuals – characteristics and social practices relating to culture are seen to influence cognitive development, resulting in the adaptation of independent (analytic)/interdependent (holistic) cognitive styles that, in turn, shape the way the individual responds to his/her environment (Witkin & Berry, 1975).
Afsari et al. 2018	Language System	Moreover, we are interested in examining the role of second language proficiency and the age of second language acquisition in the left/right spatial bias.	What is interesting is that these behavioural studies not only show a preference for the left hemispace, but they can also be modulated to the opposite direction (from right to left) or reduced toward the centre when performed by participants who are native right-to-left (RTL) readers

fMRI					
Gron et al. 2003	Language System	One's surroundings, including one's cultural environment, may directly influence the way the human nervous system becomes organized. However, very little is known about influences of upbringing with logographic or alphabetic language systems on cognition beyond language.	It remains even more obscure how rearing in cultures with a logographic or alphabetic language imprints unintentional use of neural substrate for cognitive processing beyond the language domain. However, it seems reasonable to hypothesize that upbringing with logographic characters manifests itself in an enhanced affnity to use spatially based processing routines whenever one has to learn visual material with spatial relationships.		
Gutchess et al. 2006	Westerners vs. Easterners, Westerners vs. East Asian, Indepenence vs. Interdependence, Object vs. Context	Western cultures place more value on independence and individuality than do Eastern cultures, resulting in an attentional bias toward individual objects, with less regard for context and relationships among items. In contrast, East Asian cul- tures emphasize interdependent relationships and moni- toring of context, resulting in an attentional bias toward contextual, relational processing of information.	The behavioral differences in attentional biases and judgments between Eastern and Western cultures sug- gest that there should be systematic cultural differences in neural responses to complex scenes.	Westerners perform better than East Asians at copying the absolute length of a line, regardless of frame size, whereas East Asians are more accurate than Westerners at reproducing the size of a line relative to its frame.	In the present event- related functional magnetic resonance imaging (fMRI) study, East Asians and Westerners encoded pictures that differed in the amount of object and context information.
Goh et al. 2007	Collectivist vs. Individualist, Westerners vs. East Asian, Object vs. Context	Extensive behavioral studies suggest that in visual processing, collectivist experiences bias East Asians to attend to contextual information, whereas individualistic experiences bias Westerners to process objects preferentially.			
Hedden et al. 2008	Context Dependent vs Context Independent, East Asian vs. Western, Relative vs. Absolute, Independent vs. Interdependent, China, Japan, Korea vs. North America, Western Europe	Social cognition research differentiates cultural contexts that emphasize ideas and practices of interdependence (e.g., East Asian cultures in China, Japan, and Korea) from those that emphasize ideas and practices of independence (e.g., Western contexts in North America and Western Europe)	In the study reported here, we used functional magnetic resonance imaging (fMRI) to examine where in the brain cultural experience alters processing of simple perception in conditions involving independent (abso- lute) versus interdependent (relative) judgments. On the basis of prior behavioral results, we expected Americans to exhibit culturally preferred processing during absolute tasks and East Asians to exhibit culturally preferred processing during relative tasks.		

Aron et al. 2010	Context Dependent vs Context Independent, East Asian vs. Western, Relative vs. Absolute, Independent vs. Interdependent, China, Japan, Korea vs. North America, Western Europe	We were in a strong position to test this potential interaction because the focal cultural difference-context dependent vs context indepe ent is well supported in diverse previous research and has recently been demonstrated to be linked to differences in brain response.	Research on social cognition differentiates cultural contexts that emphasize ideas and practices of interdependence (e.g. East Asian cultural contexts in China, Japan and Korea) vs ideas and practices of independence [e.g. Western cultural contexts, in North America and Western Europe.	Specifically, people from East Asian cultural contextsperform better on tasks with interdependent (relative or con- text dependent) demands, and people from Western cultural contexts perform better on tasks with independent (absolute or context independent) demands.	
Goh et al. 2010	Westerners vs. Easterners, Westerners vs. East Asians, Indivisdualist vs. Collectivist, Indepenence vs. Interdependence, Object vs. Context, Analytic vs. Holistic	Several behavioral studies have shown that Westerners, who come from a cultural background that values independence and individualism (Schwartz, 1990; Markus and Kitayama, 1991; Hong et al., 2001; Chiao et al., 2008), tend to process visual stimuli more analytically, with greater attention to objects and their features (Nisbett et al., 2001; Nisbett, 2003; Nisbett and Miyamoto, 2005). In contrast, East Asians are enmeshed in a culture that emphasizes interdependence and collectiv ism, and thus East Asians process visual stimuli more holis- tically with greater attention to contextual information.	In keeping with the cultural biases reported in previous studies, we hypothesized that Westerners would process faces more analytically whereas East Asians would process faces more holistically, and that these differences should lead to greater face selectivity in the ventral visual areas in Westerners. In contrast, East Asians should attend more to houses as con- textual information, which should be associated with greater house selectivity.	A recent eye-tracking study by Blais et al. (2008) showed that while Westerners tend to move their eyes to focus on the eyes and lips of faces, East Asians tended to maintain fixation on the nose or central area. This finding was consistent with a tendency towards analytic visual processing in Westerners with greater attention paid to the features of the face that carry more distinguishing information. In contrast, East Asians focus on one central point of the face, consistent with a holistic processing bias.	In relation to cultural differences, findings from several behavioral and eye-tracking studies suggest that East Asians attend more to contextual information than Westerners.
Jenkins et al. 2010	Westerners vs, East Asians, Analytic vs. Holistic, Object vs. Context	Westerners tend to engage in an analytical style of processing marked by a focus on salient objects independent of the context in which they are embedded. In contrast, East Asians process visual information in a more holistic fashion, attending to the relationship between object and context.			

Goh et al. 2013	Westerners vs, East Asians, Analytic vs. Holistic, Object vs. Context, Individualist vs. Collectivist	Studies on cultural differences in cognition have shown that whereas Westerners display an analytic visual processing style and attend more to features of an object in a picture, East Asians use a more holistic approach, preferentially attending to contextual information.	Indeed, neural correlates of these culture-related differences in visual processing have been observed in the fronto-parietal attentional system (Hedden et al., 2008) and ventral-visual perceptual system (Gutchess et al., 2006; Goh et al., 2007; Goh and Park, 2009; Jenkins et al., 2010), that are consistent with an analytic visual pro- cessing style in Westerners and a holistic visual processing style in East Asians.	There is evidence that neural activity differs as a function of analytic and holistic visual processing styles in Westerners and East Asians, respectively.	We also considered the rela- tionship of neural activity to differences in cultural values, specifically, to individualism in Western culture and collectivism in East Asian cultures (Nisbett et al., 2001; Nisbett, 2003; Goh and Park, 2009). These individualistic and collectivistic culture value systems are associated with distinctive social interactions and physical environments that differentially shape the cognitive processing of individuals within these cultural environments (Nisbett & Miyamoto, 2005; Miyamoto et al., 2006).

Lidell et al. 2015	Westerners vs. East Asian, Object vs. Context, Interdependence vs. Interdependence, Indivdualist vs. Collectivist	Sociocultural frameworks can affect the relevance and priority afforded to incoming visual information [1]. For instance, behavioral studies have consistently reported that Caucasian Western participants are oriented towards prominent objects and localized detail ofvisual scenes; whereas East Asian groups preferentially attend to contextual and background information [2, 3].	Such behavioral and neural patterns between cultural groups have been interpreted to reflect the culturally-reinforced values ofindependence and individualism prominent amongst Western groups, compared to the values ofinterdependence and collectivism that operate in East Asian and other non-Western groups [3, 11]. While these cultural values are represented at the population level, they also vary substantially within groups at the individual level [12] [13]. This is reflected in the construct of self-construal or self-orientation (see Table 1)[14]. Variation in the strength ofadherence to individualistic vs collectivistic values may be a salient variable that shapes the neural substrates of visual attention, guiding engagement in the social world.	To shed light on these issues, this study examines whether individual differences in self-ori- entation along the individualism–collectivism cultural value dimension affects how visual attention networks are engaged during global vs. local processing.

Paige et al. 2017	North Americans vs. East Asian, Object vs. Context, Westerners vs Easterners, Analytic vs Holistic	The present study investigates how East Asians and Americans engage perceptual and memory systems during the encoding of detailed memories. Cross-cultural cognitive research has converged around differences in perceptual processing, specifically that there are cross-cultural differences in object versus context processing. When viewing an image of a scene, Westerners typically engage more analytical processes (Nisbett, Peng, Choi, & Norenzayan, 2001), focusing on salient object infor- mation and details (Masuda & Nisbett, 2001), and engaging neural regions associated with object processing (Gutchess, Welsh, Boduro^glu, & Park, 2006) more than Easterners. On the other hand, Easterners typically favor field and contextual information, also known as holistic processing.	East Asians have been shown to allocate more attention to configural information than Americans (Miyamoto, Yoshikawa, & Kitayama, 2011), and this increases East Asians' awareness of changes when a configuration is expanded but slows their detection when a configuration is contracted (Boduroglu, Shah, & Nisbett, 2009). In contrast, Americans modulate object-processing regions more, consis- tent with analytical or local processing.	For example, because Americans focus on ob- jects and visual details, consistent with analytical processing (Masuda & Nisbett, 2001), they are better at remembering specific object features relative to other background infor- mation compared to East Asians (Millar, Serbun, Vadalia, & Gutchess, 2013). On the other hand, because East Asians focus on contextual information, consistent with holistic processing (Masuda & Nisbett, 2001), they do not recognize focal object details as well as Americans when objects are presented alone or in context against a background.	

EEG					
Lewis et al. 2008	East Asian vs. North American, Independence vs. Interdependence, Object vs. Context, Individualist vs. Collectivist	European American cultures have been characterized as displaying independent self-construal. That is, they view themselves as being independent, autonomous, auton omous, and separate from others. Individuals with independent self-construal emphasize self-reliance, competition, and uniqueness and see their behavior as resulting from their own internal thoughts, attitudes, and feelings rather than stemming from relations to others. In contrast, East Asian cultures have been characterized as displaying interdependent self-construal. That is, they view themselves as being interdependent and connected to each other. Individuals with an interdependent self-construal emphasize sociability and in-group harmony and see their behavior in relation to others' thoughts, attitudes, feelings, and actions.	Research on East Asian and European American dif- ferences in social and cognitive processes has resulted in consistent conclusions. Despite the fact that social psy- chological processes have focused on sensitivity to social cues and situational context, and that basic cog- nitive studies have focused primarily on attention to the perceptual field, both areas of research have found East Asians to attend more to the broader context and the relations among focal and surrounding events than European Americans.	To measure self-construal, participants were adminis- tered the Triandis (1995) Individualism and Collectivism Attitude Scale (IND/COL), which consists of 32 state- ments (e.g., "One should live one's life independently of others" and "I usually sacrifice my self-interest for the ben- efit of my group") asking how much subjects agree ranging from 1 (strongly disagree) to 9 (strongly agree).	

Lin et al. 2008	Westerners vs. Easterners, Independent vs. Interdependent, Context Dependent vs. Context Independent	Cultural influence on perceptual processes has also been demonstrated in one culture group using cultural priming procedure. While Western cultures result in independent self that is characterized as a self-contained and context-indepen-dent entity, Eastern cultures breed interdependent self that is regarded as a member in a group highlighting belonging to and dependence upon a context (Markus and Kitayama, 1991), all individuals are expected to flexibly define themselves as relatively more independent or interdependent depending upon current situations (Gardner et al., 1999).	On the basis of these propositions, researchers used self-construal priming, which asks subjects to circle the independent (e.g., I, mine) or interdependent (e.g., we, ours) pronouns in an essay to switch the self towardsWestern independent or Eastern interdependent styles (Gardner et al., 1999), to investigate cultural influence on perceptual processes.	The independent self-construal priming shifted the self-construal towards the Western self-styles, which has been shown to cultivate a context-independent style of cognitive processes and to facilitate focused attention to salient object and ignore the field

Goto et al. 2010	Independence vs. Interdependence, Westerners vs. East Asians, North Americans vs. East Asians, Object vs. Context, Analytical vs. Holistic	Individuals are either oriented more toward independent or interdependent self-construal based on cultural experiences. Individ uals are either oriented more toward independent or interdependent self-construal based on cultural experiences (Kitayama et al., 2007; Markus and Kitayama, 1991). For example, with respect to differences in behavior or 'style of action', research suggests that East Asian behaviors, when compared to Western behaviors, are more sensitive to knowledge held by others (Haberstroh et al., 2002) and to ingroup/outgroup status of the other (Leung and Bond, 1984). East Asians tend to have interdependent self- construals, and thus emphasize sociability and in-group harmony, and see their behavior in relation to others' thoughts, attitudes, feelings and actions. In contrast, individ-uals with an independent self-construal emphasize self-reliance, competition, and uniqueness, and see their behav- ior as resulting from their own internal thoughts, attitudes, and feelings rather than stemming from relations to others. In fact, the self has been conceptualized as a modus operandi through which behaviors are	A range of cognitive tasks has demonstrated the comparative bias or emphasis that East Asians vs North Americans place on stimuli when evaluating their environment.	Attempting to summarize the differences in cognition between East Asians and North Americans, Nisbett and colleagues characterized East Asian cognitive styles as more holistic and North American cognitive styles as more analy- tic (Nisbett et al., 2001). Thus, East Asian cognitions are thought to orient more towards the context, and attend to the relationship between the foreground and the background.	North American cognitive styles are considered analytic with more focus on the foreground, detachment of the object from context, and stronger reliance on rules and categories. These differences are thought to emerge due to differences in social systems (Kuhnen et al., 2001; Nisbett et al., 2001), differences in voluntary immigration (Kitayama et al., 2006) and perhaps differences in environmental landscapes (Miyamoto et al., 2006). Indeed, if particular cognitive styles are associated with self-construal, then analytic styles would be more strongly associated with independent self-construal and holistic styles would be more strongly associated with interdependent self-construal.

Kitayama et al. 2013	Westerners vs. Easterners, North American vs. East Asian, Analytic vs. Holistic, Independence vs. Interdependence	Evidence is mounting that people with Western versus Eastern cultural back- grounds vary in the breadth of attention. European Americans are more narrowly focused and, conversely, Asians are broader or more holistic in the application of attention to perceptual objects (Nisbett et al., 2001). For example, when presented with an animated scene and subsequently asked to remember what they saw in the video vignette, Asians were likely to remember contextual as opposed to focal stimuli more and earlier, as compared to European Americans (Masuda & Nisbett, 2001).	In Western cultures, especially European American middle-class cultures, the independence of the self is sanctioned. One primary task for those brought up in these cultural contexts is to identify their own personal goals and to achieve them. Repeated engagement in this and other related cultural tasks is hypothesized to cause a bias in attention such that perception is chronically focused on goal-relevant objects (Kitayama, Park, Sevincer, Karasawa, & Uskul, 2009). In contrast, in Asian cultures, the inter- dependence of the self with others is strongly sanctioned. One primary task for those brought up in these cultures is to recognize social expectations as well as needs and desires of others in their ingroup and to adjust their behaviors accordingly.	
Wang et al. 2014	Westerners vs. Easterners, Object vs. Context	Traditionally, cognition has been assumed to be universal. However, marked cross-cultural differences in cognitive processing have been observed between individuals in Eastern and Western cultures.	Similar differences have been observed with the Rod and Frame test [5], in scene perception [6], and categorization [7], and have led some researchers to question whether there are cross-cultural differences in object-specific and context-specific attentional processes that could account for these effects.	On the basis of findings of previous studies [5], we hypothesized that Asians would attend more to the relationship between contexts and objects. This could be at the base of observed differences in cognitive processing between Easterners and Westerners, and should be reflected in a significantly larger target P3 and/or novelty P3 among Chinese relative to German participants.

Mecklinger et al. 2014	Physical Environment	The technical term “decorum” refers to a well-established rule-system, which specifies the appropriateness of ornament to respective content or function of the building relationship (Mühlmann, 1996, 2013). It consists in marking the social/ artistic status of the piece of art by certain elements. In architecture, all buildings can be positioned on a scale between the two poles of low-ranking and high-ranking. Various ornamental elements as gates, arches, and columns, mark higher ranking buildings, such as important governmental, sacred, or military constructions. In contrast, unornamented buildings, like agricultural and industrial architecture, represent the low pole.	In fact, as the architectural ranking followed the rules of the architectural decorum of Western cultures it is reasonable to assume that the sensitivity of the N350 and the LPC is modulated by experience with these stimuli, such as the number of prior encounters with Western-style building types in media and real life. In other words, it can be assumed that people being born and growing up in a country with prevailing Western- style architecture are experienced in identifying these buildings.

Summary of EEG Waves

The electroencephalogram (EEG) is a technique used to record brain activity over time. The activity recorded are electrical impulses caused by a flow of ions into or out of the postsynaptic cell. Electrodes attached around the head of a participant detect the collective excitation and inhibition of synapses resulting from this flow of ions, thus producing a wave that represents the summation of the positive and negative charges. Various characteristics of the wave, such as time, frequency, amplitude and scalp location, allow for meaning to be drawn about the brain's electrical activity over a period of time when accomplishing a given task (Niedermeyer, 2004).

The P1 wave refers to the positive wave that peaks at about 100 ms after a stimulus presentation and the N1 wave refers to the negative wave that peaks between 90-200ms after stimulus presentation. Both waves are thought to reflect orientation and attention to the processing of visual stimuli.

The N2 wave refers to the negative wave that appears about 200 ms after stimulus onset and represents the detection of mismatching or incongruent stimuli, cognitive control in quick decision-making, and the detection of rare, but relevant stimuli based on physical properties. Therefore, in a 3-stimulus oddball paradigm, one would expect to see a greater negative N2 wave when presented with the target stimulus.

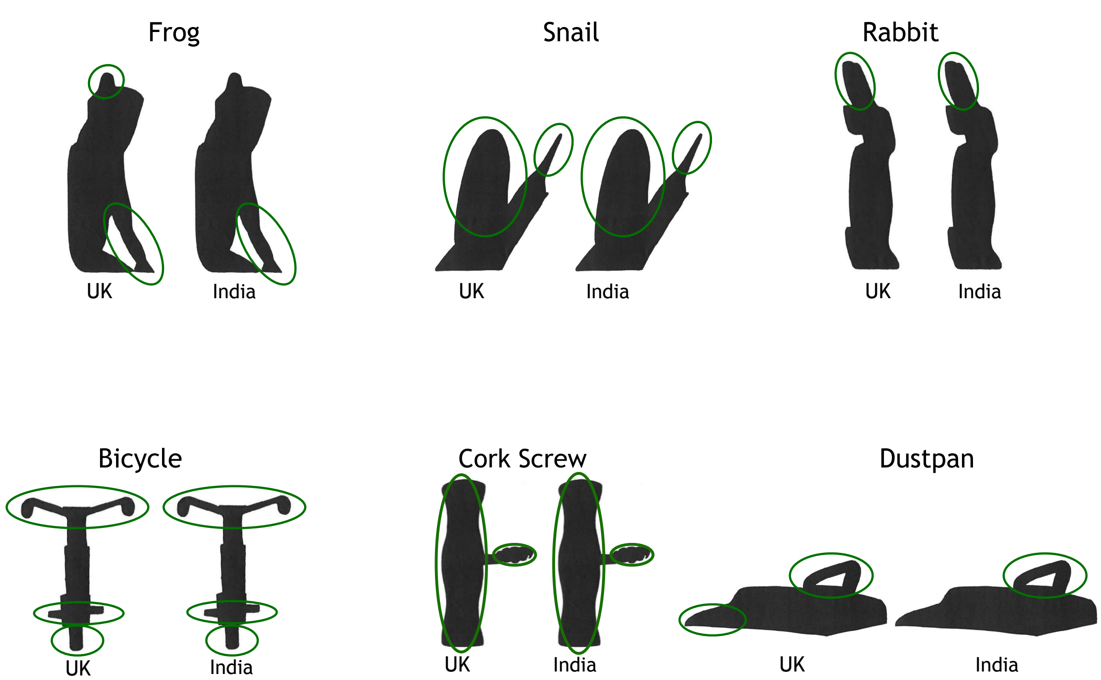
The Novelty P3 wave refers to the positive wave that appears 360-450 ms after stimulus onset, and shows a maximum amplitude located around the fronto-central regions of the scalp. The amplitude is directly correlated to the amount of attention given to a stimuli that appears on occasion but is not what is actively sought out for. For example, in the 3-stimulus oddball paradigm, one would expect to see an increase in Novelty P3 amplitude upon the appearance of the non-target, distractor object. The P300/P3/Target P3 wave refers to the third positive ERP wave that appears 300-400 ms after stimulus onset. This wave shows a maximum amplitude located around the parieto-occipital regions and is thought to represent neural activity involved in detecting rare, but meaningful events. The amplitude is directly correlated to the allocation of attention given towards the stimulus that one is actively searching for. For example, in the 3-stimulus oddball paradigm, one would expect to see an increase in Target P3 amplitude upon the appearance of the target object. The Slow Wave (SW) is thought to be an extension of the Target P3 waves that represents rehearsal and semantic elaboration of the presented stimulus.

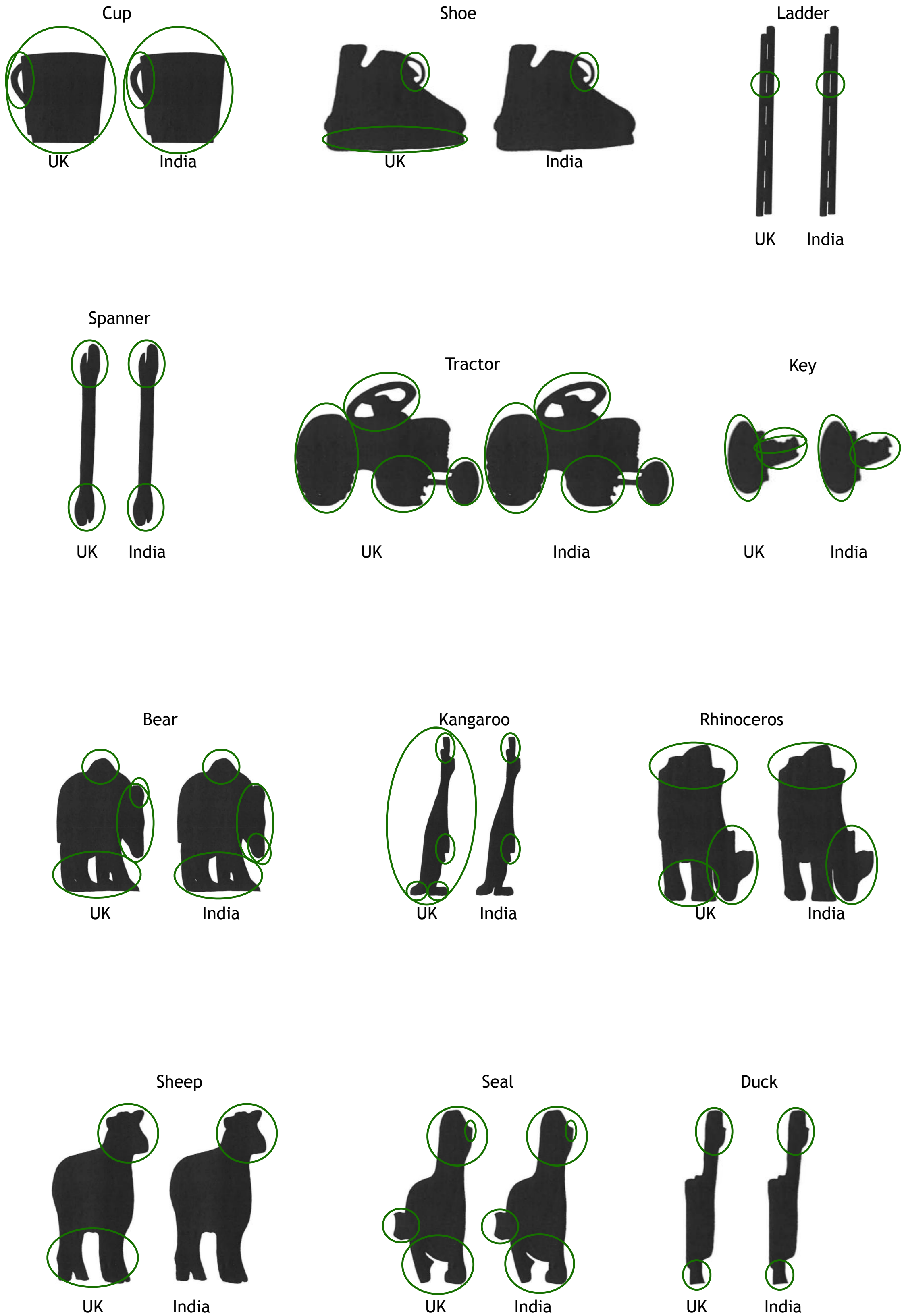
The N350 wave refers to the collection of waves that peak at various time points between 200-400 ms post stimulus presentation. The wave represents object knowledge and categorization, and its amplitude is indirectly related to one's familiarity with the object, irrespective of being able to name it. Therefore, one would expect that greater exposure to a particular object, leading to a greater detailed memory representation of it, would elicit a smaller N350 wave if presented with the same/similar object in the future. The LPC is also a collection of waves that represents object identification, memory, and decision making, however, it is directly related to one’s knowledge of an object and ability to name it.

The N400 wave refers to the negative wave that appears 400 ms after stimulus onset and is thought to represent semantic processing. Its amplitude is inversely correlated to the degree to which stimuli are semantically related, and to cloze probability, or the probability that the semantics of the target is sensical or expected. For example, one would expect a greater N400 wave if presented with a nonsensical image, thus showing a greater demand in cognitive processing for more ambiguous semantic information.

Features Attended

The following are the features that at least 30% of participants in each cultural group indicated as a feature that they felt they attended to on each object of the Silhouettes subtest.





Cup
UK
India
Shoe
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Ladder
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Spanner
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Tractor
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Key
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Seal
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Duck
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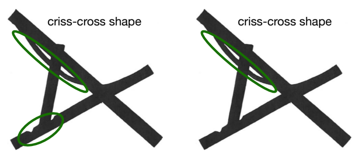
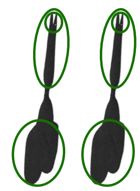
Deck Chair



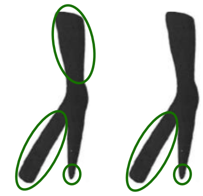
UK India

Scissors



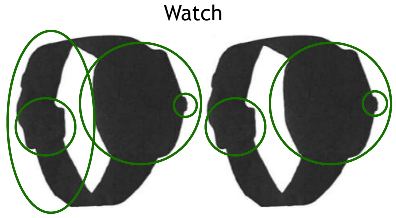
UK India

Pick Axe



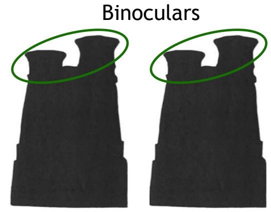
UK India

Watch



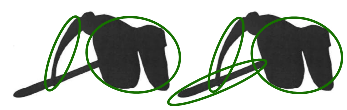
UK India

Binoculars



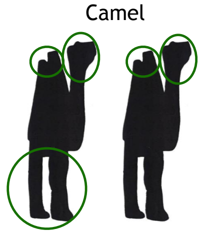
UK India

Binoculars



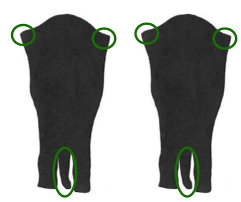
UK India

Camel



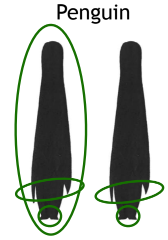
UK India

Elephant



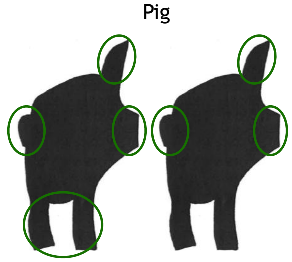
UK India

Penguin



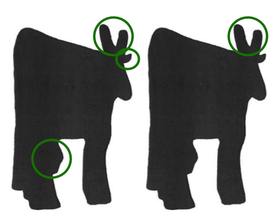
UK India

Pig



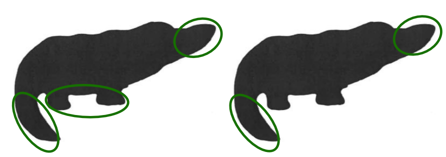
UK India

Cow



UK India

Crocodile



UK India