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Digital Manipulation of Human Faces: Effects on Emotional Perception and Brain Activity

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by

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ABSTRACT

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The study of human face-processing has granted insight into key adaptions across various social and biological functions. However, there is an overall lack of consistency regarding digital alteration styles of human-face stimuli. To investigate this, two independent studies were conducted examining unique effects of image construction and presentation. In the first study, three primary forms of stimuli presentation styles (color, black and white, cutout) were used across iterations of non-thatcherized/thatcherized and non-inverted/inverted presentations. Outcome measures included subjective reactions measured via ratings of perceived "grotesqueness," and objective outcomes of N170 event-related potentials (ERPs) measured via encephalography. Results of subjective measures indicated that thatcherized images were associated with an increased level of grotesque perception, regardless of overall condition variant and inversion status. A significantly larger N170 component was found in response to cutout-style images of human faces, thatcherized images, and inverted images. Results suggest that cutout image morphology may be considered a well-suited image presentation style when examining ERPs and facial processing of otherwise unaltered human faces. Moreover, less emphasis can be placed on decision making regarding main condition morphology of human face stimuli as it relates to negatively valent reactions. The second study explored commonalities between thatcherized and uncanny images. The purpose of the study was to explore commonalities between these two styles of digital manipulation and establish a link between

previously disparate areas of human-face processing research. Subjective reactions to stimuli were measured via participant ratings of "off-putting." ERP data were gathered in order to explore if any unique effects emerged via N170 and N400 presentations. Two main "morph continuums" of stimuli, provided by Eduard Zell (see Zell et al., 2015), with uncanny features were utilized. A novel approach of thatcherizing images along these continuums was used. thatcherized images across both continuums were regarded as more off-putting than non-thatcherized images, indicating a robust subjective effect of thatcherization that was relatively unimpacted by additional manipulation of key featural components. Conversely, results from brain activity indicated no significant differences of N170 between level of shape stylization and their thatcherized counterparts. Unique effects between continuums and exploratory N400 results are discussed.

DEDICATION

This work is dedicated to my wife, Megan, and to my parents. Thank you for the unwavering love, support, and encouragement.

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TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1. Introduction

Facial processing is involved in a vast array of critical human processes. Identification of human facial features is a skill born from evolutionary adaptations, allowing the rapid acquisition and recognition of threatening and dangerous stimuli (Green & Phillips, 2004). In this way, the speedy deduction of threatening stimuli provides quick responses to risk and aids survival in perilous scenarios. Beyond base mechanisms of evolution and survival, the recognition of faces involves a swath of varied and impactful human processes. For instance, differing emotional expressions impact cognitive functioning and control (Abdul et al., 2019). Furthermore, experiments have also examined the role of facial processing and recognition in social biases and social-cognitive frameworks that may impact crucial societal systems (i.e., ability to have a fair trial) (Abshire & Bornstein, 2003; Young et al., 2012). With implications suggesting a salient impact on a myriad of aspects involving human behavior and cognitive perception, the continued refinement in the understanding of facial processing will further inform human social interaction and cognitive conceptualization of different facial types.

Image Presentation Paradigms and Best Fit Methods

In order to best understand the intricate nature of facial processing, different presentation paradigms should be considered, and their potential utility weighed. As such, the first goal of this research is to explore exactly how humans react, both subjectively and objectively, to different phenotypical presentations of human faces. Prior research suggests that humans possess a sensitive array of processes related to identifying and analyzing faces (Donnelly et al., 2011; Kato & Konishi, 2009). Despite this, there is an apparent lack of consensus regarding best-fit presentation paradigms, with prior studies using different techniques to display faces with little empirical justification for their chosen method. Examples of this include the use of full-color

images, black and white images, images that contain visual information from the neck up only, images that solely contain visual information of the face, etc. While such studies often seek to examine similar facial recognition processes, the disparate nature of these methodologies should elicit caution when attempting to infer commonalities in results between studies. Fortunately, some researchers have begun to take steps to rectify this issue. Schindler et al. (2019) examined three different presentation paradigms of human faces across differing "naturalness" conditions: a full-colored image from the neck up, a gray-scale image from the neck up, and a gray-scale cutout image. The latter image was edited into an elliptical shape with blurred edges and included visual information of only the face and forehead. These conditions were tested with multiple faces displaying different emotional states. Researchers concluded that less natural-appearing faces, along with fearful faces, were associated with increased early electrical activity in the brain. As such, they recommend that using a gray-scale cutout paradigm would be most effective in observing an effect in early event-related potential (ERP) components.

However, it seems that decreasing naturalness in order to elicit a more robust response may also decrease a stimuli's familiarity, especially when the object was originally intended to be viewed and recognized as something natural (i.e., a human face). In the context of thatcherization, a technique that makes use inversion of the mouth and eyes, familiarity is important. More significant effects in ERP components are produced when participants view thatcherized same-race faces as opposed to thatcherized other-race faces (Hahn et al., 2012). Additionally, reducing the naturalness of an image by constricting its form to an elliptical shape and unifying its color to gray-scale may attenuate the contrast of an initial seemingly "normal" face and the subsequent realization of its thatcherization. In other words, manipulating an

otherwise inherently natural-appearing stimulus to appear unnatural may diminish the intended contrast of its other specifically-manipulated unnatural aspects.

In the case of such digital alterations to otherwise human-like faces, its subsequent effects are highly dependent upon its orientation, configuration, and stylistic execution (Bartlett & Searcy, 1993; Boutsen et al., 2006; Boutsen & Humphreys, 2003; Hahn et al., 2012). Many studies that have used thatcherized images appear to use differing presentation paradigms with little justification for selected model phenotypes over the use of others. To the authors' knowledge, there is no standardized protocol or recommendations regarding how to present these types of images within ERP-related studies. However, based on the findings of prior studies (e.g., Schindler et al., 2019) and the reasoning explained above, it is expected that discrete reactions will be observed in relation to different presentation types. This is expected to be true for both thatcherized images and digitally morphed, uncanny images, which will be described in detail in subsequent sections.

Thatcherization and Facial Processing

In order to better understand facial processing, Peter Thompson in 1980 developed an image-type characterized by specific facial elements that had been inverted 180 degrees. The original image consisted of a photograph of Margaret Thatcher (Figure 1), from which the technique earns its name, with her eyes and mouth flipped upside down. Thatcherized images built on prior research that examined the effects of a complete image inversion and the resulting difficulty in human-face processing (Thompson, 1980). Additionally, the goal was that this type of image manipulation would shed light on whether facial processing in humans functioned as a more holistic top-down process or relied more critically on the face's specific elements.

The coupling of total image inversion with thatcherized elements marks the predominant utilization of this type of image manipulation across years of research. Specifically, when the image of a human face is presented upright, any thatcherized elements are easy to identify. However, when the entire image is flipped upside-down, the thatcherized components become more difficult to perceive (Thompson, 1980). This occurs because inversion disrupts configural processing. Humans holistically perceive other human faces, incorporating all face elements into a perceptual sum rather than using isolated features (Lewis & Johnston, 1997). This type of holistic processing is also commonly referred to as configural or relational processing (Caharel et al., 2006).

Holistic processing is best understood as a core component of the overall configural processing of human faces. Configural processing also incorporates other discrete tenets of facial recognition, such as the processing of first-order relations (i.e., the recognition of an image as being a face due to the positioning of the eyes, nose, and mouth) and second-order relations (i.e., the relative distance between these features). Holistic processing then acts as the combination of these sensitivities into forming a perceptual gestalt (Maurer et al., 2002). Historically, holistic processing of the face has been studied through composite face stimuli. Researchers created these stimuli by combining the top half of one face with the bottom half of a different face, resulting in a "composite" image that displays features unique to two different individuals (Young et al., 1987). Participants are shown multiple images of these face composites and are tasked with identifying if a part of the face (top or bottom) matches any other part from composite faces seen on prior trials. The inability to recognize reoccurring components of these faces suggests an inability to separate the target information from the distracting, non-matching component. This suggests that faces are processed in a holistic manner. Interestingly, there are

differences in performance in congruent trials compared to incongruent trials, called the congruency effect (Cheung et al., 2008; Farah et al., 1998). The congruency effect describes that participants are much more readily able to identify novel elements of congruent trials (those that have composite elements of the face that are either both the same or both different from a previously studied face) as opposed to incongruent trials (those that have one part the same and one part different from a previously studied face). An important consideration in this type of experimental methodology is the participants' duration of exposure to each stimulus. Holistic processing has been found to occur in as little as 50 milliseconds (ms) of exposure to a face (Richler et al., 2009). However, when participants are allowed longer durations of exposure to the face stimuli, such as an exposure window of 2 seconds, they begin to engage in more part-based processing where they analyze discrete features of the face (Hole, 1994). Results such as these indicate that holistic analysis occurs rapidly and as the initial component of a sequential processing paradigm, suggesting that it may play an important role in determining humans' first impressions related to facial recognition.

Thatcherization has been used to better understand exactly how humans engage in holistic processing and the larger configural processing of human faces. Studies have shown that by inverting the eyes and mouth, holistic processing can be disrupted. This effect can be further enhanced when the entire image itself is inverted, as seen in a study conducted by Lewis and Johnston (1997). Participants were exposed to two different trial conditions: a "same" trial in which both faces of the pair were the same, and a "different" trial in which one face was thatcherized and the other remained unmanipulated. These face pairs were shown either right-side up or inverted 180 degrees so as to appear upside down. Participants were then required to respond as quickly as possible and indicate whether the pairs were the same or different. Results

indicated a significantly slower reaction time in trials containing thatcherized faces where the image pairs were inverted (Lewis & Johnston, 1997). This suggests that inversion produces a global slowing of the holistic analysis process in face recognition and highlights the early utility of thatcherization techniques.

More recent studies have built upon this prior research and demonstrated that the basis for thatcherization's magnitude of effect is partly due to its manipulation of elements considered highly salient features of the human face (Psalta et al., 2014). Donnelly et al. (2011) used fMRI and reaction time tests and found that both the mouth and eyes were critical focal points of facial recognition. Neonatal humans already show a preference for human faces that exhibit a gaze fixated towards the observer as opposed to a gaze that is averted. Such proclivity is implicated in developing later social skills (Farroni et al., 2002). Moreover, Batki et al. (2009) found that neonates engaged more with faces with open eyes rather than closed eyes. This, too, suggests the early existence of eye-centric facial processing and highlights the vital role of eyes in facial recognition.

In humans, the effect of thatcherization is specific to elements of the human face. Non-human objects produce a diminished or non-existent effect when components exhibit thatcherized traits. Using an electroencephalogram (EEG), Boutsen et al. (2006) examined electrophysiological data of participants in response to differing thatcherized and non-thatcherized images (EEG use and specific components will be discussed more in-depth in proceeding sections). Participants viewed images of human faces and houses across these two conditions, as well as oddball images of a chair with no thatcherized components. To thatcherize the image of the house, the front porch and front door were inverted, as well as dormer-style windows located under the roofline. By inverting these specific areas of the house, these

elements were similarly positioned within the visual field as those seen within images of human faces. Results indicated no significant electrophysiological reaction relative to thatcherized house images over non-thatcherized house images (Boutsen et al., 2006). These findings are supported by the results of another study (Donnelly et al., 2011) that tested participant reaction time in a forced-choice task of thatcherized and non-thatcherized images of a human face and a church. Participants viewed images in both an upright orientation and in an inverted orientation. Elements of the church were manipulated similarly to the prior study, displaying an inverted front door and large window. When asked to choose if the image elements were manipulated, participants answered incorrectly a significantly higher number of times. They also took longer to respond when the condition displayed the inverted thatcherized face compared to the inverted thatcherized church. Results from Boutsen et al. (2006) and Donnelly et al. (2011) indicate that specific processes are engaged in facial recognition that do not carry over into object recognition, providing strong evidence that thatcherization elicits a unique effect only when applied to faces.

The technique of thatcherization has since been used countless times across many participant types. In one study (Bertin & Bhatt, 2004) that examined infant eye gaze and detection of thatcherized images, infants distinguished thatcherized images from non-thatcherized, upright human face images. However, when the faces were inverted, results suggested that the infants could not determine which image incorporated the thatcherized elements. This is likely due to an underdeveloped ability for configural processing in infants (Kato & Konishi, 2009). To further explore this ability, Kato and Konishi (2009) examined different scan paths of infants aged six months to 13.5 months old in response to upright and inverted faces. In order to determine a scan path, a "path" of individual facial focal points was developed through eye-tracking particular areas of interest (AOIs). They found that holistic

processing is refined through the early aging/developmental process and that scan paths are grouped more towards internal facial features at older ages. Older participants demonstrated a propensity towards fixating on inverted faces. These findings point to a biologically engrained process paramount to the effective development of facial processing and recognition. Moreover, they also impart the significance of internal facial features, as well as hint at the ability to recognize upside human faces as actually being human in (as opposed to inversion effects impairing the processing of overall contextual information that may result in the face being "recognized" as an object). Similar studies have used facial inversion to further understand how and when infants develop the ability to recognize faces based on internal facial features instead of the external facial configuration (e.g., Leo & Simion, 2009; Rose et al., 2008)

Thatcherization has also seen a great deal of use in studies exploring the recognition of faces from different races. Often referred to as the "other-race effect" or "own-race bias," this theory posits that faces of the same race are more easily remembered and recognized (Chiroro & Valentine, 1997; Meissner & Brigham, 2001; Wiese et al., 2014). To test this theory within the context of thatcherized images, Hahn et al. (2012) used both thatcherized and non-thatcherized images of human faces across multiple races. Participants' reactions were measured using an EEG. The electrophysiological response was significantly modulated in response to thatcherized images of the same-race faces as opposed to thatcherization of other-race faces. Overall, this suggests that humans process faces differently depending on whether the face stimuli are of matching or differing race from the observer.

Thatcherization also reliably produces an image deemed "grotesque" by its observers (Dahl et al., 2010; Searcy & Bartlett, 1996). Grotesque is defined by Merriam-Webster (n.d.) as "fanciful, bizarre; absurdly incongruous; departing markedly from the natural, the expected, or

the typical." Murray et al. (2000) tested the effects of inversion on grotesque perception, employing unaltered human face images and images of human faces manipulated in differing ways. Researchers developed a "spatial" manipulation condition that used classic thatcherization techniques and altered images by increasing the distance between the eyes and mouth (resulting in a much longer or wider face). Additionally, a "component" manipulation was used to whiten areas of the eyes, and the teeth were blackened. Participants rated the images on a scale of one to seven, ranging from normal to bizarre. When upright, the images containing thatcherized elements and other spatial alterations were rated as more grotesque than all other conditions. The blackened eye and teeth manipulation was also rated significantly more grotesque than the control condition, but not to the same degree as the spatial alterations. In keeping with other literature, the effects of thatcherization significantly decreased when the entire image was inverted. These findings are further supported by the results of an fMRI task that required participants to indicate whether faces contained thatcherized elements in both upright and inverted images (Donnelly et al., 2011). Imaging results showed that upright thatcherized images elicited activation of neural networks involved in evaluating emotional and social stimuli. These results reinforce the emotionally-laden grotesque appearance of thatcherized faces.

Overall, thatcherization provides unique insight into how humans process facial features. It acts to pinpoint salient features involved in face recognition and how configural processing disrupts specific feature manipulation. Additionally, it informs typical subjective reactions to the presentation of such altered stimuli. Thatcherization also has potential for further use through its coupling with a theory that deals with similar processes, the Uncanny Valley.

Uncanny Valley Theory and Facial Processing

The Uncanny Valley, a theory developed by roboticist Masahiro Mori in 1970, was originally utilized to understand how humans interact with human-like robots. The theory posits that as robots become more human-like in appearance, they elicit more favorable responses from their human observers (Mori et al., 2012). Such a response was described initially as *shinwakan*: a Japanese term roughly translated as meaning *affinity* or *familiarity*. More commonly, however, the literature shows that this term is more appropriately described as *likability* (Kätsyri et al., 2015). The relationship theorized in the Uncanny Valley shows an interesting response curve, climbing initially in likability as the robot becomes more anthropomorphic, but dropping steeply as the representation enters territory that could be deemed almost human-like but not quite human (Mori et al., 2012). As the human-like representation becomes fully human in appearance, the favorability response begins once again to rise, and the traits quickly become more likable. From this characteristic dip, the Uncanny Valley earns its name. Such representations of human-like entities that fall into this "valley" commonly include prosthetics and *bunraku* puppets, a traditional Japanese theatre puppet that possesses human-like qualities (Mori et al., 2012).

While the Uncanny Valley theory is often referenced when creating robots, as technological advances continue, it has seen influence and uses in differing industries (Seyama & Nagayama, 2007). Indeed, the Uncanny Valley's unappealing effects are also elicited in human-like forms that are not robotic, such as manipulated images of real faces and digital creations (Zell et al., 2015). As such, months of work and considerable financial investments are commonly attributed to creating high-fidelity, digitally constructed characters for movies and avatar creation in virtual environments and video games (Schindler et al., 2017; Seyama &

Nagayama, 2007). Using the Uncanny Valley as a guide, creators and innovators strive to create human-like entities that fall outside the valley in an effort to avoid unappealing character design.

Interestingly, the exact mechanism involved in the human response to uncanny representations is undetermined. In fact, the current state of research regarding what type of image manipulation produces the most “uncanny” effect is inconclusive. Recent studies have attempted understand this phenomenon better, using a series of images along a "morph continuum" (e.g., Cheetham et al., 2011; Schindler et al., 2017; Zell et al., 2015). This allows researchers to present a series of manipulated images depicting a human face and head with characteristics that become increasingly or decreasingly human-like in appearance. Mori’s theory originally states that simply almost-human-like entities should produce the most unsettling effect. However, Seyama and Nagayama (2007) found that morphed images of entities with an almost perfectly human appearance alone were not adequate to reliably produce the unpleasantness described by the Uncanny Valley. Several morph continuums were used with different non-human starting points, including a doll head, a computer-generated image, and a cartoon-like drawing of a face. Each of these faces was progressively morphed into more and more human-like depictions. Overall, a mismatch of manipulated facial elements, such as abnormally large eyes paired with an otherwise normal head, produced the most unpleasant effect. These findings suggest that while near-human representations are necessary for evoking a response characteristic of the Uncanny Valley, this quality alone does not reliably produce a dip in likability. Instead, the mismatch of facial elements was vital in producing the uncanny effect. These results are supported by a study (Cheetham et al., 2013) that utilized eye-tracking of participants exposed to ambiguous and unambiguous face conditions. Participants’ gazes dwelled longest on the eyes and mouths of the more ambiguous images, which were categorized by

differing skin textures/tones and differing facial geometry. This suggests that the eyes in these morph conditions are highly salient and require additional perceptual processing.

This mismatch quality of facial elements is an influential factor in producing an image that evokes responses characteristic of uncanniness. Macdorman et al. (2009) concluded that participants found images that used mismatching facial proportions to be most disturbing. Specifically, mismatched textures and eye size in relation to the head were most eerie. More recently, Zell et al. (2015) examined the perception of morphed images created using high-fidelity three-dimensional scans of real humans. Researchers developed a host of different conditions, including the use of differing head shapes, skin appearances (e.g., blemishes and skin irregularities), materials (e.g., more cartoon-like in appearance or more realistic), shading, and expressions. Participants responded to a series of questions regarding their perceptions of these images. Results indicated that the shape of the head was the most salient factor in predicting how "real" participants interpreted the image to be. Additionally, researchers concluded that a mismatch in head shape and material, such as a realistic head shape with cartoon material, resulted in the most unappealing character designs. This stands at odds with Mori's original premise that the degree of realism alone dictates the most robust response to uncanny representations.

Further supporting the impact of mismatched human elements is a functional magnetic resonance imaging (fMRI) study conducted by Saygin et al. (2012) that utilized movements of a non-human robot, human-like android, and human actor. The robot was built using a metal frame designed to resemble the upper body of an adult human. Additionally, it was constructed to allow 42 degrees of movement across the upper body, allowing for dynamic head and arm movements. This resulted in movements that were human-like but still distinctly robotic in execution. To

create a condition deemed uncanny in appearance, researchers constructed an android using the same robot but with added elements including realistic silicon skin, hair, and a silicon face created from a mold of the female actor. Movements across the three conditions included actions such as drinking from a cup, waving, and context-dependent directional head nodding (commonly used to indicate non-verbal responses of "yes" or "no"). fMRI results showed a significant increase in brain activity in areas linked to the "predictive coding framework of neural processing" in response to actions performed by the android (Saygin et al., 2012, p. 419). This theoretical framework of neural processing suggests that brain activity in specific regions will be higher in the presence of stimuli that are unexpected or not commonly predicted (e.g., Friston, 2005, 2010; Jakobs et al., 2009). Put simply, participants showed increased fMRI activity in reaction to the uncanny condition consistent with the activity associated with unexpected stimuli, linking incongruous element processing with the presentation of uncanny elements.

It is important to note that these effects are not specific to real-world applications of uncanny agents. In fact, these results are similarly seen in the behaviors of computer-generated entities as well. In one study (Groom et al., 2009) examining the effects of a full-bodied three-dimensionally rendered female avatar, participants consistently rated realistic human behaviors performed by the avatar as less likable than unrealistic behaviors, or a series of behaviors that demonstrated mixed realism. Mixed realism was categorized by pairing realistic body movements without lip-syncing. The avatar was human in presentation and possessed a realistic face but exhibited distinct traits of computer generation (i.e., smooth skin textures, unrealistic lighting conditions, etc.),resulting in an avatar that is human-like but not convincingly fully human. These findings suggest that a more favorable reaction is produced when a computer-

generated avatar's behaviors are consistent with its presentation. If the elements of its appearance are incongruous with the realism of its behaviors, it yields an undesirable effect marked by less likability and increased participant discomfort.

To further illustrate the impact of incongruous human features, a study conducted by Mitchell et al. (2011) examined the effects of voice and appearance pairings. Participants rated differing combinations on their humanness, eeriness, and warmth. Images of a robot and a human were used and paired with voices deemed synthetic or human. Unsurprisingly, participants rated the robot presentation-synthetic voice pairing as the least human and the human presentation-human voice pairing as the most human. A significant interaction effect was found for eeriness where participants rated a mismatch of physical presentation with voice type to be significantly eerier than the other matched presentations.

Pathogen-Avoidance: A Common Mechanism?

In viewing both the effects of thatcherized and uncanny images, it is clear that humans are highly sensitive to incongruous human features. When familiar components involving human entities are juxtaposed with unexpected elements that are inhuman or near-human in nature, they evoke negative reactions (e.g., grotesque, eerie, unfamiliar, disturbing, etc.). The mechanism of these particular types of reactions may be rooted in an evolutionary adaptation of pathogen-avoidance (Macdorman, 2006; MacDorman & Entezari, 2015; Wang et al., 2015). Pathogen-avoidance is described as being an integral component of the behavioral immune system. This is a robust set of psychological defense mechanisms that impact social attitudes, beliefs, and behaviors within the context of self-preservation (Gruijters et al., 2016; Shook et al., 2015).

A basic example of this can be seen via a study conducted by Fitzgerald et al. (2018). Participants on a college campus tasted water that they were told came from different sources,

such as a restroom sink, kitchen sink, or water fountain. The water was accompanied by an image of the location it was said to come have from (though in reality the water did not come from these sources). Overall, participants consumed significantly less water when they believed it had come from the restroom sink and also rated the water as not only being less clean, but of lower quality taste. This study shows that perceptions of pathogen existence can lead to demonstrable impacts on behavior and perception, manifesting in avoidance behaviors (Fitzgerald et al., 2018).

Within the context of human appearance, the presentation of mismatched elements that are incongruous with expected features may initiate a warning to the possibility of communicable disease. Such a warning acts as an inherent safeguard to ensure suitable distance maintenance and can be manifested in multiple ways in response to the perceived threat. These reactions can be cognitive, such as developing negative beliefs, or emotional, such as experiencing anxiety or feelings of disgust (Park et al., 2003). The heuristic pathogen-avoidance response is described as being over-inclusive, eliciting reactions to features that may not be directly linked with disease, such as limb amputation from an accident, scarring/disfigurement from injuries and burns, etc. (Park et al., 2003). This could explain the uncanny response elicited by prosthetics originally described by Mori, though the context of prosthetic presentation may differ. For instance, a prosthetic limb that is attached to a human body may evoke a sense of eeriness because of the mismatch of a human body paired with an appendage that does not exactly match its wearer (e.g., subtle differences in color tones between the human body and prosthetic device, differing materials and texture, inhuman or robotic movement of the prosthetic appendage, etc.). This may signal an alarm process to the observer that the appendage is in some

way diseased or infectious, as it deviates from a lifetime of observationally reinforced expectancies.

Additionally, a prosthetic appendage presented on its own, such as a hand on a table, if sufficiently human-like in appearance, may evoke a reaction due to the innate avoidance of corpses and severed body parts (Curtis & Biran, 2001; Mori, 1970). These types of implications have been expanded to include more broad aspects of human social interaction as well. Perhaps controversially, the pathogen-avoidance theory has been implicated as an influential aspect of developing social stigmas and xenophobic attitudes (Faulkner et al., 2004; Kurzban et al., 2001).

In a study conducted by Ainsworth and Maner (2019), mechanisms of pathogen-avoidance were explored within the context of preferential facial features of the opposite sex. Researchers primed participants by disease cues and then were shown images of two faces and instructed them to choose which one they found more desirable. Of the two faces, one had been digitally manipulated such that it possessed a high degree of symmetry between facial features. The rationale for this type of manipulation is that individuals with perfectly symmetrical facial construction may represent a lower possibility of having contracted a contagious disease. It is important to remember that processes inherent to pathogen-avoidance are over-inclusive, resulting in nuanced avoidance paradigms that manifest in numerous ways. Results showed that when primed with disease cues prior to exposure to the faces, participants showed a significant preference towards the symmetrical faces of the opposite sex (Ainsworth & Maner, 2019). This indicates that avoidance of diseases/pathogens plays an important role in the decision-making processes of mate selection. Additionally, this works to underscore the general salience of digitally manipulated facial features within the context of pathogen-avoidance.

It is worth briefly mentioning that a similar type of negative reaction has been elicited in participants in response to otherwise harmless animals such as cockroaches and spiders, but not in response to animals that would be far more likely to harm humans, such as lions and sharks (Mathcett & Davey, 1991). Fear of the latter animal group is present but does not function at a similar level of disgust as the former group. Some believe that these types of reactions to relatively harmless animals may be driven by socially instilled mechanisms rather than biological function, a product of the pretechnological era, ill-informed association between the animal and epidemics (Davey, 1994). Regardless of whether this avoidance response operates as a societal or biological function, it is clear that it is impactful and can inform a range of human interactions, including how humans perceive and react to thatcherized and uncanny entities.

The uncanny valley theory and thatcherized images have foundations rooted in psychological principles, with implications that may help inform how humans interact with one another. They both elicit similar subjective reactions to the respective images. However, this subjective component explains only half of the potential impact of these different types of images. By using an EEG, electrophysiological data can be measured in the brain in order to understand more discrete, objective influences and reactions these types of images may evoke.

Event-Related Potentials and the Electroencephalogram

The EEG has been used to measure of brain activity since its first rudimentary use by Hans Berger in 1929 (Luck, 2005). Through the use of electrodes located at differing points across the scalp, differences in electrical potential can be measured that correspond to the brain's response to specific stimuli or events (Hugdahl, 1995). These differing responses that can be reliably elicited in repeated experimental conditions are called event-related potentials (ERPs). Some of these components have been identified as being particularly useful in understanding

facial recognition and processing. Such components commonly include the P100, N170, P250, early positivity negativity (EPN) (Langeslag et al., 2018), and late positive potential (LPP) (Boutsen et al., 2006; Hahn et al., 2012; Kunkel et al., 2018;). It is common practice for an ERP to be labeled to denote the typical amount of time required for a particular response to occur to a stimulus. For example, in the case of the P100, if an image is displayed to a participant, one could expect to see a positive deflection in brain activity (measured in microvolts) to occur about 100ms post image exposure. Due to high amounts of variability, typical EEG studies will utilize a large number of trials so that brain activity responses can be measured many times (Hugdahl, 1995). This allows for an average of all responses to be taken, resulting in a composite waveform called the grand average, which helps to mitigate the variability across discrete trials and participants.

Additionally, to help create a unified system for EEG use, the international 10-20 system was created, which standardizes electrode placement on the scalp (Jasper, 1958, as cited in Hugdahl, 1995). The result is a system that facilitates accurate and consistent placement of electrodes along the scalp that correspond to the differing cortical lobes. Such refinement in techniques has afforded the EEG extensive use in many clinical and research applications.

N170 Background

Of the previously mentioned ERPs, the N170 is perhaps the most well-studied component involved in the neural processing of human faces (Bentin et al., 1996). It is uniquely suited for facial recognition, demonstrating a diminished response or complete absence in the presence of inanimate objects and other non-face component recognition (Bousten et al., 2006; Eimer, 2000a, 2000b). Using a relatively limited set of electrode sites (Luck, 2005) compared to more recent studies, early studies conducted by Jeffreys (1989) as well as Bötzel and Grüsser (1989)

documented the existence of N170-like reactions to face image. A response was found to occur between 150-200ms post image exposure and was evoked by faces displayed in photographs, drawings, inverted images, and images with missing components (Jeffreys, 1989).

A response was found to occur between 150-200ms post image exposure and was evoked by faces displayed in photographs, drawings, inverted images, and images with missing components (Jeffreys, 1989). Additionally, non-human face stimuli such as animal faces, human hands, and cars were used. Participants were shown multiple images across several experiments. In order to ensure attention to the images, participants were asked to count the number of images that appeared within each category. Results showed that a negative deflection response reliably occurred, on average, at 172ms post-presentation of the differing human face stimuli, but was non-existent for the other images. Bentin et al. concluded that the results indicate a process of structural analysis involved in the neural categorization of the image as a human face (1996). Furthermore, it was found that the amplitude of the N170 response was delayed when participants were shown images of inverted faces. Despite this, the amplitude of the N170 was not diminished, suggesting a categorization process that is not attenuated in effect but that takes longer to actuate when visual information is presented in a non-normal fashion. Moreover, studies have shown that inversion tends to increase N170 amplitude in response (Sadeh & Yovel, 2010). This demonstrates that participants still recognized that the image, despite its inversion, was human in nature, and the larger amplitude may result from more cognitive effort required to process it.

It is worth mentioning that “recognition” within this context refers to the innate processing of the human face rather than concepts of familiarity. In N170 research, participant familiarity with the human stimuli and its interaction with component manipulation have been

explored in detail. Using images of celebrities such as actors and politicians, Bentin and Deouell (2000) found no significant difference in N170 between familiar and unfamiliar faces. Additionally, Eimer (2000) found there to be no effect of familiarity on ERP magnitude. However, this could be due to a lack of personal interest in these familiar images (Caharel et al., 2006). To explore this, Caharel et al. (2006) examined both the behavioral and neural effects that image familiarity has on processing and the N170 by using images of participants' own faces, family members, and friends. Images were presented in upright and inverted conditions, along with an upward shift manipulation of the eye positions. As expected, reaction times in recognition of unaltered familiar faces were faster than those that were unfamiliar. EEG findings indicated that familiar faces produced a larger N170 response than unfamiliar faces and faces with shifted eyes.

Interestingly, the familiarity effect disappeared when the images were inverted, further reinforcing the disruption of configural processing inherent in inversion. However, in an examination of familiar vs. unfamiliar faces and caricatures, it was found that caricatured unfamiliar faces evoked larger N170s in comparison to caricatured familiar faces (Kaufmann & Schweinberger, 2008). Researchers suggest that the enhanced effects of familiarity may be due to more robust memory representations in emotionally connected images and their involvement in structural processing. However, such findings could also indicate temporal overlap of later processes closely associated with other ERP components such as the N250 (Caharel et al., 2006).

To further illustrate the potential impact of familiarity, a study conducted by Hahn et al. (2012) examined the effect of viewing human faces belonging to the same race as participants and faces from other races. Both thatcherized and non-thatcherized conditions were used. Findings indicated that a larger N170 was produced when participants viewed faces of other

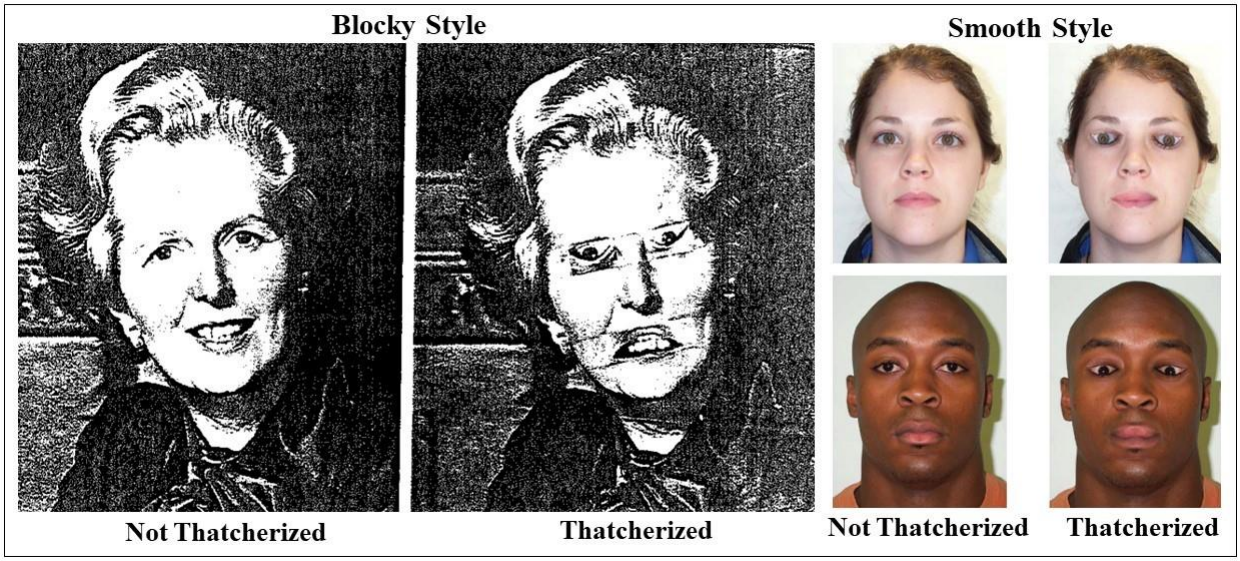
races in comparison to same races. Also, they found that thatcherization resulted in a slight decrease in N170 amplitude (Hahn et al., 2012). Regardless of the function and effect of familiarity, most studies conducted to understand configural processing and image manipulation use unfamiliar stimuli, and the use of participant-specific familiar imagery is rarer still. This likely results from attempts to control for confounding influence and allows for a more hermetic evocation of ERP data, as well as a more simplified and replicable methodology. Overall, it is difficult to conclusively say the exact impact that familiarity has on the presentation and amplitude of the N170.

Thatcherization Technique and the N170

Thatcherization techniques have changed over time since the original thatcherized image was constructed by Thompson in 1980. Initially, such images were typically created in a "blocky" cutout fashion, denoted by including the inversion of large sections of the areas immediately surrounding the eyes and mouth (Figure 1.1 for comparison of techniques).

Figure 1.1

Thatcherization Style Comparison



Note: "Blocky Style" image from Thompson, P. (1980); "Smooth Style" image from Hahn et al., (2012).

This resulted in an image where the manipulation was more obvious. Through more sophisticated digital image-editing software, recent thatcherized images are characterized by more subtle manipulations. Inversion is restricted to just the desired elements, omitting any immediate surrounding areas. Additionally, after inversion of the eyes and mouth, image smoothing around the edges of the newly oriented elements can be used to make the inversion appear more natural.

Perhaps due to such differences in thatcherization technique, results are mixed as to whether thatcherization enhances negative deflection for image presentation or attenuates it (Boutsen et al., 2006; Carbon et al., 2005; Hahn et al., 2006). Hahn et al. (2012) posit that this contrast may result from the differences described above, attributing more smoothly thatcherized images (as opposed to using blocky cutouts of internal facial features) used in recent studies to contain less visual noise. It is believed that this requires less effort to analyze and produces a more diminutive N170 that is solely impacted by the "configural disruption" of the manipulated elements (Hahn et al., 2012, p. 122). In this study, thatcherized images with smoothed edges of specific component manipulation are used. The purpose of this is to create image types that are similar to the images created in more modern studies.

Uncanny Valley and the N170

A robust body of literature examining the N170 in the presence of uncanny images is lacking. Despite the overall paucity of research in this area compared to other experimental manipulations, one study has offered the promise of potential in N170 utilization that warrants further exploration. In a study conducted by Schindler et al. (2017), a set of digitally altered

human face images originally developed by Zell et al. (2015) was used. These images were represented in various states along a 6-point continuum of stylization. Ranging from an unaltered human face to one that is completely computer-generated, the photos were morphed to become increasingly animated and less life-like in appearance. This resulted in a set of images that were intended to capture the characteristic dip in likability detailed in the Uncanny Valley theory while maintaining the high likability of the polar ends (i.e., most abstract and most realistic). It is important to note that while the highly stylized and subsequently least human image in this continuum is drastically different from the unaltered image, it still appears uniquely human, akin to a children's cartoon-like animated movie character. Results showed a significantly larger N170 response to the most abstract and most realistic image conditions. A subsequent u-shaped response curve emerged, indicating an overall smaller N170 response to the images deemed most abstract and situated along the middle of the continuum. This response curve seems to approximate that of the uncanny valley, indicating that the less desirable images promote a smaller N170. These findings could result from the image manipulation type, as the most stylized image was characterized by neotenic properties like smooth skin and larger features. Such features have been linked in previous studies with larger N170 amplitudes (Proverbio et al., 2010). Schindler et al. (2017) conclude that neotenic features are important elements to include in future uncanny valley research that uses computer-generated, morphed images. Such work may more accurately inform where along the morph continuum characteristic dips in likability occur by utilizing the N170 to help identify representations deemed most uncanny.

N400 Background

The N400, an ERP component first described by Kutas and Hillyard (1980), is evoked in the context of mismatched and unexpected information. The N400 was originally studied within

the context of semantic tasks. Kutas and Hillyard (1980) found that words deemed semantically inappropriate, such as reading the sentence containing “he took a sip from the transmitter” (Kutas & Hillyard, 1980, p. 203), produced a large negative deflection about 400ms post-presentation. Additionally, the physical appearance of such words elicited a similar result, seen through the unexpected presence of a word appearing larger than its neighbors. This study is an early example of mapping the neural reprocessing of incongruous information.

Since these initial findings, N400 research has expanded beyond a strictly linguistic context, incorporating more varied elements in stimuli types. For example, an enhanced N400 response has been found in categorically-mismatched pairings of images of famous individuals (Barrett & Rugg, 1989). Images of celebrities from eight categories (i.e., actors, politicians, pop stars, etc.) were paired with another celebrity image from either a matching or non-matching category. An initial image was shown that was quickly followed by the presentation of its “pair.” Participants were asked to indicate whether or not the two images matched in a category. A larger N400-like ERP occurred in response to the mismatched pairs as opposed to matching pairs, indicative of reprocessing that extends into visual information beyond strictly linguistic-based influence.

These results reinforce the findings of a study conducted by Sitnikova et al. (2003). Demonstrating the varied nature of N400 sensitivity, researchers did not use static images but rather employed dynamic stimuli in the form of videos depicting the use of real-world, ordinary objects. The specific use of the object was presented in either congruous or incongruous conditions. For example, a congruous condition depicted a video of a man using a razor blade to shave. In the incongruous format, the man would instead pick up and use a rolling pin. Results

showed an enhanced N400 effect in response to the incongruous use of the object, indicating a network of real-world, dynamic semantic processing.

Thatcherization and the N400

Little research has specifically examined the N400 within the context of thatcherized images. Despite this, the N400 does show promise in its potential to be sensitive to thatcherized elements. Based on prior findings, there is support for the N400 and its sensitivity to human faces and human-like faces with manipulated elements. However, in many studies, verbal information is typically attached to the stimuli in a way that may impact the N400 evocation by providing a semantic reference (i.e., telling participants that a photograph of a person belongs to a category such as "politician" or "sports star"). In asking the participants if subsequent stimuli "matched," meaning belonged to the same category, it is difficult to ascertain if the N400 is evoked in response to the mismatched elements of the visual information or to incongruence of learned semantic qualities. Researchers describe this effect as the "priming by proxy hypothesis" (Olivares et al., 1994, p. 40). In order to circumvent this, Olivares et al. (1994) required participants to study differing images of realistic, drawn human faces in the absence of semantic information over the course of several sessions. Participants were then shown images of the previously learned stimuli that either matched the original learned condition or contained mismatched elements of facial components from the other learned face stimuli. A large, negative ERP occurring around 400ms post-presentation was elicited for the mismatched conditions. This indicates that semantically based information is not required to elicit an N400 response to visual information. Additionally, this suggests that the N400 is sensitive to mismatched elements specific to human faces, as it does not necessarily depend on the priming and learning of verbal information (Olivares et al., 1994; Olivares et al., 1999).

Further support for the N400's sensitivity to faces can be seen in the results of a study that examined congruous and incongruous facial expressions (Balconi & Pozzoli, 2005). Researchers used black and white real images of human male faces displaying prototypical emotional expressions (happy, sad, and fearful). Since these are universal human expressions, they inherently contain learned semantic context associated with their display. These same faces were also digitally morphed to display emotional expressions that were a 50% composite of two prototypical emotions. As this product was a new expression that is not characteristic of any learned emotional display, the manipulation resulted in a face that featured a realistic expression devoid of any semantic value (Balconi & Pozzoli, 2005). These morphed faces elicited an N400 response, reinforcing the existence of cognitive processes involved in decoding anomalous face-based semantic information. While studies such as these do not specifically investigate the effects of thatcherization on the N400, they do use images that, like thatcherization, contain configural manipulations of salient facial components. This points to the N400's potential utility in examining thatcherization effects on the neural processing of human faces.

Uncanny Valley and the N400

While the exact theoretical underpinnings of the uncanny valley have yet to be fully established, an emerging explanation is that the unfamiliarity or eeriness associated with almost-human-like stimuli is driven by a mechanism sensitive to mismatched features (Kätsyri et al., 2015; Saygin et al., 2012; Urgen et al., 2018; Zell et al., 2015). In fact, character designs comprised of realistic material on a cartoon-shaped head, and cartoon material on a realistically shaped head produced the most unappealing appearance (Zell at al., 2015). This type of incongruity, as discussed earlier, is influential in the elicitation of an N400 response.

Despite the N400's current underutilization in its application to better understand the human response to uncanny representations, there is nascent support for its potential use in such formats. In a study conducted by Urgen et al. (2018), researchers examined ERP response in the presence of congruent and incongruent motions of a robot, android, and human stimulus (the experimental conditions are the same as those used in Saygin et al. (2012), described earlier). Results showed a significant N400 response to the uncanny android condition. This suggests that humans form certain learned expectations regarding human appearance. When these expectations are violated due to the movements of the behavioral actuator, an N400 is produced, implicating sensitivity to incongruous elements of human representation. While this experiment used motion to enhance the effects of the N400 response (and in so doing lend support to Mori's (1970) original theory positing that motion enhances the effect of what is deemed uncanny), motion is not required to elicit a negative response typical of uncanny imagery (Looser & Wheatley, 2010; Yamada et al., 2013). Overall, the N400's unique sensitivity to incongruous information and semantic value should provide insight into uncanny imagery processing.

Conclusion

While previously segmented and examined independently, there exists substantial evidence to believe that thatcherization and uncanny imagery influence facial processing in similar ways, perhaps even sharing a common mechanism. Inferences from theory and prior results suggest that thatcherized and uncanny imagery possess commonalities in subjective reactions, though this has yet to be specifically examined. Additionally, current research lacks consensus in findings of electrophysiological response data and the exact behavior of ERPs in relation to these image types. In order to better understand possible connections and provide support for a common mechanism, both image types should be integrated into an experimental

methodology that examines both subjective and objective responses to thatcherized and uncanny image manipulations. By developing a well-rounded understanding of the processes inherent to pathogen-avoidance within the context of digitally manipulated images, inferences can be made regarding the underlying principles driving reactions seen in research utilizing these two image types. Such fundamental principles, particularly within the context of uncanny imagery, have remained elusive to researchers. Furthermore, this may provide critical insight into salient qualities of thatcherized images, which are used frequently in studies of facial processing. This series of studies provides multiple novel means to explore potential similarities between image types. Potential findings have implications for the understanding of the fundamental human quality of pathogen-avoidance and its impact on human perception. Additional benefits can be seen in further understanding different aspects of social behavior, recommendations for therapeutic techniques, and best-fit practices in the film and video game industries.

The Present Study

The purpose of this dissertation was twofold. As such, there were two distinct sets of methodologies written as individual studies. These two individual manuscripts were prepared and formatted for publication according to guidelines for the intended target journal.

Note: Due to the nested nature of this dissertation and its studies, as well as complicated stimuli-type due to their morphology across differing continuums, this section was intended to provide a conceptual scaffolding for the following sections that include the manuscripts for S*tudies 1* and *2*. Due to formatting considerations in the preparation of manuscripts with specific stylistic guidelines, it was the author's intent for this list to serve as a complete and quick reference for the overall hypotheses of the dissertation document.

Study 1

The objective of *Study 1* was to find the best fit method for the presentation of digitally manipulated images. Given the lack of consensus and consistency in utilizing different presentation methods, determining which digitally manipulated presentation paradigm yields optimal results required exploration. This was be accomplished by comparing both subjective (ratings of grotesqueness) and objective reactions (N170 ERP amplitude) to images across three of the most commonly used phenotypical image types, or *conditions* (full color, black and white, and cutout). Effects of *inversion* (not inverted, inverted) and *thatcherization* (not thatcherized, thatcherized) were also explored across each level of *condition*. It was predicted that across all image types, full color, right side up, thatcherized images would produce significantly higher grotesque ratings and larger amplitude N170 ERPs.

Schindler et al. (2017) examined the effect of *condition* using non-thatcherized images of human faces. Results indicated that faces that appeared less natural were associated with increased N170, EPN, and P1 responses. As such, they recommend that using a gray-scale cutout paradigm would be most effective in observing an effect in these early ERP components.

However, as discussed, unilaterally decreasing naturalness may detract from stimuli's inherent familiarity. Constricting its form to an elliptical shape and unifying its color to gray-scale may further attenuate the contrast of an initial seemingly "normal" face and the subsequent realization of its thatcherization. This may diminish the intended contrast of its other specifically-manipulated unnatural aspects. As such, in regards to *condition*, it was predicted that full-color images would elicit significantly larger N170s and produce significantly higher scores of grotesqueness.

Thatcherization is a technique used for exploring disruptions in the configural processing of human faces and is one of the most commonly used methods of digital alteration in these image types. Based on the discussion of prior research, it was expected that thatcherized images would elicit a larger N170 and produce significantly higher grotesque ratings than non-thatcherized images.

The inclusion of different states of *inversion* provided additional insight into whether or not the technique of thatcherization produced the intended effects and was also included to be consistent with prior research. Additionally, with what is known about the disruption in processing associated with inverted images, it was predicted that inverted images would elicit a significantly larger N170 than right side up images due to the additional effort required to process them. Furthermore, total inversion of human faces makes their appearance inherently unnatural and unexpected. Because of this, it was predicted that right-side-up images will produce significantly higher grotesque score ratings.

Study 1 Hypotheses. Objective: To determine a best fit method for the presentation of digitally manipulated stimuli of human faces.

- **Hypothesis I (a): Condition Main Effect (N170):** Full-color images will elicit a significantly more negative N170 than the black and white and cutout conditions.
- **Hypothesis I (b): Condition Main Effect (Grotesque Rating):** Full-color images will produce significantly higher grotesque ratings than the black and white and cutout conditions.
- **Hypothesis II (a): Thatcherization Main Effect (N170):** Thatcherized images will elicit a larger N170 than non-thatcherized images.

- **Hypothesis II (b): Thatcherization Main Effect (Grotesque Rating):** Thatcherized images will produce significantly higher grotesque ratings than non-thatcherized images.
- **Hypothesis III (a): Inversion Main Effect (N170):** Inverted images will elicit a larger N170 than right-side-up images.
- **Hypothesis III (b): Inversion Main Effect (Grotesque Rating):** Right-side-up images will produce significantly higher grotesque ratings than inverted images.
- **Hypothesis IV: Three-Way Interaction (Grotesque rating):** Across all image types, full color, right side up, thatcherized images will produce significantly higher grotesque ratings.

Study 2

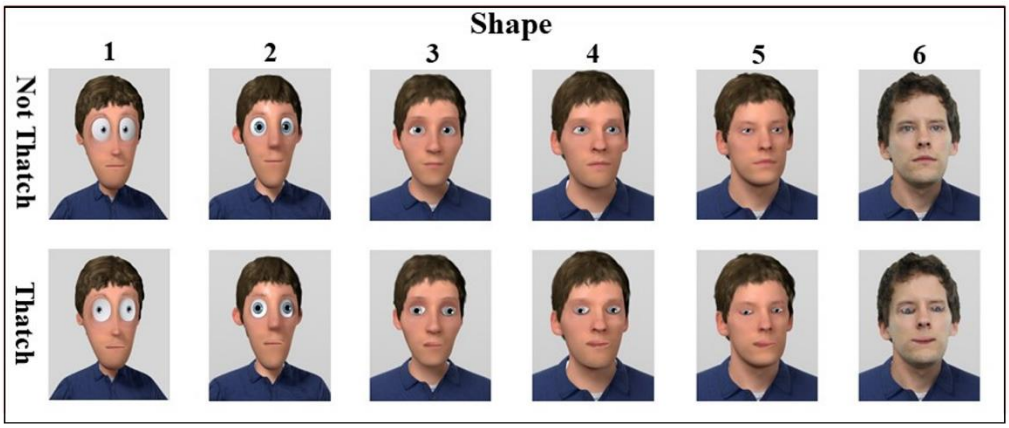
The objective of *Study 2* was to explore participants' subjective (ratings of off-putting) and objective (N170 and N400 ERP amplitude) reactions to both uncanny and thatcherized images. *Study 2* had an explicit focus on uncanny imagery as opposed to general presentation formats (as explored in *Study 1*). This hybrid form of thatcherized uncanny images had not yet been examined in prior research. Images were used in either a non-thatcherized or thatcherized configuration. An important element of uncanny representations is the existence of perceived "mismatch" between key components (Kätsyri et al., 2015). While "mismatch" can be conceptualized in numerous ways, prior research (Schindler et al., 2017; Zell et al., 2015) has found that skin texture and head shape are salient components of manipulation when examining unpleasantness in human and human-like representation. As such, both *shape* and *material* were examined independently in *study 2*. It was believed that examining both of these elements would provide additional support for any evidence of effect across the dependent measures instead of examining only one uncanny featural manipulation alone.

Dr. Zell provided the base images to be used as stimuli for this study. The original set of images contained each level of shape and material and every combination of these two variables across the morph continuum. For the purpose of this study, shape was centered at material level 4, and material was centered at shape level 5. The rationale for this methodological decision stemmed from the findings of Zell et al. (2015) in which the stimuli with the greatest level of mismatch produced the largest response. Therefore, examining effects along a continuum of theoretically most mismatched image presentation (level 1) and the most realistic image presentation (level 6) for both shape and material allowed for a precise exploration into the variables and effects of interest in *study 2*.

Shape Methodology. This section of Study 2 examined shape and thatcherization across a morph continuum (a series of images ranging from highly stylized to unaltered in appearance). This continuum displayed images across six levels, ranging from level 1 as a highly cartoonish character to level 6 as a real, unaltered image of a male human's head and face (Figure 1.2).

Figure 1.2

Study 2 Shape Stimuli



Material 4 was used for all levels of *shape*. This was the second most "realistic" skin texture. This level of material was selected because material 5 (one step more realistic than

material 4) was deemed too heavily stylized with its inclusion of veins and shading of skin texture, which resulted in a distracting image. Moreover, due to these stylistic choices in manipulation, level 5 actually appeared *less* realistic, and as a result, material 4 appeared to be the most appropriate level in terms of featural manipulation. Since material 4 was used for all shapes, shapes 1 and 2 should exhibit the greatest degree of mismatch as these were the most cartoon shaped images which also had a realistic skin texture. Therefore, they were predicted to produce significantly higher off-putting ratings than more realistic shapes towards the opposite end of the continuum.

There was also a version of the morph continuum in which the images were thatcherized. It was predicted that *thatcherized* images would produce higher off-putting ratings than non-thatcherized images. Additionally, it was anticipated that an effect of thatcherization would not be observed in the most unrealistic conditions of *shape* (i.e., positions 1 and 2). However, in the most realistic conditions (i.e., positions 5 and 6), thatcherized images would be significantly more off-putting than non-thatcherized images. Given the current literature, there exists little reason to believe that thatcherizing already highly uncanny imagery will produce an added effect; the uncanny images should already contain high levels of mismatch and off-putting qualities.

In keeping with the findings of Schindler et al. (2017), it was hypothesized that the most unrealistic (i.e., position 1) and the most realistic (i.e., position 6) stimuli would elicit larger N170 responses in comparison to other stimuli positions, regardless of thatcherization.

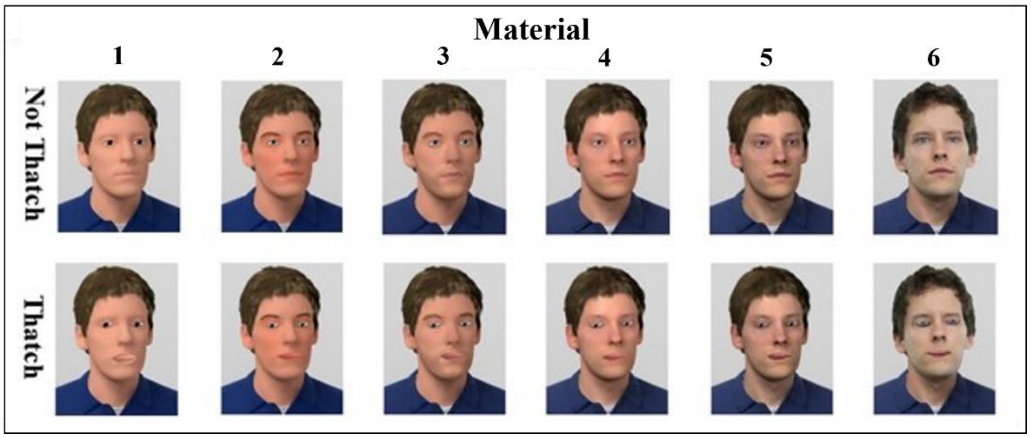
Not much is known regarding the N400 and uncanny/Thatcherized stimuli, and as a result, the predicted effect regarding the N400 was exploratory in nature. However, it has been shown that the N400 is particularly sensitive to mismatched and unexpected information (Barrett

& Rugg, 1989; Kutas & Hillyard, 1980). For these reasons, N400 responses were expected to be largest in response to thatcherized images. Additionally, the N400 amplitude was predicted to be largest for the most unrealistic condition (position 1) and would decrease in amplitude, resulting in the smallest amplitudes in the most realistic conditions (i.e., positions 5 and 6).

Material Methodology. *Material and thatcherization* were examined across a similar morph continuum. This continuum also existed across six levels, ranging from level 1 (human-shaped head with very smooth and cartoonish skin texture) to level 6 (real, unaltered image of a male human's head and face; Figure 1.3).

Figure 1.3

Study 2 Material Stimuli



Shape level 5 was used for all levels of *material* as shape level 5 was the most realistic level of manipulated image type. While shape level 6 was technically more realistic as it is an unaltered image, it is not computer generated and thus did not possess differing levels of manipulated features. In other words, shape level 5 was the most realistic level of shape upon which *material* could be manipulated accurately and reliably. Therefore, materials 1 and 2 possessed the largest degree of mismatch when displayed on shape level 5. As a result, these

images were predicted to produce significantly higher off-putting ratings than more realistic shapes along the continuum.

As in *Study 1*, there was a matched continuum of thatcherized images. It was predicted that thatcherized images would produce higher off-putting ratings than non-thatcherized images. Additionally, in the most unrealistic conditions of material (i.e., positions 1 and 2), an effect of thatcherization would not be observed. However, in the most realistic condition (i.e., positions 5 and 6), thatcherized images would be significantly more off-putting than non-thatcherized images.

Similar to the rationale provided for shape regarding the N170 and thatcherized images, it was hypothesized that the most unrealistic (i.e., position 1) and the most realistic (i.e., position 6) stimuli would elicit larger N170 responses in comparison to other stimuli positions, regardless of thatcherization.

Finally, predictions regarding the N400 were exploratory due to the overall lack of existing research in this area. Considering what *is* known about N400 ERPs, it was expected that thatcherized images would produce a larger N400 response than non-thatcherized images. Additionally, N400 responses would be largest in the most unrealistic condition (position 1) and would decrease in amplitude, thus resulting in the smallest amplitudes in the most realistic conditions (i.e., positions 5 and 6).

Study 2 Hypotheses. Objective I: To explore participants' subjective ratings of both uncanny and thatcherized images to understand which images are perceived as being most "off-putting" ("repellent, disconcerting"), and to investigate if an interaction emerges between ratings of uncanny and thatcherized images.

- **Objective II:** To better understand how objective reactions, measured via the ERP components N170 and N400, behave in the presence of thatcherized, uncanny, and thatcherized uncanny images.

Shape. **Hypothesis I:** Shape Main Effect (Off-Putting Rating): Along the shape continuum, the most unrealistic shape (level 1) will produce significantly higher off-putting ratings than the more realistic shape (level 6).

- **Hypothesis II: Thatcherization Main Effect (Off-Putting Rating):** Along the **shape** continuum, thatcherized images will produce higher off-putting ratings than non-thatcherized images.
- **Hypothesis III: Shape by Thatcherization Interaction (Off-Putting Rating):** In the most unrealistic conditions of **shape** (i.e., levels 1 and 2), an effect of thatcherization will not be observed. However, in the most realistic conditions (i.e., levels 5 and 6), thatcherized images will be significantly more off-putting than non-thatcherized images.
- **Hypothesis IV: Main Effect of Shape (N170)**: Along the **shape** continuum, the most unrealistic (i.e., level 1) and the most realistic (i.e., level 6) stimuli will elicit larger N170 responses in comparison to other stimuli levels, regardless of thatcherization.
- **Hypothesis V (Exploratory): Main Effect of Shape (N400):** Along the **shape** continuum, N400 responses will be largest in the most unrealistic condition (level 1) and will decrease in amplitude, resulting in the smallest amplitudes in the most realistic conditions (i.e., levels 5 and 6).

Material. **Hypothesis I:** Material Main Effect (Off-Putting Rating): Along the material continuum, the most unrealistic material (level 1) will produce significantly higher off-putting ratings than most realistic material (level 6).

- **Hypothesis II: Thatcherization Main Effect (Off-Putting Rating):** Along the **material** continuum, thatcherized images will produce higher off-putting ratings than non-thatcherized images.
- **Hypothesis III: Material by Thatcherization Interaction (Off-Putting Rating):** In the most unrealistic conditions of **material** (i.e., levels 1 and 2), an effect of thatcherization will not be observed. However, in the most realistic condition (i.e., levels 5 and 6), thatcherized images will be significantly more off-putting than non-thatcherized images.
- **Hypothesis IV: Main Effect of Material (N170)**: Along the **material** continuum, the most unrealistic (i.e., level 1) and the most realistic (i.e., level 6) stimuli will elicit larger N170 responses in comparison to other stimuli levels, regardless of thatcherization.
- **Hypothesis V (Exploratory): Main Effect of Thatcherization (N400):** Thatcherized images will produce a larger N400 response than non-thatcherized images.
- **Hypothesis VI (Exploratory): Main Effect of Material (N400):** Along the **material** continuum, N400 responses will be largest in the most unrealistic condition (level 1) and will decrease in amplitude, resulting in the smallest amplitudes in the most realistic conditions (i.e., levels 5 and 6).

Chapter 2. Best Fit Presentation Modalities of Digitally Manipulated Facial Stimuli: Subjective Reactions and Event-Related Potentials

Target Journal: Psychophysiology

Title: Best Fit Presentation Modalities of Digitally Manipulated Facial Stimuli: Subjective Reactions and Event-Related Potentials

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Short Title: Presentation of Digitally Manipulated Images

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Abstract

The study of human face-processing has granted insight into key adaptions across various social and biological functions. However, there is an overall lack of consistency regarding digital alteration styles of human-face stimuli. This is especially true as it relates to studies that have examined the effects of thatcherized images. In this study, three primary forms of stimuli presentation styles (color, black and white, cutout) were used across iterations of non-thatcherized/Thatcherized and non-inverted/inverted presentations. Outcome measures included subjective reactions measured via ratings of perceived "grotesqueness," and objective outcomes of N170 ERP effects measured via encephalography. Results of subjective measures indicated that thatcherized images were associated with an increased level of grotesque perception, regardless of overall condition variant and inversion status. There were no discrete effects of condition on grotesque ratings, indicating that differences in color, black and white, and elliptically cutout images did not alone modulate negatively valent perceptions of human faces. A significantly larger N170 was found in response to cutout-style images compared to other conditions, thatcherized compared to non-thatcherized images, and inverted compared to right side up images. This is likely due to the increased cognitive effort required to process these types of images. Results suggest that cutout image morphology may be considered a well-suited image presentation style when examining ERPs and facial processing of human faces. Moreover, less emphasis can be placed on decision making regarding main condition morphology of human face stimuli as it relates to negatively valent reactions.

1 INTRODUCTION

The identification of human facial features is a skill born from evolutionary adaptations, allowing the rapid acquisition and recognition of threatening and dangerous stimuli (Green & Phillips, 2004). Additionally, processing facial features across differing emotional states is an essential aspect of social interaction and has also been shown to be related to aspects of cognitive performance (Abdul Rahman & Wiebe, 2019; Hering et al., 2018). With implications suggesting a salient impact on many different aspects of human functioning, many studies have sought to elucidate how humans process and understand facial features and expressions.

1.1 Manipulation of Human Face Stimuli

One such study saw the introduction of thatcherized images to illustrate that the processing of human facial elements is affected by the image's orientation (Thompson, 1980). The original image consisted of a photograph of Margaret Thatcher, from which the technique earns its name, with her eyes and mouth manipulated so as to appear upside down. According to Thompson (1980), this was done in an attempt to build on prior research that examined the effects of a complete image inversion and the resulting difficulty in processing and recognition of the face. Images that had been manipulated in such a manner appeared off-putting. Furthermore, when the entire image was reoriented so that it was upside-down, the inverted eyes and mouth of the face became more challenging to identify.

In order to build upon these early findings, thatcherization has been used to explore how humans engage in the holistic processing of human faces. Studies have shown that holistic processing can be disrupted by inverting the eyes and mouth. This effect can be further enhanced when the entire image itself is inverted. For example, Lewis and Johnston (1997) conducted a

study in which participants were shown a pair of faces. Participants were then exposed to two different trial conditions: a "same" trial in which both faces of the pair were the same, and a "different" trial in which one face was thatcherized and the other remained unmanipulated. These face pairs were shown either right-side-up or inverted 180 degrees to appear upside down. Participants were then required to respond as quickly as possible and indicate whether the pairs were the same or different. Results indicated a significantly slower reaction time in trials containing thatcherized faces where the image pairs were inverted (Lewis & Johnston, 1997). This suggests that inversion produces a global slowing of the holistic analysis process in face recognition and highlights the early utility and application of thatcherization techniques.

1.2 Thatcherization and Grotesqueness

Thatcherization has also been shown to reliably produce an image deemed "grotesque" by its observers (Dahl et al., 2010; Murray et al., 2000; Searcy & Bartlett, 1996). Grotesque is defined by Merriam-Webster (n.d.) as "fanciful, bizarre; absurdly incongruous; departing markedly from the natural, the expected, or the typical." Murray et al. (2000) tested the effects of inversion on grotesque perception, employing unaltered human face images and images of human faces manipulated in differing ways. Researchers developed a "spatial" manipulation condition that used classic thatcherization techniques and also altered some images by increasing the distance between the eyes and mouth (resulting in a much longer or wider face). Additionally, a "component" manipulation was used to whiten areas of the eyes, and the teeth were blackened. Participants rated the images on a scale of one to seven, ranging from normal to bizarre. When upright, the images containing thatcherized elements and other spatial alterations were rated as more grotesque than all other conditions. The blackened eye and teeth

manipulation was also rated significantly more grotesque than the control condition, but not to the same degree as the spatial alterations. In keeping with other literature, the effects of thatcherization were significantly decreased when the entire image was inverted. These findings are further supported by the results of an fMRI task that required participants to indicate whether faces contained thatcherized elements in both upright and upside images (Donnelly et al., 2011). Imaging results showed that upright thatcherized images elicited activation of neural networks involved in evaluating emotional and social stimuli.

1.2 Electrophysiological Impact of Thatcherization

EEG provides an objective means to explore facial recognition within the context of thatcherized images. Such event-related potentials (ERPs) commonly examined include the P1 (Hahn et al., 2012), N170 (Boutsen et al., 2006), P250 (Milivojevic et al., 2003), early positivity negativity (EPN; (Langeslag et al., 2018), and late positive potential (LPP; Kunkel et al., 2018;). Of these, the N170 has been shown to be particularly germane to facial recognition processes. In a study conducted by Bentin et al. (1996), the N170 response was compared across multiple faces and non-face presentation conditions. It was found that the amplitude of the N170 response was delayed when participants were shown images of inverted faces. Despite this, the amplitude of the N170 was not diminished, suggesting a recognition process that is not attenuated in effect but that takes longer to actuate when visual information is presented in a non-normal fashion. Additionally, this N170 response was shown to be unique to the identification of human faces, as there was a lack of a significant presentation in the presence of non-human face stimuli (Bentin et al., 1996). This human face-specific quality of the N170 has been shown numerous times across subsequent studies (Boutsen et al., 2006; Eimer, 2000a, 2000b).

1.3 Methods of Face Presentation

Given the link between face-related stimuli and ERP components, it is important to understand best-fit methods for stimuli construction. Numerous studies have used differing methods for the presentation of thatcherized images and face-related stimuli in general. One study sought to understand these types of optimal presentation conditions for stimuli presentation (Schindler et al., 2019). Researchers examined three different presentation paradigms of human faces across differing "naturalness" conditions: a full-colored image from the neck up, a gray-scale image from the neck up, and a gray-scale cutout image. The latter image was edited into an elliptical shape with blurred edges, which only included visual information from the mid-forehead, down to the corner of the eyes, around the cheeks, and ended at the chin. Researchers tested these conditions with multiple faces displaying different emotional states. It was concluded that these faces that appeared less natural, along with fearful faces, were associated with increased N170, EPN, and P1 responses. As such, they recommend that using a gray-scale cutout paradigm would be most effective in observing an effect in these early ERP components.

However, it seems that decreasing naturalness in order to elicit a more robust response may also decrease familiarity of the stimulus, particularly when the object is originally intended to be viewed and recognized as something natural (i.e., a human face). Furthermore, reducing the naturalness of an image by constricting its form to an elliptical shape and unifying its color to gray-scale may attenuate the contrast of an initial seemingly "normal" face and the subsequent realization of its thatcherization. Put simply, manipulating an otherwise inherently natural-appearing stimulus to appear unnatural may diminish the intended contrast of its other specifically-manipulated unnatural aspects.

1.4 Methods of Thatcherization

The original thatcherized images produced by Thompson (1980) are characterized by a "blocky" inversion of the eyes and mouth. Visual material that surrounded the eyes and mouth was included in the inversion, resulting in the manipulation of rectangular sections of the face that extended beyond the targeted area. This resulted in an image where the manipulated components appeared quite obvious.

The predominant technique used to thatcherize images has changed with more recent advances in technology. Image editing software readily allows for a more finely tuned method of inversion. Thatcherized images are typically created by inverting only the eyes and mouth, while the larger area is left unaltered. Furthermore, once the eyes and mouth have been flipped, researchers are able to smooth and blur the lines around these features. This type of thatcherization technique is most commonly used in current research. Currently, no consensus exists about the exact methods to thatcherize an image of a human face, and as reported by Hahn et al. (2012), varying degrees of integration (i.e., smoothing, shading, blurring, etc.) can be seen across different studies.

1.5 Present Study

The present study seeks to partially replicate the study conducted by Schindler et al. (2019) in order to better understand their results within the context of thatcherized images. The saliency of thatcherization and its subsequent effects depends on its orientation, configuration, and execution (Bartlett & Searcy, 1993; Boutsen et al., 2006; Boutsen & Humphreys, 2003; Hahn et al., 2012). Many studies that have used thatcherized images appear to use differing presentation paradigms with little justification for selected model phenotypes over the use of

others. To the authors' knowledge, there is no standardized protocol or recommendations regarding how to present these types of images within ERP-related studies. However, based on the findings of prior studies (i.e., Schindler et al., 2019) and the reasoning explained above, a significantly more negative N170 effect is expected to be seen when thatcherized images are presented in the neck-up, full-color condition. Additionally, due to the increased degree of configural disruption caused by image inversion and thatcherization, it is predicted that these types of images will be associated with significantly larger N170 amplitudes compared to their non-inverted/non-thatcherized counterparts.

Finally, thatcherized and inverted images are also expected to be rated as significantly more grotesque than non-inverted images due to their inherently inhuman-like appearance. As an extension of this rationale, full-color images are expected to be rated as overall more grotesque than the black and white and cutout conditions. This is due to color images' retainment of more visual information that will ostensibly allow their manipulated elements to be more clearly visible.

2 METHOD

Data were collected at the Brain Computer-Interface Lab located at East Tennessee State University in Johnson City, Tennessee. All experimental procedures were approved by the East Tennessee State University Institutional Review Board.

2.1 Participants

A power analysis using MorePower version 6.0.4 (Campbell & Thompson, 2012) was conducted in order to determine an appropriate target sample size. MorePower is a free statistical

calculator that offers more flexibility (and subsequent accuracy) with complex ANOVA-based designs than other statistical calculators (Campbell & Thompson, 2012). It was determined that a sample size of 36 participants should yield adequate power to conduct the study by using an eta squared value of .10 (moderate to large effect) and an alpha criterion of .05.

In total, 36 undergraduate participants were recruited at East Tennessee State University. Participants were enrolled via the ETSU Psychology Research Participant website SONA. All participants were over the age of 18. The mean participant age was 20 (*SD* = 3.064), and 21 were female. Thirty-three of the participants identified as white, two as Asian/white, and one as other.

2.2 Stimuli and Apparatus

Participants were seated in a chair in a quiet room and responded via a Dell KB212-B keyboard located on a table in front of them. Keystrokes were logged through the input of either the line of number keys located at the top of keyboard or the numeric keypad located on the right of the keyboard surface. Participants were able to rest their hands on the table's surface and select number keys based on their subjective ratings with little overall movement. Image presentation was controlled via E-Prime 3.0 build 3.0.3.80 (Psychology Software Tools, Inc.) on a Dell PC running Microsoft Windows 10 Education v21H1. Stimuli were presented on a Dell UltraSharp 2007WFP 20" Widescreen 1680x1050 16:10 LED monitor with a Dell 1708FB-BLK Color Profile.

Participants sat with a viewing distance of approximately 90 cm to the monitor. The stimuli of faces, which were 5.5 cm x 9 cm in size, appeared centered on the screen, with a horizontal visual angle of 3.50° and a vertical visual angle of 5.72°.

Images of faces were collected from the Radboud Faces Database (Langner et al., 2010). In keeping with the methodology of Schindler et al. (2019), images of faces were manipulated into three main conditions: a full-colored image from the neck up, a gray-scale image from the neck up, and a gray-scale cutout image (Figure 2.1).

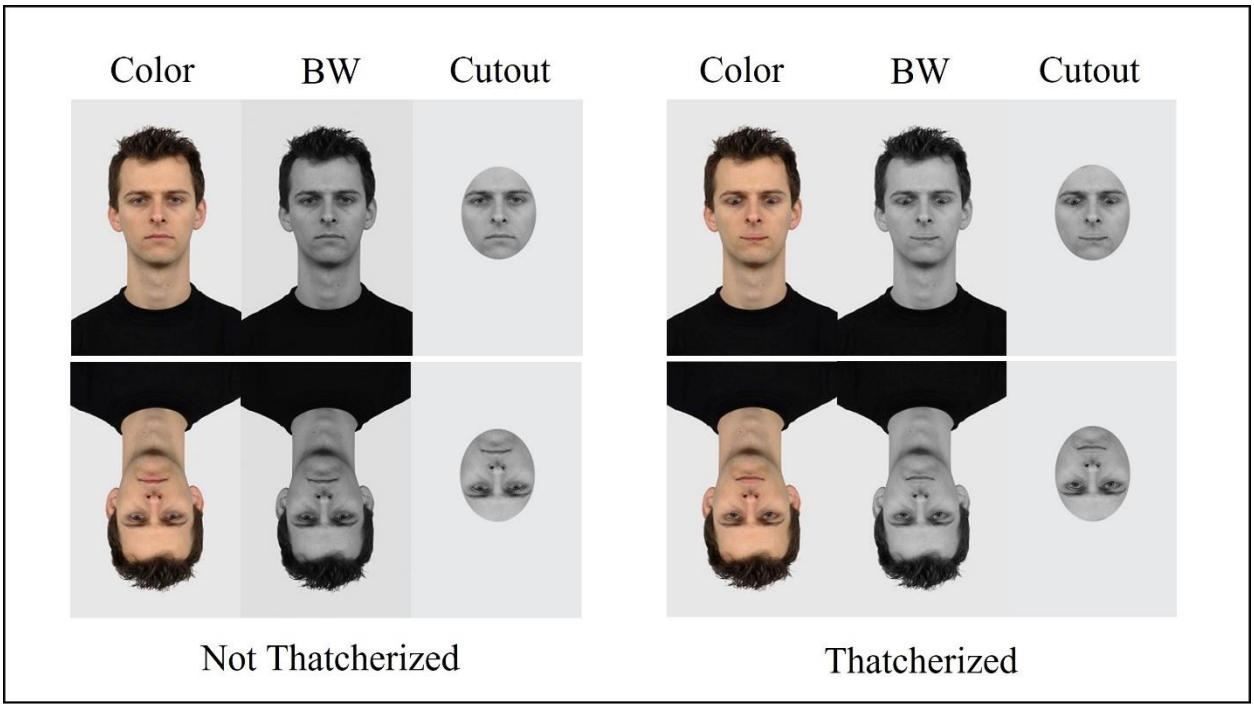

Figure 2.1

Example of one stimulus across conditions and thatcherization. BW = black and white. Facial expressions were also either neutral or thatcherized across conditions.

Thatcherization was accomplished by rotating the eyes and mouth of the faces 180 degrees in Adobe Photoshop. Per methodology detailed in Hahn et al. (2012), the edges of the rotated facial elements were blended to maintain a more natural appearance. Images in the cutout condition were created by cropping visual information outside of the immediate face area,

resulting in an image that displayed information from the top of the forehead to the bottom of the chin. This resulted in an elliptical shape.

2.3 Procedure

In total, 12 male and 12 female faces were utilized. Participants were instructed to respond to the three different naturalness conditions in differing presentation blocks. Each block contained 24 normal (non-thatcherized) images, 24 thatcherized images, 24 inverted normal, and 24 inverted thatcherized images, for a total of 96 trials per block (3 blocks, 288 trials in total). Stimuli presentation was randomized. Before each trial, a black fixation cross on a white background was presented for 1500ms. followed by a stimulus for 400ms. Next, participants were asked to rate, via number-key press, the grotesqueness of the stimuli on a 5-point Likert scale adapted from the measure used by Hahn et al. (2012). This scale rated grotesqueness from 1 (“not at all grotesque”) to 5 (“very grotesque”). Selecting a rating ended the trial. Participants had 4000ms to respond to the scale before the presentation of the next fixation cross and stimulus. Block order presentation was randomized across participants.

2.3 EEG Recording and ERP Preparation

Data were collected using a 32-channel EEG cap. The EEG was amplified with two Guger Technologies g.USBamp amplifiers. The recordings were grounded to the left mastoid and referenced to the right mastoid at 256 Hz and filtered using a 0.5-30 Hz bandpass filter. The impedance was kept under 20 kΩ.

EEG data were preprocessed in EEGLAB using artifact subspace reconstruction (ASR) to identify and remove low-quality channels. Removed channels were re-referenced based on

common average and interpolated. Components containing large amounts of eye blink artifacts were identified and rejected using independent components analysis (ICA) and visual inspection via ICLabel (at least 90% confidence threshold for rejection). Epochs were baseline corrected using a 200ms pre-stimulus duration. Epochs of -200 to 800ms were time-locked at 0ms for stimulus presentation.

A time window was defined, based upon visual inspection of the N70 waveform, for the analysis of the N170 ERP ranging from 120ms to 220ms. N170 amplitude was defined as the most negative peak within this time window. The reported results are based on a composite 'waveform' averaged across the following lateralized electrodes: P3, P4, P7, P8, Po7, Po8, O1, and O2. Each participants' peak amplitude occurring in the specified window was recorded for analysis.

3 RESULTS

3.1 Statistical Analyses

Separate repeated-measures ANOVAs were used to examine outcomes of grotesque ratings, N170 amplitude, and N170 latency across within-subject factors of *condition* (color, black and white, cutout), *thatcherization* (not thatcherized, thatcherized), and *inversion* (not inverted, inverted). For instances of violation of sphericity, Greenhouse-Geisser corrected values were reported unless otherwise stated. Post-hoc comparisons were performed using Bonferroni correction unless otherwise specified. Main effects and interactions for *thatcherization*, *inversion*, and *condition* were examined. Effect sizes η^2_p are reported.

3.2 Behavioral Results

3.2.1 Main Effects

In keeping with prior research, a significant main effect was observed for grotesqueness ratings of *thatcherization*, $F(1, 35) = 334.491$, $p < .001$, $\eta^2_p = .905$, with thatcherized images ($M = 3.089$, $SD = 0.775$) being rated as more grotesque than non-thatcherized images ($M = 1.493$, $SD = 0.466$). Furthermore, a main effect was observed for *inversion*, $F(1, 35) = 38.961$, $p < .001$, $\eta^2_p = .527$, such that non-inverted (right side up) images ($M = 2.531$, $SD = 0.565$) were rated as more grotesque than inverted images ($M = 2.051$, $SD = 0.676$). Contrary to predictions, no differences in *condition* were found, indicating no significant difference of grotesque rating across color, black and white, and cutout image types.

3.2.2 Interactions

It was predicted that color, right side up, thatcherized images would elicit significantly higher grotesque ratings than all other image types. However, the interaction between *condition*, *inversion*, and *thatcherization* failed to reach significance ($p = 0.522$). Additionally, when collapsed across *inversion*, there was no significant interaction between *condition* and *thatcherization* ($p = 0.079$).

However, a significant interaction emerged between *thatcherization* and *inversion*, $F(1, 35) = 2.637$, $p < .001$, $\eta^2_p = .886$. Post-hoc analysis of pairwise comparisons indicated that inverted non-thatcherized images ($M = 1.699$, $SD = 0.575$) were rated as more grotesque than non-inverted (right side up) non-thatcherized images ($M = 1.287$, $SD = 0.357$; $p < .001$). Non-inverted (right side up) thatcherized images ($M = 3.776$, $SD = 0.774$) were found to be more

grotesque than inverted thatcherized images $M = 2.402$, $SD = 0.777$; $p < .001$) (Figure 2.2 for details).

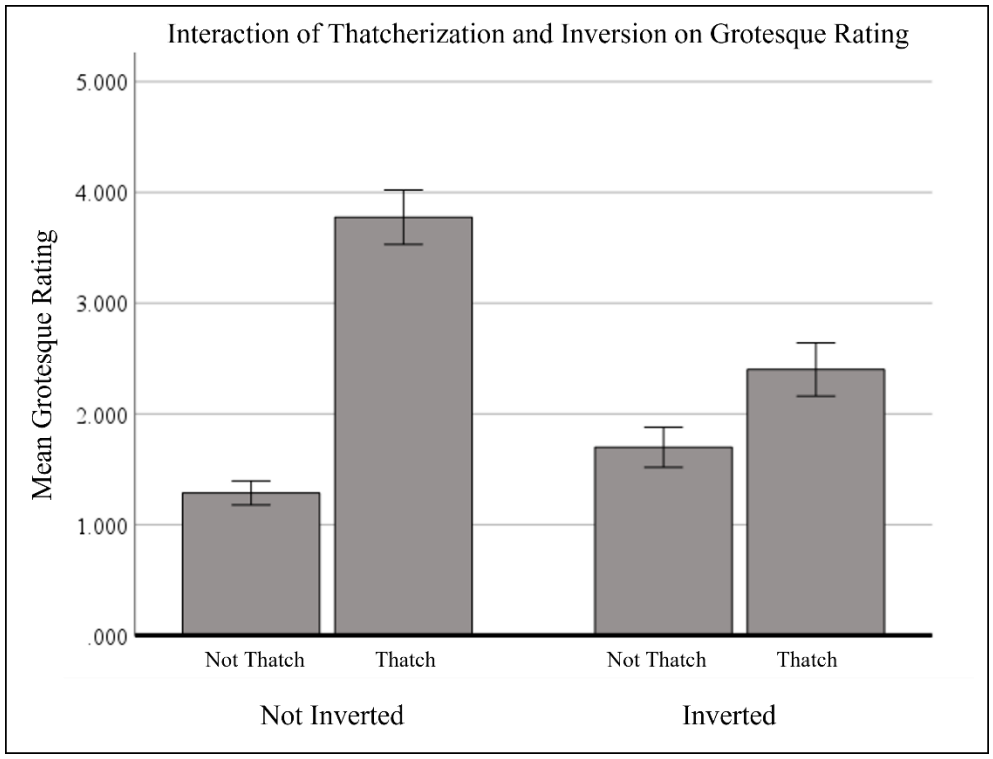

Figure 2.2

Bar graph displaying interaction of *thatcherization* and *inversion* on grotesque ratings. Error bars are based on +/- 2 SE and were conducted using standard plotting methods in SPSS.

3.3 N170 Results

3.3.1 Amplitude

N170 amplitude was defined as the most negative value within the range of 120ms to 220ms occurred, averaged across each of the selected electrode locations. A 3-way repeated-measures ANOVA including the factors of *condition*, *thatcherization*, and i*nversion*, was used to

examine amplitude differences among the conditions. A significant main effect emerged for *condition*, $F(1.712, 61.619) = 5.914$, $p = .007$, $\eta^2_p = .141$. Bonferroni adjusted pairwise comparison revealed that the N170 was significantly larger in the cutout condition ($M = -1.504$, $SD = 1.485$) compared to the color condition ($M = -.997$, $SD = 1.807$). The black and white condition did not significantly differ from the color and cutout conditions (Figure 2.3).

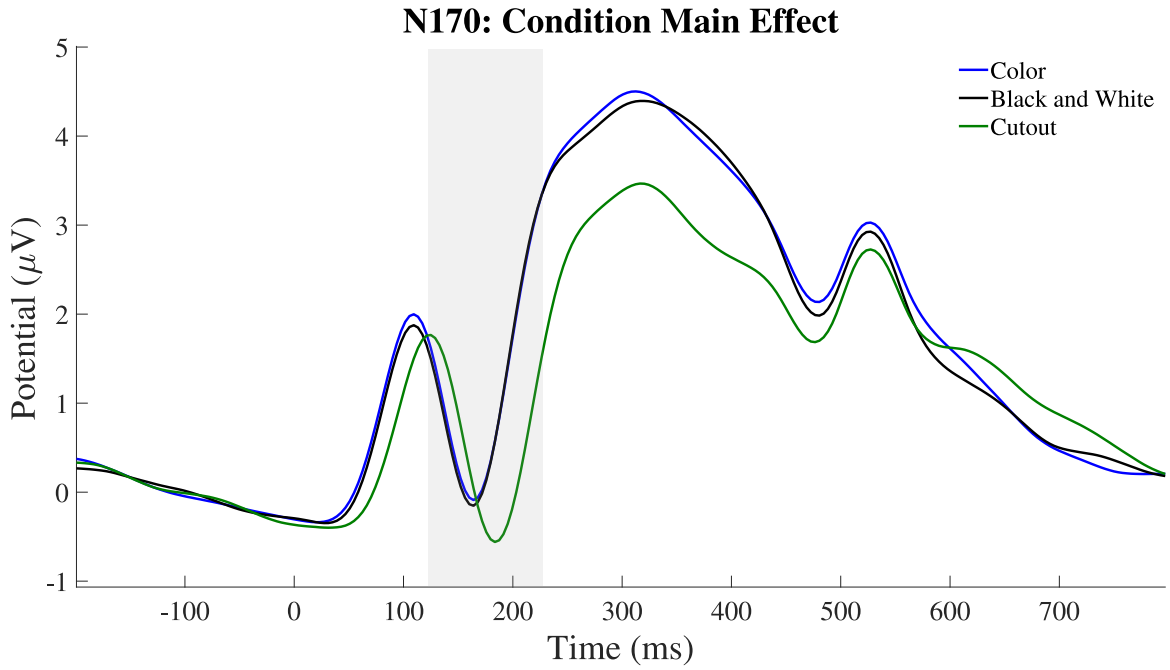

Figure 2.3

Mean waveforms for the main effect of *condition*. Waveforms constructed from averages across P3, P4, P7, P8, Po7, Po8, O1, and O2 electrodes.

A significant main effect was observed for *thatcherization*, $F(1, 37) = 4.188$, $p = .048$, $\eta^2_p = .104$, indicating a significantly more negative N170 in response to thatcherized images ($M = -1.272$, $SD = 1.749$) compared to non-thatcherized images ($M = -1.115$, $SD = 1.731$) (Figure 2.4).

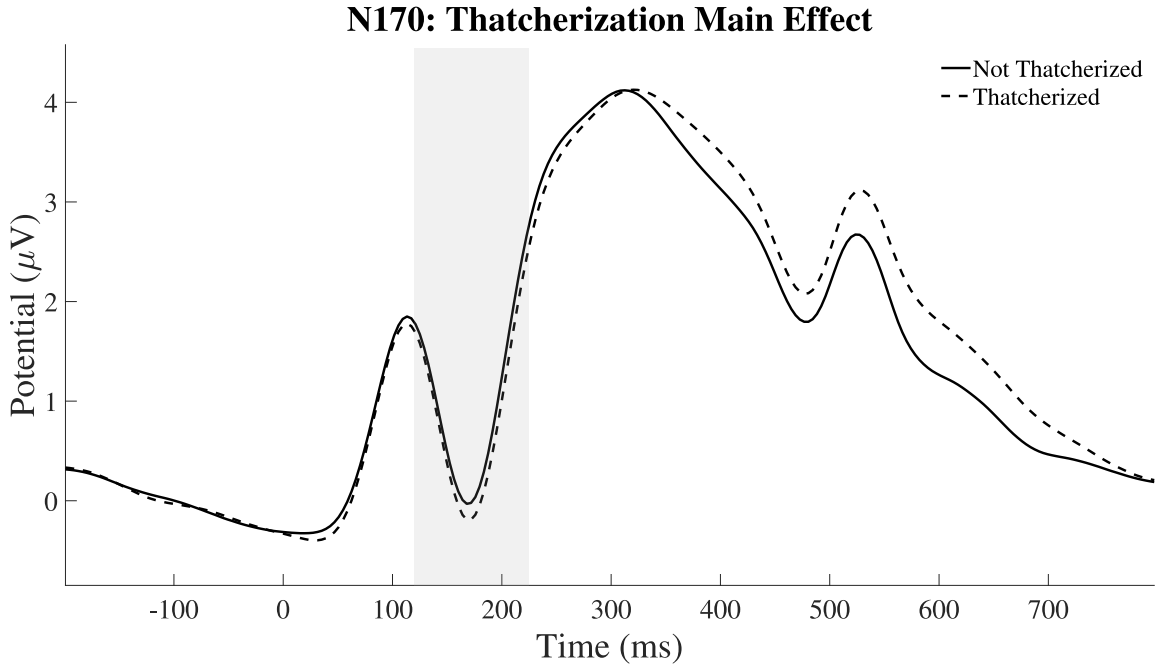

Figure 2.4

Mean waveforms for the main effect of *thatcherization*. Waveforms constructed from averages across P3, P4, P7, P8, Po7, Po8, O1, and O2 electrodes.

Finally, the main effect for *inversion* was also significant, $F(1, 36) = 43.715$, $p < .001$, $\eta^2_p = .548$, with inverted images ($M = -1.625$, $SD = 1.699$) producing a significantly more negative N170 than right side up images ($M = -.762$, $SD = 1.676$) (Figure 2.5).

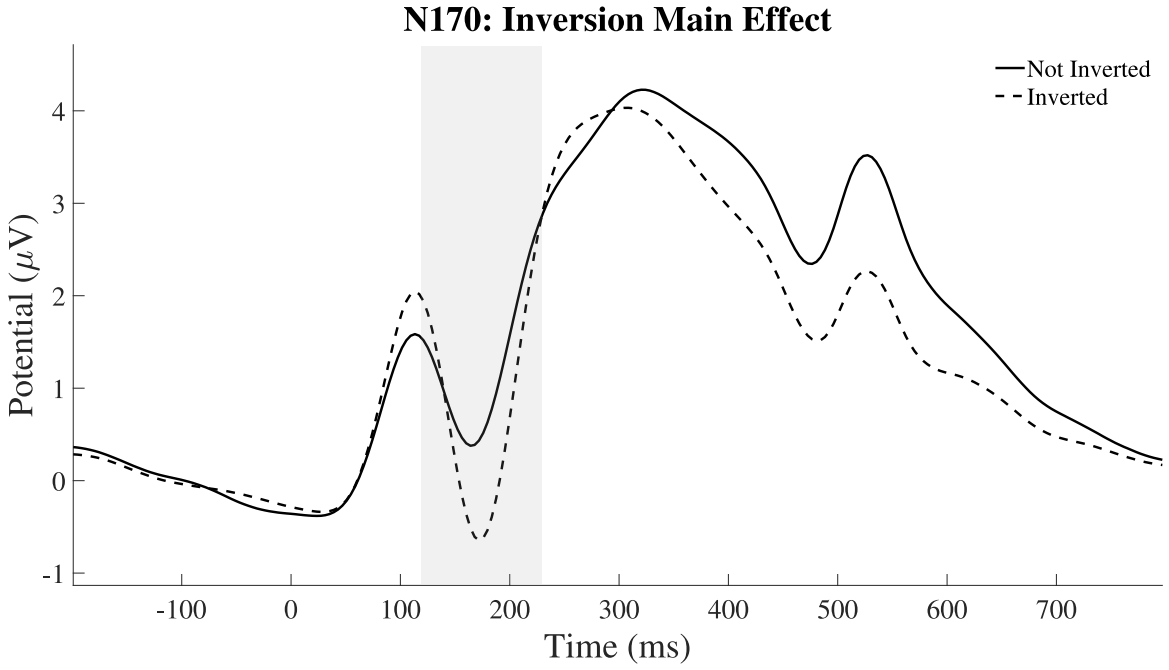

Figure 2.5

Mean waveforms for the main effect of *inversion*. Waveforms constructed from averages across P3, P4, P7, P8, Po7, Po8, O1, and O2 electrodes.

A significant interaction effect was found for *condition* and *inversion*, $F(1.516, 54.586) = 21.917$, $p < .001$, $\eta^2_p = .373$ (Figure 2.6). Non-inverted images in the cutout condition ($M = -1.459$, $SD = 1.723$) were associated with a significantly more negative N170 than non-inverted images in the color ($M = -.379$, $SD = 1.624$) and black and white ($M = -.448$, $SD = 1.624$) conditions. There were no significant differences between inverted images across the three conditions. *thatcherization* by *condition* failed to reach significance ($p = .117$) as did the overall interaction between *condition*, *inversion*, and *thatcherization* ($p = 0.309$).

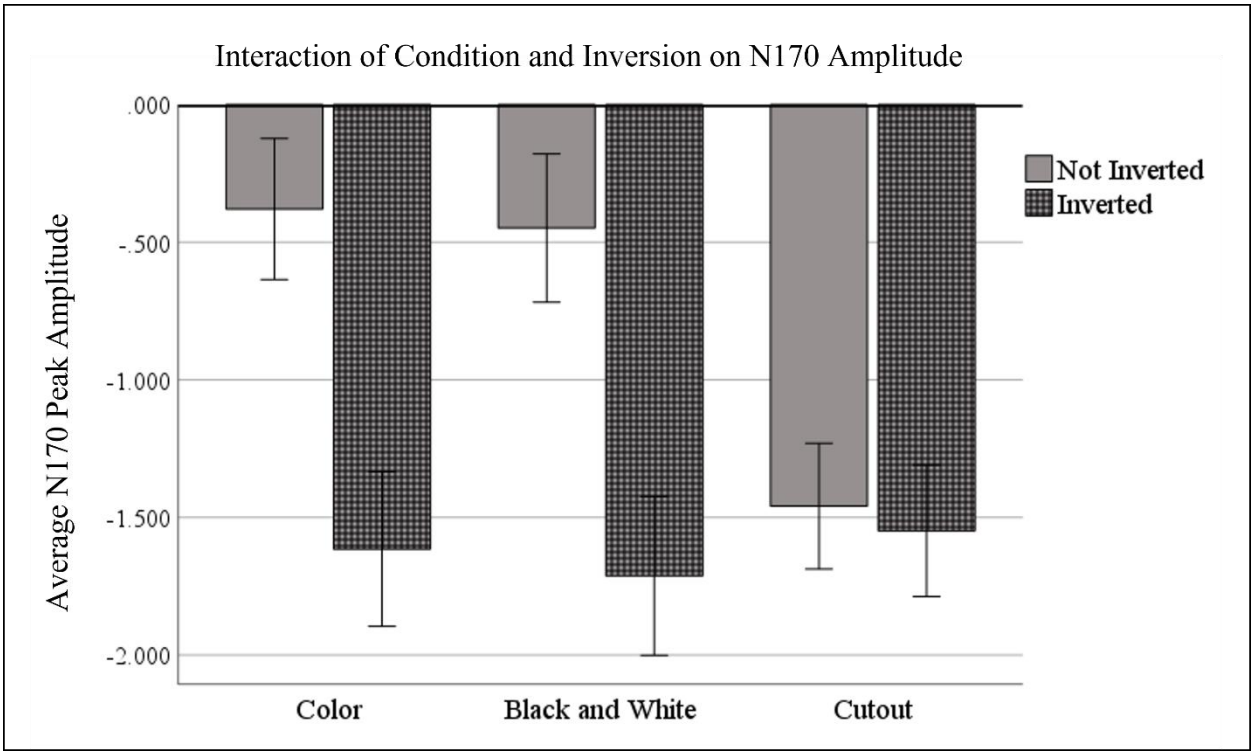

Figure 2.6

Interaction of *condition* and *inversion* on N170 amplitude.

3.3.3. Latency

N170 latency was defined as the time at which the most negative value within the range of 120ms to 220ms occurred, averaged across each of the selected electrode locations. A repeated-measures ANOVA was used to examine N170 latency. A main effect was found for *condition*, $F(1.503, 54.125) = 14.350$, $p < .001$, $\eta^2_p = .991$ (Figure 2.3). Peak N170 response to images within the cutout ($M = 177.447$, $SD = 18.049$) condition occurred significantly later than those in response to the color ($M = 170.047$, $SD = 15.943$) and black and white ($M = 168.249$, $SD = 154.349$) conditions. N170 latency did not significantly differ between color and black and white stimuli.

In keeping with prior research (Bentin, 1996), N170 latency varied significantly based on status of *inversion*, $F(1, 36) = 4.632$, $p < .038$, $\eta^2_p = .114$. Overall, inverted images (M = 173.503, SD = 16.585) produced a significantly later N170 peak than non-inverted images (M = 170.327, SD = 17.151; Figure 2.5), indicating an inversion-driven disruption in configural processing that resulted in the relatively delayed processing of facial stimuli.

Finally, a significant interaction emerged between *condition* and *inversion,* $F(2, 72)$ = 4.622, $p < .013$, $\eta^2_p = .114$ (Figure 2.7). Latency of non-inverted cutout images (M = 177.913, SD =15.496) was associated with a significantly delayed N170 compared to non-inverted color (M = 167.520, SD = 17.447) and black and white images (M = 165.547, SD = 16.018). There were no significant differences between inverted images across the three conditions.

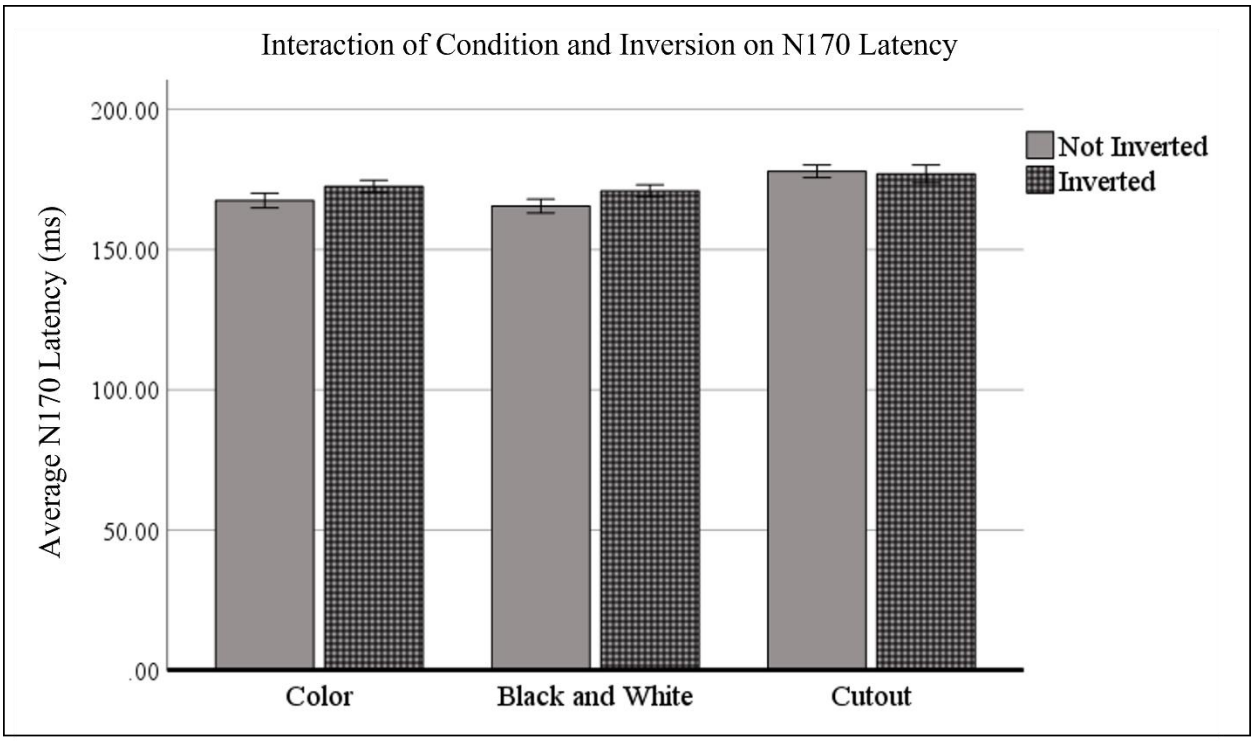

Figure 2.7

Interaction of *condition* and *inversion* on N170 latency.

There was no significant difference in N170 latency between non-thatcherized and thatcherized images (p = .926). Additionally, interactions between *thatcherization* and *inversion* (p = .527), *thatcherization* and *condition* (p = .065), and a three-way interaction between all variables (p = .181) failed to reach significance.

4 DISCUSSION

Numerous presentation styles of human face stimuli have been used across studies for differing purposes. In this study, the three most commonly used types of presentation paradigms are compared (color, black and white, and cutout) to better understand differences that may exist between them. Prior to this research, there has been little consensus regarding which type of presentation style should be considered a best-fit method when looking at manipulations of facial features such as thatcherization and ERP presentation.

Grotesque has long been the adjective of choice used to describe thatcherized images. With the featural manipulations of inverted eyes and mouths, such images are described as instilling a sense of disquiet in their observers (Dahl et al., 2010; Searcy & Bartlett, 1996). This study found that participants did indeed rate thatcherized images as being significantly more grotesque than their non-thatcherized counterparts.

A central feature of thatcherization's effect is that it diminishes when the entire image is presented upside down. This is due to a disruption in configural processing caused by inversion, which renders the featural manipulations more difficult to detect (Dahl et al., 2010). Results from this study support this theory, as non-inverted thatcherized images were rated as significantly more grotesque than inverted thatcherized images. This attenuation in the aversive salience of the

manipulated features reflects the well-studied effect of inversion on the facial processing of key facial components.

It was anticipated that there would be a significant effect of *condition* indicating that color images elicited significantly higher ratings of grotesqueness than black and white and cutout images. The rationale is that color images would allow for the improved acquisition of the thatcherized elements and thus an enhancement of negative emotional valence in response. Humans are not typically accustomed to seeing human faces in greyscale color pallets (black and white condition) or with surrounding featural components removed (cutout condition). As a result, it was reasoned that these types of images might detract from the thatcherized elements due to competing "noise" of unfamiliar visual information. However, contrary to predictions, no main effect for *condition* was found. Furthermore, no significant interaction effects related to grotesqueness ratings were found for *condition* across any combination of other variables. These results suggest that when exploring the effects of *thatcherization* on subjective reactions of grotesqueness, any of the three presentation styles can be used effectively, and greater emphasis may be placed on selecting an image type based on other outcome variables of study.

Contrary to subjective ratings, a significant effect was found for *condition* on N170 amplitude. Cutout images were associated with a significantly more negative N170 than color images. In a study conducted by Schindler et al. (2019), results indicated that *less natural* presentations of human faces resulted in larger N170 amplitudes and that specifically cutout images produced the largest N170 of the three conditions examined. One of the critical differences from Schindler et al. (2019) is that the present study includes the use of thatcherized images. As previously discussed, these types of image manipulations appear grotesque and unnatural to the viewer. With this in mind, and considering the rationale discussed above

regarding predictions of the color condition enhancing negative salience of thatcherization (and as an extension of unnaturalness), it was expected that color images would produce a significantly more negative N170 than black and white and cutout conditions. However, this appears not to be the case as indicated by the lack of significant findings in both *condition* on grotesqueness as well as color images on N170 amplitude. Moreover, the degree of perceived grotesqueness may be a better descriptor of emotionally laden qualities, which may be more accurately captured in later ERP components.

The enhanced N170 amplitude associated with the cutout condition may be explained by decreased interstimulus perceptual variance (ISPV). As the name suggests, ISPV relates to the amount of variation between like-stimuli, often seen through differences in shape and quantified at a pixel level. The cutout condition was characterized by an oval shape that framed the central features of the face, thus removing visual noise and reducing variations that remained in the color and black and white conditions (i.e., differences in the shape of heads, chins, hair, etc.). As such, the cutout condition inherently possesses lower ISPV, which has been shown to produce enhanced N170 amplitudes (Thierry et al., 2007).

The significant effect of cutout images on N170 modulation can be further explained by the cognitive effort required to process such images. Cutout morphology likely requires more cognitive effort to process, resulting in enhanced negative deflections around 170ms post-stimulus presentation (Schindler et al., 2019). This is supported by the findings of a significantly more negative N170 amplitude for inverted images compared to non-inverted images. Inverted images require more cognitive effort to process due to the inherent disruption in configural processing (Searcy & Bartlett, 1996). Furthermore, the main effect for *thatcherization* showed that thatcherized images produced a significantly more negative N170 than non-thatcherized

images. Both inversion and thatcherization produce unnatural images that result in a more cognitively taxing image to process.

Prior research indicates that inverted cutout images produce a significantly more negative N170 than non-inverted image conditions. Interestingly, in the current study, it was found that when inverted, this condition-specific effect no longer exists. This may indicate that inversion's disruptive effect on configural processing is so pronounced that it attenuates (or perhaps supersedes) the effects of perceptual differences between conditions. Such reasoning may also explain the lack of significant findings between *thatcherization* and *inversion*. Overall, there was no interaction effect between *thatcherization* and *inversion*, indicating that while these factors contribute significantly to N170 modulation independently, there is no meaningful additive effect via their combination. As mentioned, a key use of thatcherized human faces in research has been its use in highlighting this disruptive effect of inversion. However, these results indicate that this effect is not necessarily a unique feature of thatcherization, as inversion appears to impact cutout image processing with regards to N170 amplitude similarly. Despite this, thatcherization may still be uniquely poised for research in this area given the negative emotional valence associated with its featural manipulations – something that the cutout condition failed to demonstrate.

Peak latencies were examined to understand the temporal relationship of *condition*, *thatcherization*, and *inversion* on N170 presentation. Overall, N170 latency was significantly later for cutout images than for color and black and white images. Inverted images were also associated with later peak N170 amplitudes than non-inverted images. These results support the notion of greater cognitive effort required to process cutout and inverted images, as evidenced by their larger N170 amplitudes. Latency results also mirrored the significant interaction between *condition* and *inversion* on N170 amplitude. It appears that manipulating human faces to increase

processing and recognition difficulty significantly affects both amplitude and latency of the associated N170 response. However, an interesting caveat was the lack of significant difference in latency between non-thatcherized and thatcherized images. In fact, the mean latency of these two conditions differed by less than a tenth of a millisecond. This may be due to more subtle differences between non-thatcherized and thatcherized images relative to the differences seen in images within *condition* and *inversion* image types. In other words, the difference between a non-inverted and inverted image is the entire orientation of the face itself, altered into a state that is entirely unfamiliar to the viewer. Conversely, thatcherization is an inversion of only the eyes and mouth. This may result in less time required for perceptual processing of thatcherized images as compared to the other presentation types used in this study.

Results of the present study support the findings described by Schindler et al. (2019). Additionally, our results indicate that if examining subjective, emotionally laden reactions to thatcherized images, such as perceived grotesqueness, no presentation condition (color, black and white, cutout) can be recommended as being better suited than the other. However, it is clear that cutout image presentation results in larger, albeit delayed, N170 ERPs than color or black and white images. As such, cutout image morphology may be considered a well-suited image presentation style when examining ERPs and facial processing of otherwise unaltered human faces. Moreover, these results support a strong link between N170 amplitude and latency modulations via perceptual processing effort. Depending on specific methodology, utilizing inversion may effectively "wash-out" other effects of interest from different featural manipulations.

5 Limitations and Future Directions

The current study has several potential limitations. First, as is typical of research conducted using a sample from a college population, there is a lack of overall diversity across participants. Ages, ethnicities, and education levels are primarily homogenous. Future research in this area would ideally ensure a more diverse sample of participants across multiple demographic factors. Second, thatcherization was the only form of manipulation used that targeted specific, salient features of the face. In order to draw more generalizable conclusions, more forms of targeted manipulation may be warranted in future studies. For instance, the use of highly pixilated, darkened, removed, or scrambled face components could be utilized to further explore the effects of *condition* across various forms of face manipulation. Third, results were gathered during the COVID-19 pandemic. Participants were required to complete the study in person. This may have biased the sample population across demographic strata (i.e., health condition, political views, etc.). Finally, ISPV may have been a contributing factor between differences in *condition*. Future studies in this area may consider selecting and modifying stimuli to contain similar levels of ISPV within each level of *condition*, as a way to control for any influence that ISPV has at that variable's level. Additionally, when using specific stimuli of human faces repeated across varying levels of *condition*, grouping and analyzing for differences in *condition* across these specific images may help control for differences introduced ISPV discrepancies.

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Chapter 3. Thatcherized and Uncanny Faces: Combined Methods Analysis of Salient Image Manipulations

Target Journal: Psychophysiology

Title: Thatcherized and Uncanny Faces: Combined Methods Analysis of Salient Image Manipulations

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Abstract

Almost human-like entities, considered to be "uncanny" in appearance, have been studied with a particular focus on the sense of unease that they evoke in viewers. More recent studies have examined the effects of uncanny stimuli on event-related potentials (ERPs), such as the N170. While this particular avenue of scientific inquiry has yielded interesting results, it may describe a similar process that has been studied for decades. Thatcherized images, which also possess elements of structural mismatch and decreased human-like appearances, have been used with similar effects since their discovery in 1980 (Thompson, 1980). The purpose of the present study was to explore commonalities between these two styles of digital manipulation and establish a link between previously disparate areas of human-face processing research. Subjective reactions to stimuli were measured via participant ratings of "off-putting." EEG data were also gathered in order to explore if any unique effects emerged via N170 and N400 event-related potentials. Eduard Zell (see Zell et al., 2015) provided two main "morph continuums" of uncanny stimuli, which were modified for the purposes of the current study. A novel approach of thatcherizing images along these continuums was used. Thatcherized images across both continuums were regarded as more off-putting than non-thatcherized images, indicating a robust subjective effect of thatcherization that was relatively unimpacted by additional manipulation of key featural components. Conversely, results from brain activity indicated no significant differences of N170 between level of shape stylization and their thatcherized counterparts. Unique effects between continuums and exploratory N400 results are discussed.

1 INTRODUCTION

Digitally manipulated images of human faces have been used better to understand discrete and global processes in human face processing and how humans subjectively react to human-like entities. Such research serves a critical role in understanding human evolution and interaction, as facial processing is involved in a vast array of fundamental human processes. Identification of human facial features is an evolutionary adaptation that allows for the rapid deployment of essential evolutionary functions, such as threat detection (Green & Phillips, 2004). In this way, the speedy deduction of threatening stimuli provides a quick response to risk and helps survival in perilous scenarios. Experiments have also examined the role of facial processing and recognition in social biases and social-cognitive frameworks that may impact crucial societal systems (i.e., ability to have a fair trial) (Abshire & Bornstein, 2003; Young et al., 2012). With implications suggesting a salient impact on a myriad of aspects, the continued refinement of the understanding of facial processing through image manipulations of human faces will further inform social interaction as well as cognitive conceptualizations of different facial types.

1.1 Thatcherization

One such image manipulation, thatcherization, is characterized by the inversion of the eyes and mouth and is used to better understand both discrete and global processes in human face processing (Thompson, 1980; Lewis & Johnston, 1997). The predominant use of this image type occurs in two differing presentation conditions: thatcherized images presented in upright and overall inverted (flipped upside-down) conditions. This latter condition renders the manipulated elements of the face much harder to identify, resulting in delayed reaction time in identifying

whether or not an inverted image contained thatcherized elements (Lewis & Johnston, 1997) and increased error rate in identifying such images (Donnelly et al., 2011).

Additionally, thatcherized images appear unsettling to participants, commonly described as grotesque (Dahl et al., 2010; Murray et al., 2000; Searcy & Bartlett, 1996). Grotesque is defined by Merriam-Webster (n.d.) as "fanciful, bizarre; absurdly incongruous; departing markedly from the natural, the expected, or the typical." Donnelly et al. (2011) found that in response to upright thatcherized faces, fMRI results indicated activation of neural networks involved in evaluating emotional and social stimuli. These results reinforce the emotionally-laden grotesque appearance of thatcherized faces.

Overall, thatcherization provides unique insight into how humans process facial features. It acts to pinpoint salient features involved in face recognition and how configural processing can be disrupted by specific feature manipulation. Additionally, it informs typical subjective reactions to the presentation of such altered stimuli. Thatcherization also has potential for further use through its coupling with a theory that deals with similar processes, the Uncanny Valley.

1.2 Uncanny Images

The Uncanny Valley, a theory developed by roboticist Masahiro Mori in 1970, posits that as robots become more human-like in appearance, they elicit more favorable subjective responses from their human observers (Mori et al., 2012). This effect continues until the representations become *almost* human but still not quite perfectly human in appearance, resulting in a dramatic dip (or "valley") in favorability ratings. This results in sensations of eeriness, disquiet, and disgust in the viewer (Macdorman et al., 2009; Zell et al., 2015). Recent studies have attempted to understand this phenomenon better using a series of images along a "morph

continuum" (e.g., Schindler et al., 2017; Zell et al., 2015). Such a continuum allows researchers to present a series of manipulated images depicting a human face and head with characteristics that become increasingly or decreasingly human-like in appearance. This mismatched quality of facial elements is an increasingly popular avenue of exploration for understanding what types of human-like representations produce the most unsettling effects. For example, Macdorman et al. (2009) concluded that mismatched textures and eye size in relation to the head were found to be most eerie. More recently, Zell et al. (2015) indicated that the shape of the head was the most salient factor in predicting how "real" participants interpreted the image to be. Additionally, researchers concluded that a mismatch in head shape and material, such as a realistic head shape with cartoon material, resulted in the most unappealing character designs (Schindler et al., 2017). While research continues to explore the most unappealing character designs, there has yet to be a general consensus regarding the underlying principle of exactly *why* these human-like entities are unappealing.

Incongruence is a principal factor affecting the processing of, and subsequent reaction to, human features (Schindler et al., 2017). When familiar components involving human entities are juxtaposed with unexpected elements that are inhuman or near-human in appearance, they evoke negatively valent reactions (e.g., grotesque, eerie, unfamiliar, disturbing, etc.). Such subjective responses to these images could stem from a biologically driven pathogen-avoidance mechanism. Pathogen-avoidance is described as being an integral component of the behavioral immune system. This is a robust set of psychological defense mechanisms that impact social attitudes, beliefs, and behaviors within the context of self-preservation (Kurzban & Leary, 2001; Gruijters et al., 2016; Shook et al., 2015).

Within the context of human appearance, the presentation of mismatched elements that are incongruous with expected features may initiate a warning to the possibility of communicable disease. Such a warning acts as an inherent safeguard to ensure suitable distance maintenance and can be manifested in multiple ways in response to the perceived threat. These reactions can be cognitive in nature, such as the development of negative beliefs, or emotional, such as experiencing anxiety and feelings of disgust (Park et al., 2003). These altered characteristics that violate expectations of typical human appearance may trigger feelings of aversion as a means of protection. Evolutionarily speaking, it is in the best interest of preservation to avoid a potentially deadly illness.

With this in mind, the subjective response to both thatcherized and uncanny imagery has not been explored in tandem, and may be best viewed through a lens of pathogen-avoidance. While the verbiage used to describe the emotional reactions evoked from exposure to these images is different, they do share semantic similarities that may indicate a fundamentally related process. If the reactions do indeed stem from a typical pathogen-avoidance response, it would be most appropriate to measure a reaction based on its propensity to evoke a response that is *repelling* in nature. After all, this theory posits that avoidance is the behavioral operation that acts as the product of experiential negative emotion (Faulkner et al., 2004; Kurzban & Leary, 2001).

In order to most accurately capture this, verbiage that clearly implicates avoidance while being synonymous to the root descriptions of both the thatcherized grotesque response and uncanny imagery response (e.g., unpleasantness), should be used. To meet these criteria, “off-putting” may be the most experimentally suitable description to measure a common response to

these different stimuli types. Defined as “repellent, disconcerting” (Merriam-Webster, n.d.), this word incorporates the emotionally unsettling aspect with the added incorporation of avoidance.

1.3 Manipulated Human Face Stimuli and the N170

The EEG has been used to measure of brain activity since its first rudimentary use by Hans Berger in 1929 (Luck, 2005). Through the use of electrodes located at differing points across the scalp, differences in electrical potential can be measured that correspond to the brain’s response to specific stimuli or events (Hugdahl, 1995). These differing responses that can be reliably elicited in repeated experimental conditions are called event-related potentials (ERPs). One such ERP, the N170, has reliably been shown to be involved in the neural processing of human faces (Bentin et al., 1996). The N170 is elicited when participants are presented with inverted (Bentin et al., 1996; Itier and Taylor, 2004) and thatcherized images (Boutsen et al., 2006; Carbon et al., 2005). This intimates that despite image manipulation, participants still recognize these images as being human in nature. Overall, there remains no consensus regarding the exact effect of thatcherization on the N170. This is likely due to differences in techniques. Older studies that used thatcherized images processed images using blocky cutout stylizations that did not blend the surrounding areas with manipulated elements. More recently, the thatcherization processes use techniques that result in a higher fidelity image with blended textures around the eyes and mouth.

Despite one study (Schindler et al., 2017) finding a diminished N170 response to uncanny images, a distinct lack of robust findings exists using this type of image manipulation. While a consensus in scientific findings has yet to be reached on the exact N170 response to thatcherized or Uncanny images, their findings suggest that both may produce a diminished

N170 response. The preliminary report for the N170 in uncanny research shows that a U-shaped response is produced, indicating a weaker N170 deflection to more uncanny images (Schindler et al., 2017). If thatcherized images with smoothed features do indeed create a smaller N170 as well (Hahn et al., 2012), they may evoke a similar N170 response as the one seen in response to uncanny stimuli. Such findings would further indicate that both sets of image types evoke comparable responses due to shared underlying influences and processes.

1.4 Manipulated Human Face Stimuli and the N400

Use of the N400 component may help to further explore potential commonalities in thatcherized and uncanny imagery. The N400 has repeatedly been shown to be evoked in the context of unexpected information. Historically, its use has been specific to more verbal tasks, indicating that it is reliably elicited in semantic incongruities where a word is inappropriate and unexpected (i.e., "I prefer my coffee with cream and dog"). Recently, however, exploration of the N400 has expanded beyond a strictly verbal context and is being used in research for image and face recognition (Kutas & Federmeir, 2011).

The N400 possesses the potential to further the understanding of mismatched information in human faces. Mismatched qualities of human faces are inherently unexpected due to their deviation from learned, typical representations of human anatomy. In fact, in a study utilizing robots of differing human-likeness, Urgen et al. (2018) found an increased N400 in response to exposure to a robot comprised of human-like skin and clothing over a human-shaped frame. This response indicates a violation of expectations in the context of an uncanny image comprised of mismatched features.

This may inform the off-putting nature of thatcherization. Thatcherized images produce an appearance containing mismatched, unexpected features that evoke an adverse reaction. Research shows that similar negative emotions are elicited in the presence of uncanny images, which also possess a mismatched quality of elements (Saygin et al., 2012; Urgen et al., 2015; Zell et al., 2015). The coupling of similar subjective responses, along with a fundamental likeness in manipulation, points to a common mechanism between these two image types that may be elucidated using the N400 ERP.

1.5 Present Study

The primary objective of the present study was to explore participants' subjective (via ratings of "off-putting") and objective reactions (via N170 and N400 ERPs) to both uncanny and thatcherized images of humans faces. This allowed for the investigation of potential interactions between these two manipulation types. Using stimuli provided by Eduard Zell (see Schindler et al., 2017; Zell et al., 2015), a novel method of combining thatcherized and uncanny stimuli along two independent morph continuums (*shape* and *material*, discussed in Method section) was used.

It was predicted that the most unrealistic, highly stylized images along both the *shape* and *material* continuum would produce the highest ratings of off-putting. Additionally, it was predicted that thatcherized images would overall produce higher off-putting ratings than non-thatcherized images. An interaction between thatcherization and stylization level was also expected, such that there would be no additive effect of thatcherization at the most stylized levels on the morph continuums, but an effect would be seen at the most realistic levels.

In regards to ERP findings, the most unrealistic (level 1) and realistic (level 6) images along the shape and material morph continuums would produce the largest N170 ERPs. It was

also predicted that most unrealistic (level 1) images would produce the largest N400 ERPs due to their incongruous features.

2 GENERAL METHOD

Data were collected at the Brain Computer-Interface Lab located at East Tennessee State University in Johnson City, Tennessee. All experimental procedures were approved by the East Tennessee State University Institutional Review Board.

2.1 Participants

A power analysis using MorePower version 6.0.4 (Campbell & Thompson, 2012) was conducted in order to determine an appropriate target sample size. MorePower is a free statistical calculator that offers more flexibility (and subsequent accuracy) with complex ANOVA-based designs than other statistical calculators (Campbell & Thompson, 2012). It was determined that a sample size of 36 participants should yield adequate power to conduct the study by using an eta squared value of .10 (moderate to large effect) and an alpha criterion of .05.

In total, 36 undergraduate participants were recruited at East Tennessee State University. Participants were enrolled via the ETSU Psychology Research Participant website SONA. All participants were over the age of 18. The mean participant age was 21 (SD = 5.122), and 25 were female. Thirty-two of the participants identified as white, three as black, and one as Asian/white.

2.2 Materials

Participants were seated in a chair in a quiet room and responded via a Dell KB212-B keyboard located on a table in front of them. Keystrokes were logged through the input of either

the line of number keys located at the top of keyboard or the numeric keypad located on the right of the keyboard surface. Participants were able to rest their hands on the table's surface and select number keys based on their subjective ratings with little overall movement. Image presentation was controlled via E-Prime 3.0 build 3.0.3.80 (Psychology Software Tools, Inc.) on a Dell PC running Microsoft Windows 10 Education v21H1. Stimuli were presented on a Dell UltraSharp 2007WFP 20" Widescreen 1680x1050 16:10 LED monitor with a Dell 1708FB-BLK Color Profile.

Participants sat with a viewing distance of approximately 90 cm to the monitor. The stimuli of faces, which were 10.2 cm x 13.5 cm in size, appeared centered on the screen, with a horizontal visual angle of 6.48° and a vertical visual angle of 8.57°.

2.3 Stimuli

In order to build upon prior research, images originally constructed by Zell et al. (2015) and further edited and made available by Schindler et al. (2017) were used. Schindler et al. (2017) selected the six most salient mismatched and unappealing stimuli from prior research. In order to enhance presentation uniformity, images were then edited to make the faces nearly the same size and for the eyes to be located in the same positions (gazing forward). The images contained an unmanipulated image of a human male as the "natural" control condition. The morphed images consisted of a digitally rendered 3D scan of the face and a series of images developed by digital artists that increase in caricatural appearance, becoming more cartoon-like along the continuum.

In a study conducted by Schindler et al. (2019), it was concluded that stimuli of faces that were grey scaled and cutout so as to appear uniform and oval-shaped were associated with the

largest N170 ERPs. However, presenting images in this condition would not allow for differences in manipulation techniques to be examined using the current methodology. As such, full color, non-cutout images were used.

Zell et al. (2015) found that the mismatch of shape and material produced the most "unappealing" character designs. A separate morph continuum was used to examine the discrete effects of *shape* (Figure 3.1; first row) and *material* (Figure 3.1; third row) mismatch. Both continuums ranged from highly stylized (level 1) to entirely human (level 6) in appearance.

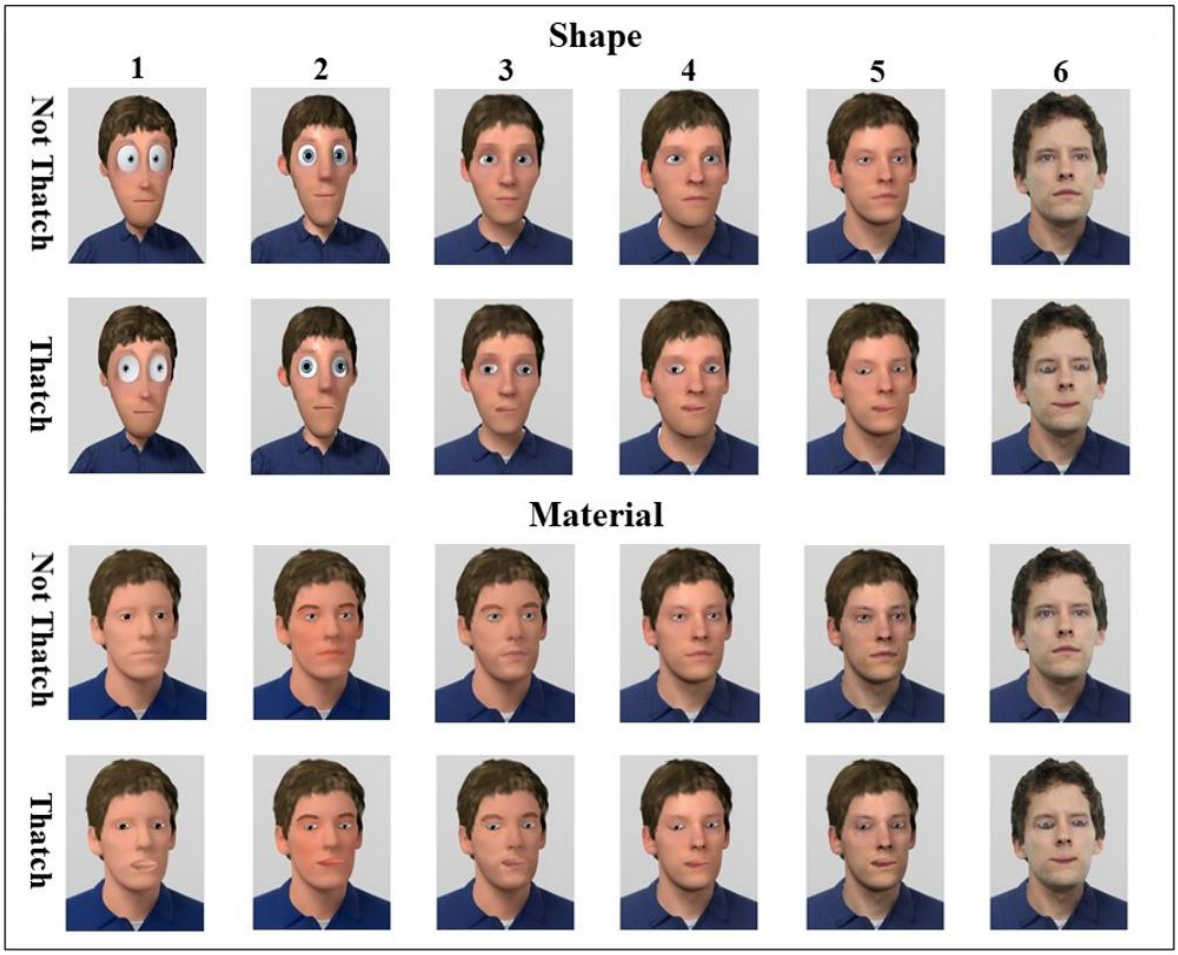

Figure 3.1

Morph continuum of stimuli used in *shape* and *material* stylizations. Level is denoted by the number of each column at the top of the figure. Stylization decreases from left to right along the continuum.

A novel approach was used to better understand differences in responses to uncanny and thatcherized images. Stimuli along both morph continuums were presented in either thatcherized (Figure 3.1; second row) or non-thatcherized (Figure 3.1; fourth row) conditions. Thatcherization was accomplished by rotating the eyes and mouth 180 degrees in Adobe Photoshop. Per the methodology detailed by Hahn et al. (2012), the edges of the rotated facial elements were

blended with the surrounding area. The aim of this methodology was to examine whether or not a unique effect is produced from the combination of these manipulations.

2.3.1 Shape Stimuli

Shape was examined across a morph continuum of six levels, ranging from level 1 (highly cartoonish character with an oblong head shape), to level 6 (real, unaltered image of a male human's head and face (Figure 3.1; top two rows).

Material 4 was used for all levels of *shape*. This is the second most "realistic" skin texture. This level of material was selected because material 5 (one step more realistic than material 4) was deemed too heavily stylized with its inclusion of veins and shading of skin texture, which resulted in a distracting image. Moreover, due to these stylistic choices in manipulation, level 5 actually appeared *less* realistic, and as a result, material 4 appeared to be the most appropriate level in terms of featural manipulation. Since material 4 was used for all shapes, levels 1 and 2 on the *shape* continuum should exhibit the greatest degree of mismatch as these are the most cartoon-like images with a realistic skin texture.

Each level of the continuum was also thatcherized. This amounted to 12 images in total for the *shape* condition (six non-thatcherized levels of *shape*, six thatcherized levels of *shape*).

2.3.2 Material Stimuli

Material was examined across a morph continuum of six levels, ranging from level 1 (face with very smooth skin textures and lack of variation in color) to level 6 (Figure 3.1; bottom two rows).

Shape level 5 was used for all levels of *materials*. This is the most realistic level of digitally manipulated shape. Due to centering at this level of shape, *material* levels 1 and 2 should exhibit the greatest degree of mismatch along this continuum.

Each level of the continuum was also thatcherized. This amounted to 12 images in total for the *material* condition (six non-thatcherized levels of *material*, six thatcherized levels of *material*).

2.4 Procedure

Stimuli presentation for *shape* and *material* conditions occurred across two blocks. Block sequence was randomized. All 12 of the respective condition's stimuli were presented in one block, 12 times each, for a total of 144 image presentations. The image order was randomized but formatted so that the same trial was not be presented twice in a row. Before each trial, a black fixation cross on a white background was presented for 1500 ms followed by a stimulus for 600ms. (The temporal aspects of stimuli presentation were based on the methodology used by Schindler et al. (2017)). Next, via number-key input, participants rated the off-putting nature of the stimuli on a 10-point Likert scale ranging from 0 ("not at all off-putting") to 9 ("very off-putting"). The selection of a rating ended the trial. Participants had 4000 ms to respond to the scale before the trial ended and the presentation of the next fixation cross began.

2.5 EEG Data Preparation

Data were collected using a 32-channel EEG cap and amplified with two Guger Technologies g.USBamp amplifiers. The recordings were grounded to the left mastoid,

referenced to the right mastoid at 256 Hz, and filtered using a 0.5-30 Hz bandpass filter. Impedance was kept under 20 kΩ.

EEG data were preprocessed in EEGLAB using artifact subspace reconstruction (ASR) to identify and remove low-quality channels. Removed channels were re-referenced based on common average and interpolated. Components that contained large amounts of eye blink artifacts were identified and rejected using independent components analysis (ICA) and visual inspection via ICLabel (at least 90% confidence threshold for rejection). Epochs were baseline corrected to 200 ms pre-stimulus. Epochs of -200 to 800 ms were time-locked at 0 ms for stimulus presentation.

Based on visual inspection of the data, N170 amplitude was defined as the most negative value 120ms to 180ms time range. Similarly, N170 latency was defined as the time at which the most negative value occurred within the window. The reported results are based on a composite 'waveform' averaged across the following lateralized electrodes: P3, P4, P7, P8, Po7, Po8, O1, and O2.

Also based on visual inspection of the data, N400 amplitude was defined as the most negative value in the 480ms to 550ms time range, and latency was defined as the time at which the most negative value occurred within the window. The reported results are based on a composite 'waveform' averaged across the following lateralized electrodes: F3, Fz, F4, Fc3; Fcz, and Fc4.

2.6 Statistical Analyses

Repeated-measures ANOVAs were used to examine outcomes of off-putting ratings, as well as N170 and N400 amplitudes and latencies. Two separate ANOVAs comprised of within-

subject factors of *shape* (levels 1-6) and *thatcherization* (non-thatcherized, thatcherized), and *material* (levels 1-6) and *thatcherization* were used. For instances of violation of sphericity, Greenhouse-Geisser corrected values were reported unless otherwise specified. Post-hoc comparisons were performed using Bonferroni correction. Main effects for *shape, material,* and *thatcherization* were compared across the outcomes of interest, as well as interaction effects among these variables. Effect sizes η^2_p are reported.

3 RESULTS

3.1 Behavioral Results

3.1.1 Shape x Thatcherization

Participants rated their perception of each image's off-putting nature on a scale from 0 ("not at all off-putting") to 9 ("very off-putting"). As predicted, a main effect was found for *shape*, $F(2.113, 73.945) = 14.303$, $p < .001$, $\eta^2_p = .290$. The most stylized image shape (level 1; $M = 5.061$, $SD = 2.489$) was rated as significantly more off-putting than all other levels of shape across the continuum except for level 6, which was qualified by the *shape* x *thatcherization* interaction (Figure 3.2).

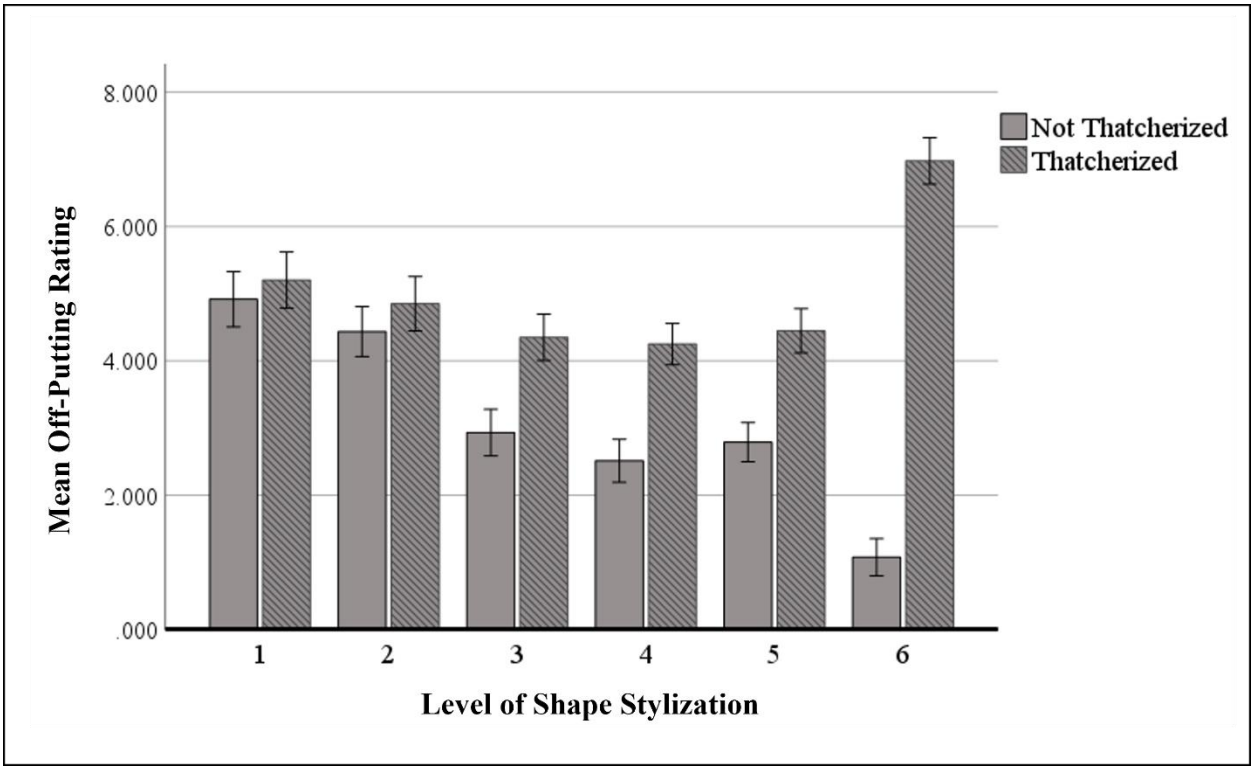

Figure 3.2

Bar graph of off-putting ratings for the *shape* x *thatcherization* interaction. Error bars represent +/- 1 SE.

As predicted, a significant main effect for *thatcherizatio*n emerged, $F(1, 35) = 112.688$, $p < .001$, $\eta^2_p = .763$, with thatcherized images (M =5.014, SD = 2.328) being rated as more off-putting than non-thatcherized images (M = 3.112, SD = 2.377).

A significant interaction was observed between *shape* and *thatcherization, F*(2.416, 84.576) = 115.327, $p < .001$, $\eta^2_p = .767$. It was predicted that there would be no significant additive effect of thatcherization at the most stylized levels of shape (levels 1 and 2). In contrast, thatcherization in the most realistic conditions (levels 5 and 6), was expected to produce significantly higher off-putting ratings. As predicted, thatcherized images at levels 5 (M = 4.49,

SD = 1.974) and 6 (*M* = 6.978, *SD* = 2.066) were significantly more off-putting than their non-thatcherized counterparts, (*M* = 2.791, *SD* = 1.751) and (*M* = 1.077, *SD* = 1.665), respectively. However, this effect was not specific to these levels. As shown in Figure 3.2, all thatcherized images were rated as significantly more off-putting than their non-thatcherized counterparts. This finding indicates an additive effect of thatcherization on subjective perception at even the most presumably uncanny levels of shape presentation (i.e., levels 1 and 2). Interestingly, the level 6 manipulation of *shape* produced the largest mean off-putting score when thatcherized.

3.1.2 Material x Thatcherization

A main effect was observed for *material*, $F(2.112, 73.918) = 19.229$, $p < .001$, $\eta^2_p = .355$. Post-hoc comparisons using Fisher's least significant difference (LSD) indicated that when collapsed across *thatcherization*, the image with the most unrealistic material skin (level 1) (*M* = 3.378, *SD* = 1.655) was rated as significantly *less* off-putting than the image with the most realistic material skin (level 6) (*M* = 4.330, *SD* = 1.461). This finding stands in contrast to predictions. However, level 1 was rated as significantly more off-putting than levels 2 and 4 (Figure 3.3).

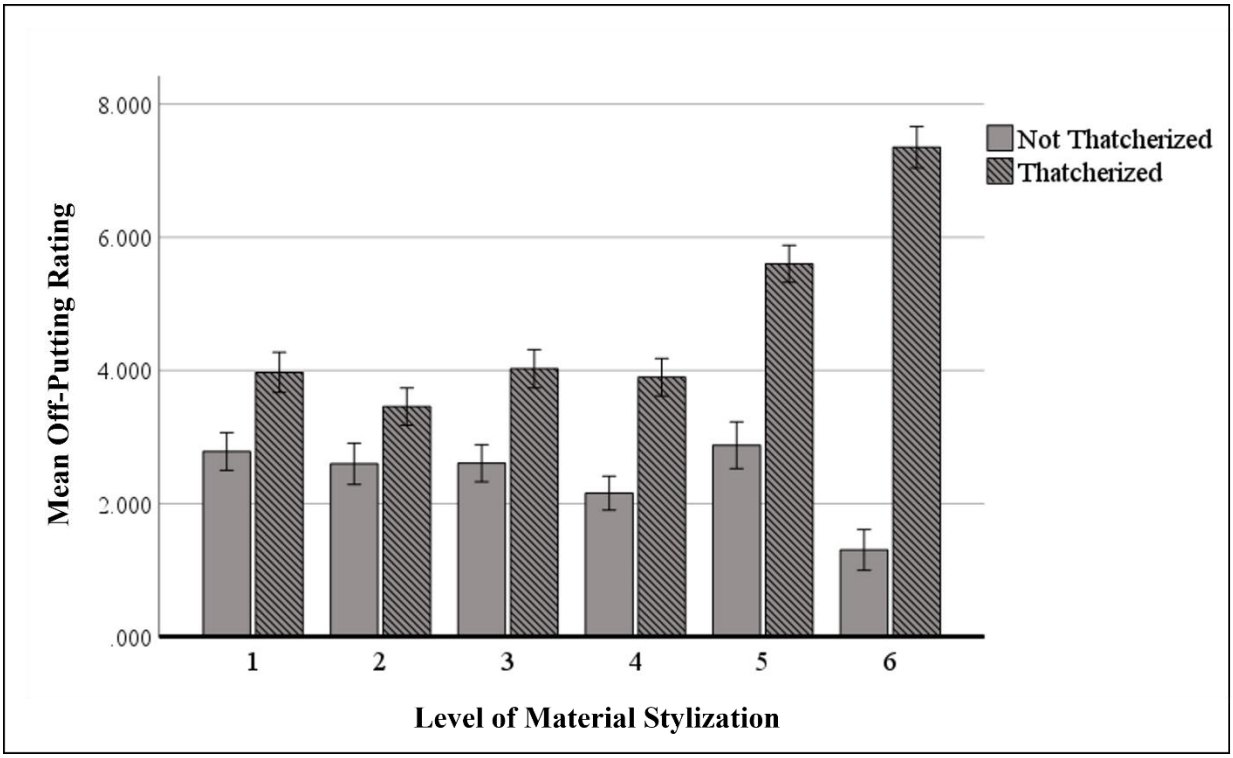

Figure 3.3

Bar graph of off-putting ratings for the *material* x *thatcherization* interaction. Error bars represent +/- 1 SE.

As predicted, a significant main effect for *thatcherizatio*n was observed, $F(1, 35) = 177.768$, $p < .001$, $\eta^2_p = .836$, with thatcherized images ($M = 4.719$, $SD = 2.193$) being rated as more off-putting than non-thatcherized images ($M = 2.390$, $SD = 1.852$).

A significant interaction was observed between *material* and *thatcherization*, $F(2.348, 82.179) = 106.704$, $p < .001$, $\eta^2_p = .753$. It was predicted that in the most unrealistic conditions of *material* (i.e., levels 1 and 2), an effect of thatcherization would not be observed. However, in the most realistic conditions (i.e., levels 5 and 6), thatcherized images will be significantly more off-putting than non-thatcherized images. Mirroring the results found with the manipulation of *shape*, thatcherized images at levels 5 ($M = 5.602$, $SD = 1.666$) and 6 ($M = 7.352$, $SD = 1.874$)

were significantly more off-putting than their non-thatcherized counterparts, (*M* = 2.880, *SD* = 2.104) and (*M* =1.308, *SD* = 1.838), respectively. Thatcherized images at levels 1 and 2 were *also* rated as being significantly more off-putting than their non-thatcherized counterparts (Figure 3.3). Similar to the findings with *shape*, the *material* x *thatcherization* interaction indicates an additive effect of thatcherization at even the most uncanny levels of material presentation, contrary to predictions.

3.1.3 Stylization Type (Shape and Material) x Level (1 – 6) x Thatcherization (non-thatch and thatch)

The 3-way ANOVA was similar to the 2-way ANOVAs; however, shape and material were included as a factor (henceforth referred to as *stylization*) in order to explore if either manipulation produced unique effects across outcomes of off-putting ratings.

All statistical tests reached significance. Thus, only the 3-way interaction is discussed, $F(3.352, 117.305) = 4.735$, $p = .003$, $\eta^2_p = .119$ (3-way means presented in Table 1). Of particular note, non-thatcherized images of *shape* (*M* = 3.112, *SD* = 2.383) were significantly more off-putting than non-Thatcherized stimuli in the *material* condition (*M* = 2.390, *SD* = 1.852). Additionally, s*hape* level 1 (*M* = 5.061, *SD* = 2.476) was rated as significantly more off-putting than *material* level 1 (*M* = 3.378, *SD* = 1.844). Interestingly, participants rated *material* level 6 (*M* = 4.330, *SD* = 3.558) as significantly more off-putting than *shape* level 6 (*M* = 5.061, *SD* = 3.507), despite these images being exactly the same (unaltered image of male face).

Table 2.1

Means of Stylization for Type by Level by Thatcherization Interaction

Means of Stylization Type x Level x Thatcherization Interaction on Off-Putting Ratings

	Not Thatcherized		Thatcherized	
Level	Shape	Material	Shape	Material
1	4.919	2.785	5.204	3.972
2	4.436	2.600	4.851	3.458
3	2.933	2.609	4.352	4.028
4	2.514	2.160	4.251	3.899
5	2.791	2.880	4.449	5.602
6	1.077	1.308	6.978	7.352
Stylization Grand Mean	3.112	2.390	5.014	4.719

3.2 Event-Related Potentials

3.2.1 N170 Amplitude

Two-way repeated-measures ANOVAs were used to examine the factors of *shape* and *thatcherization* and also used to examine the factors of *material* and *thatcherization*. As with the behavioral analyses, a 3-way repeated-measures ANOVA examined the factors of *stylization* (*shape* and *material*), *level* (1 – 6) and *thatcherization*.

Main effects for the *shape* x *thatcherization* ANOVA did not reach statistical significance *shape* (p = .052), *thatcherization* (p =.647). However, the *shape x thatcherization* interaction was statistically significant $F(5, 175) = 2.692$, $p = .023$, $\eta^2_p = .071$. Of note, as shown in Figure 3.4, thatcherized images at *shape* level 6 (M = -1.529, SD = 2.451) produced a significantly more negative N170 than thatcherized images at levels 4 (M = -0.561, SD = 2.621) and 5 (M = -0.572, SD = 2.749); however, N170 amplitude across *shape* was not significant for non-thatcherized images (Figure 3.5).

The *material* x *thatcherization* ANOVA reveled a significant main effect for *material*, $F(5, 175) = 2.354$, $p = .043$, $\eta^2_p = .063$. It was predicted that *material* levels 1 and 6 would be associated with the most negative N170 amplitudes. Interestingly, mean comparisons show that *material* levels 5 and 6 were associated with this effect instead. Despite this, post-hoc pairwise comparisons using Fisher's LSD show that level 6's mean peak amplitude was only significantly larger than levels 2 and 4, while level 5 was significantly larger than level 2 only (Figure 3.5). There was no significant main effect of *thatcherization* ($p = .184$), nor was there a significant interaction between *material* and *thatcherization* ($p = .221$).

The 3-way ANOVA revealed no main effect or interaction that included *stylization*.

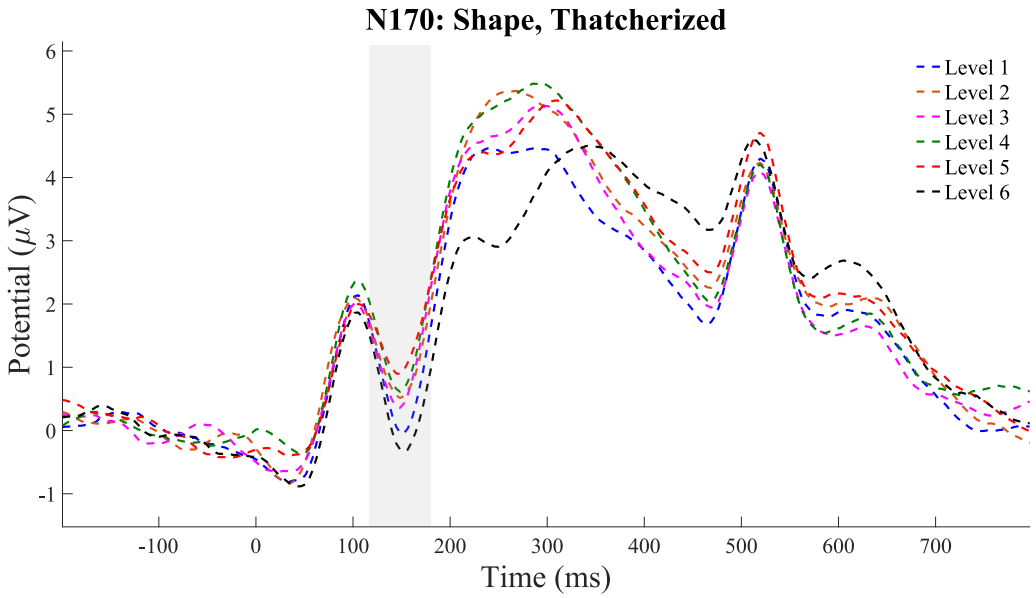

Figure 3.4

Mean waveforms for thatcherized *shape* stimuli, averaged across electrode locations P3, P4, P7, P8, Po7, Po8, O1, and O2.

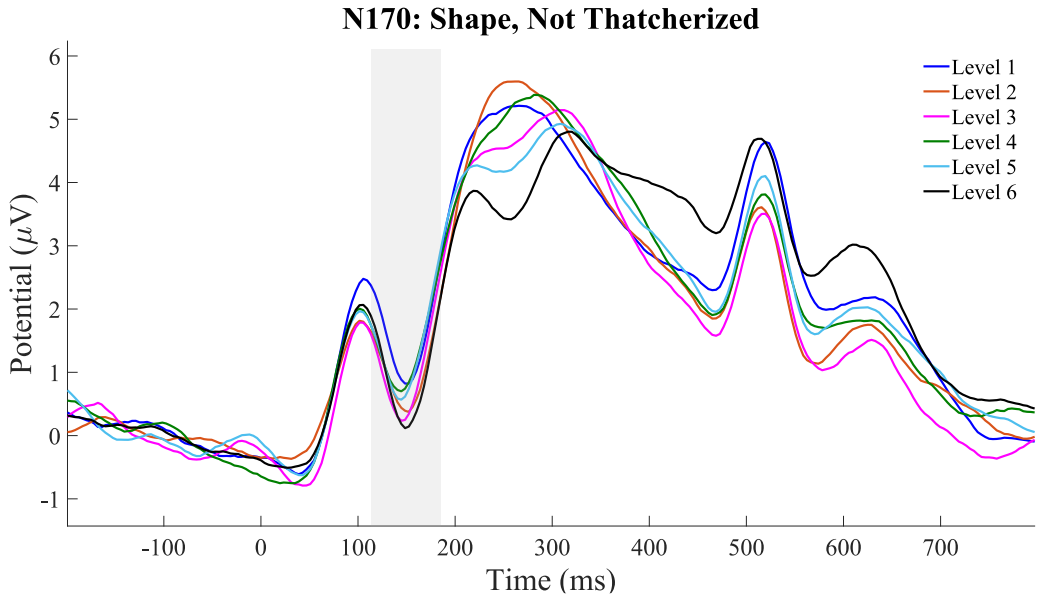

Figure 3.5

Mean waveforms for non-thatcherized *shape* stimuli, averaged across electrode locations P3, P4, P7, P8, Po7, Po8, O1, and O2.

3.2.2 N170 Latency

Two-way repeated-measures ANOVAs were used to examine the factors of *shape* and *thatcherization* and also used to examine the factors of *material* and *thatcherization*. In addition, as with the N170 amplitude analyses, a 3-way repeated-measures ANOVA examined the factors of *stylization* (*shape* and *material*), *level* (1 – 6) and *thatcherization*.

Main effects for the *shape* x *thatcherization* ANOVA did not reach statistical significance *shape* (p = .210), *thatcherization* (p =.858), nor the interaction (p = .710).

The *material* x *thatcherization* ANOVA showed a significant main effect of *material*, $F(3.617, 126.597) = 3.554$, $p = .011$, $\eta^2_p = .092$, such that the most realistic levels of *material* (levels 5 and 6) produced an N170 significantly later than levels 1-4 (Figure 3.6). No other main effects or interactions were observed.

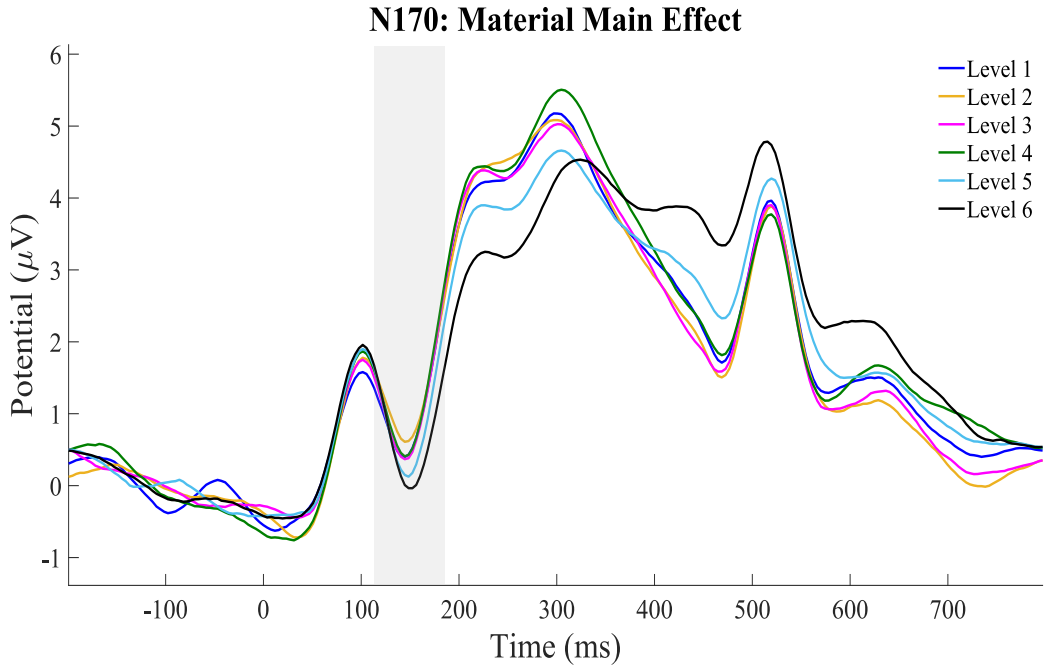

Figure 3.6

Mean waveforms for *material* level, collapsed across *thatcherization,* averaged across electrode locations P3, P4, PO7, PO8, P7, P8, O1, and O2.

The 3-way ANOVA did not reveal a significant main effect for *stylization*. However, a significant interaction emerged between *stylization* and *image level*, $F(5, 175) = 262.827$, $p = .017$, $\eta^2_p = .075$. This interaction was driven solely by a large difference between shape level 1 images ($M = 163.28$, $SD = 16.257$) and material level 1 images ($M = 159.146$, $SD = 17.043$). This indicates that the N170 response occurred later for level 1 shape continuum images as opposed to level 1 material continuum images.

3.2.3 N400 Amplitude

The analysis of the N400 was exploratory in nature. Three ANOVAs, analogous to those used to examine N170, were used to examine N400 amplitude. The *shape* x *thatcherization*

analysis showed a significant main effect of *shape* level, $F(5, 175) = 4.252$, $p = .001$, $\eta^2_p = .108$. Pairwise comparisons were conducted using Fisher's LSD in order to avoid type II error due to inflated family-wise error and loss of power. Results of this post-hoc analysis indicated that N400 amplitude in response to *shape* level 1 ($M = -4.253$, $SD = 2.647$) was significantly larger than level 3 ($M = -3.650$, $SD = 2.012$) images (Figure 3.7). Interestingly, *shape* level 6 was associated with a significantly more negative N400 than levels 2, 3, and 4. While this analysis was exploratory, there was a tentative prediction that the largest N400 would be found in response to the most stylized images (level 1) and would be smallest for the most realistic images (level 6). On the contrary, a nearly opposite response trend emerged. There was no significant main effect for *thatcherization* or significant interaction between *shape* and *thatcherization*.

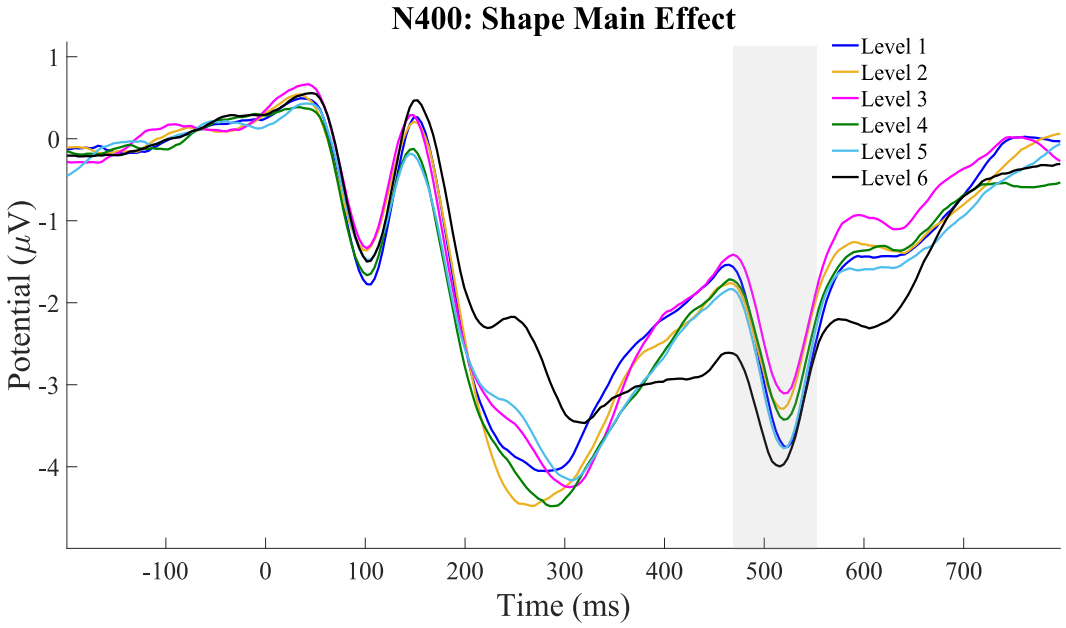

Figure 3.7

Mean waveforms for *shape* level collapsed across *thatcherization*, and averaged electrode locations F3, Fz, F4, Fc3; Fcz, and Fc4.

The *material* x *thatcherization* analysis revealed a significant main effect for *material*, $F(3.326, 116.418) = 5.063$, $p = .002$, $\eta^2_p = .126$. Level 6 of *material* produced the most negative N400 amplitudes, which were significantly larger than all other manipulation levels, except level 4 (Figure 3.8). Mean amplitude values indicated that thatcherized images produced a larger N400 response than non-thatcherized images; however, this effect did not reach statistical significance ($p = .080$). The material x thatcherization interaction did not reach statistical significance ($p = .194$

The 3-way ANOVA revealed no main effect or interaction that included *stylization*.

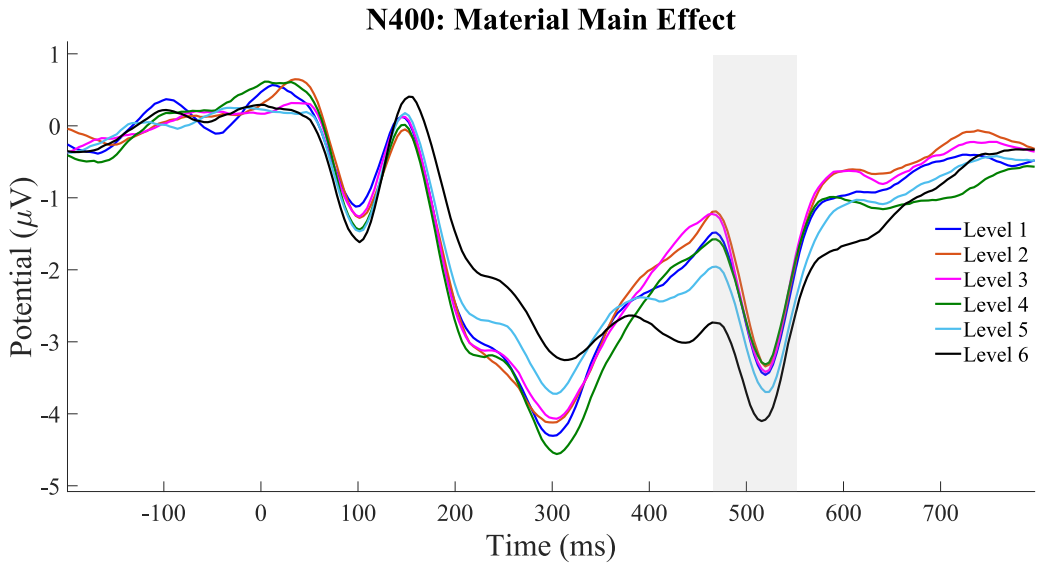

Figure 3.8

Mean waveforms for *material* level collapsed across *thatcherization*, and averaged electrode locations F3, Fz, F4, Fc3; Fcz, and Fc4.

3.2.4 N400 Latency

Three additional ANOVAs were conducted in order to examine N400 latency. The *shape* x *thatcherization* analysis revealed a main effect of *shape*, $F(4.039, 141.375) = 3.367$, $p = .011$, $\eta^2_p = .088$. Of particular note, the most stylized level of *shape* (level 1) had a significantly later N400 ($M = 525.553$, $SD = 13.613$) than the most realistic image (level 6) ($M = 519.242$, $SD = 17.499$) (Figure 3.7). Neither the main effect of *thatcherization* ($p = .240$) or the interaction ($p = .490$) reached statistical significance.

The *material* x *thatcherization* analysis showed a significant main effect of *material*, $F(5, 175) = 2.417$, $p = .038$, $\eta^2_p = .065$. In this case, the most realistic image (level 6) was associated with a N400 that occurred earlier than *material* levels 2-5 (Figure 3.8). Additionally a significant main effect for *thatcherization* emerged, $F(1, 35) = 8.497$, $p = .006$, $\eta^2_p = .195$. Non-thatcherized images ($M = 522.862$, $SD = 13.843$) were associated with significantly later N400 than thatcherized images ($M = 525.089$, $SD = 12.898$). The *material* x *thatcherization* interaction failed to reach significance ($p = .230$).

The 3-way ANOVA revealed no main effect or interaction that included *stylization*.

4 DISCUSSION

Overall, this study explored the subjective and objective reactions to both uncanny (stylized) and thatcherized images. It was hypothesized that uncanny images (e.g., those with the greatest featural mismatch located at the end of the morph continuum) would produce higher off-putting ratings. These images, as well as the unaltered image at the opposite end of the continuum (level 6), were predicted to be associated with significantly larger N170 amplitudes. While the extant literature regarding the N400 shows that it may be well suited for inclusion in a

study using this methodology (Kutas & Federmeier, 2011), it has not been used with these specific types of stimuli before. As such, the N400 analysis was exploratory.

4.1 Behavioral Data

Prior research has predominantly used "grotesque" to capture the aversive nature of thatcherized stimuli. In the uncanny literature, numerous terms have been used in attempts to capture or describe the aversive nature of uncanny entities (i.e., unfamiliar, unlikable, etc.). In the present study, "off-putting" was used to rate the subjective reactions to stimuli. Off-putting is defined as "repellent or disconcerting" (Merriam-Webster, n.d.). Prior research has suggested that mismatched, uncanny entities may tap into evolutionary safeguards reminiscent of pathogen-avoidant mechanisms or even more general danger-avoidance mechanisms (Moosa & Ud-Dean, 2010). For these reasons, "off-putting" is used as it may capture both the negative emotional valence of the stimuli as well as the behavioral quality of avoidance.

Consistent with predictions, the level 1 image on the *shape* continuum produced the highest off-putting scores compared to other shape levels, regardless of thatcherization. Level 1 of *shape* contains the most mismatched features, as it is comprised of a highly stylized cartoon-shaped head with a realistic skin texture. According to Schindler et al. (2017), high degrees of element mismatch in humanoid (but not fully human) appearing entities may be a driving perceptual factor in establishing uncanniness. Therefore, the level 1 images used in this study may be considered the most uncanny stimuli along their respective stylization continuums.

Thatcherized images were found to be more off-putting than non-thatcherized images. The effect of *thatcherization* can be seen more clearly when viewed within the context of its interaction with *shape*. For example, the non-thatcherized, unaltered human face stimuli (level 6)

were significantly less off-putting than all other non-thatcherized stimuli. Intuitively this makes sense as this image contained no altered aspects that would contribute to increased uncanniness. However, when this image was thatcherized, it was found to be significantly more off-putting than all other thatcherized stimuli on the same continuum. This supports the well-documented effect that thatcherization has on the subjective perception of human face stimuli.

Thatcherized, level 6 stimuli were rated as significantly more off-putting than the thatcherized level 1 stimuli, suggesting a comparatively weaker effect of thatcherization on already uncanny images. While an effect of this nature was predicted, thatcherized levels 1 and 2 stimuli were still rated as significantly more off-putting than their non-thatcherized counterparts, indicating that there still is an additive effect of thatcherization on the subjective perception of already uncanny entities.

Off-putting ratings across *material* level and *thatcherization* largely mirror those seen within the *shape* manipulation. Contrary to predictions, *material* continuum level 6 stimuli (unaltered human face) were rated as being significantly more off-putting than levels 1-4 of *material*. This indicates that participants found the real, unaltered face to be more off-putting than most other faces, including the most uncanny, mismatched stimuli. However, this effect is likely explained by the large influence of extremely high off-putting scores reported for *material* level 6 when thatcherized. As seen in the interaction between *material* and *thatcherization*, level 6 stimuli were rated on average as the least off-putting when not thatcherized but received the highest off-putting rating by a large margin when thatcherized.

When thatcherized, *material* level 5 was rated as being significantly more off-putting than thatcherized stimuli in levels 1-4. This provides good support for the theoretical conceptualization of the manipulated images along the continuum. Level 5 contains the least

amount of mismatch of the digitally altered images and, therefore, can be considered the least uncanny of the stylized images. In fact, the effects of thatcherization at level 5 mirror those of the real human face at level 6.

This is further supported by the results of the N170 amplitudes across level of *material*. Levels 5 and 6 both exhibited the largest mean peak N170 amplitudes. Despite this, no clear trend emerged regarding these specific levels of *material* and significant differences between the more uncanny stimuli (levels 1-4).

In order to understand if the *shape* and *material* conditions produced any unique effects on the outcome variables of measure, results were compared across these two factors ("*stylization*" when *shape* and *material* are discussed as a single, two-factored variable).

Overall, participants rated stimuli on the *shape* continuum as more off-putting than *material*. While interstimulus perceptual variance (ISPV) is often used in conjecture with ERP analysis (specifically N170), this may help to also explain the differences seen in subjective response. There undoubtedly existed higher amounts of ISPV on a level-to-level basis across the *shape* continuum than the *material* continuum. These stimuli possessed different head shapes and sizes and internal facial features such as eyes, noses, and mouths. Because of this, there existed more variation between each level of *shape* stimuli in comparison to each level of *material* stimuli. This may have allowed for more potential sources of off-putting features to be present in the *shape* continuum.

Furthermore, participants endorsed *shape* level 1 as significantly more off-putting than *material* level 1 in both the non-thatcherized and thatcherized formats. This shows that *shape* produces a more salient behavioral response than *material* at the highest degree of featural mismatch. Additionally, when looking at mean score comparisons of non-thatcherized stimuli

across both continuums, *shape* level 1 produced the overall highest score of any other non-thatcherized stimulus across both *shape* and *material*.

An interesting effect emerged regarding the realistic stimuli at the ends of the continuums. Levels 5 and 6 of *material* were rated significantly more off-putting than their *shape* manipulated counterparts. Of particular note, level 6 is the exact same image in both the *shape* and *material* continuums, as it is an unaltered human face. The significant three-way interaction revealed more information about this specific effect. *Material* level 6 was only significantly more off-putting than *shape* level 6 when both were thatcherized. There was no significant difference found between them when they were both in their non-thatcherized forms. This still raises questions about why the images, when thatcherized, were rated differently during separate blocks despite being the same image. Keeping in mind the overall greater aversive nature of the *shape*-altered stimuli, participants may have viewed the thatcherized level 6 stimuli and perceived it as less off-putting relative to the other stimuli they had viewed in that block.

4.2 N170

The N170 ERP is a widely studied ERP that has been shown to be particularly sensitive to human face stimuli (Bentin et al., 1996). Prior research has examined the N170 within the context of thatcherized stimuli (Carbon et al., 2005) and uncanny stimuli (Schindler et al., 2017), but not these two forms of image manipulation in tandem. While the results of the present study did not indicate a significant main effect of *thatcherization* or *shape* level on N170 amplitude, there was a significant interaction effect of these two variables. More specifically, *shape* level 6, when thatcherized, produced a significantly larger N170 amplitude than thatcherized images at *shape* levels 4 and 5. Again, level 6 on the continuum is a human face that has not been stylized

across any uncanny-like manipulations. When this level is thatcherized, it produces higher ratings of off-putting and a larger N170 deflection. There are several potential explanations for these effects.

Extant research shows that N170 deflection has an evident proclivity for human faces over non-human stimuli (Boutsen et al., 2006). As images 1-5 on the *shape* continuum possess some form of uncanny manipulation, they are inherently less human in appearance than level 6. It stands to reason that thatcherized level 6 stimuli's larger N170 deflections were due to a combination of the N170's inherent sensitivity to human faces, combined with the added effort required to process the thatcherized components. Overall, these results suggest that the effect of thatcherization on N170 amplitude is greatly attenuated when used on uncanny entities.

Another potential explanation is that all other levels on the morph continuum contain elements of uncanny manipulation. In this way, they all share common features that are inherently non-human in nature and may prime participants to be more sensitive to such differences. When a level 6 stimulus appears, it breaks from the expected image types and subsequently increases the cognitive effort required to process it.

The results of *material* level on N170 amplitude yielded interesting results. Examination of the means revealed that higher levels of *material* (levels 5 and 6) were associated with the largest N170 amplitudes in comparison to other images along the *material* continuum. However, these differences were statistically significant in few instances. Level 6 was significantly larger than levels 2 and 4, while level 5 was significantly larger than level 2. The clustering of larger amplitudes towards the end of the continuum (levels 5 and 6) was likely attributable to these images being the most realistic in nature. However, the lack of significantly larger amplitudes towards the other end of the continuum was surprising (levels 1 and 2), as these images should

theoretically require more cognitive effort to process, thus resulting in larger N170 amplitudes relative to middle-continuum images.

Similar to *shape*, there was no main effect of *thatcherization* on N170 amplitudes for *material* stimuli. Additionally, there was no significant interaction between *material* level and *thatcherization*. Regarding N170 amplitude, there is no statistically discernable effect of thatcherization on stimuli where the predominant featural manipulation is the realism of skin texture material.

There was a significant interaction of *shape* level and *thatcherization* on N170 amplitude that was not found for images along the *material* continuum. This may be due to a combination of thatcherization technique and *material*-specific elements. On the less realistic, lower levels of the *material* continuum, image texture is very uniform and smooth in appearance. When thatcherized, the eyes and mouths are inverted and blended into the surrounding areas. This may have caused the thatcherized elements to become less perceivable as they are blended into an already homogenous area.

4.3 N400

The N400 is particularly sensitive to unexpected, mismatched information (Balconi & Pozzoli, 2005; Kutas & Hillyard; 1980). Along the *shape* continuum, both non-thatcherized and thatcherized level 6 stimuli were associated with the largest N400 deflections. This may have been due to the other image types along the continuum. The presentation of a real human face amongst digital entities may have elicited a larger N400 due to its novel nature relative to the other stimuli types. No significant effect of *thatcherization* was seen on N400 amplitude. Again,

this may be due to contextual priming of stimuli that are already strange in appearance, diminishing the unexpected appearance of thatcherized images.

Along the material continuum, N400 amplitude analyses revealed that *material* level 6 stimuli again produced the largest negative deflection. Similar to the results discussed in regards to *shape*, this is likely due to the unexpected nature of the realistic human face stimuli amongst all other stimuli that have some form of digital manipulation. While there was no statistically significant difference between N400 amplitude and *thatcherization*, the N400 deflection was larger for thatcherized stimuli than non-thatcherized stimuli.

Overall, differences were found between the *shape* and *material* manipulations regarding participants' subjective ratings of off-putting. This study adds to the body of literature detailing the salient effects of thatcherization, as it was shown that thatcherized images produced an additive effect of off-putting, aversive perception to already digitally altered images. Despite this, there were no significant differences between these two forms of image manipulation related to N170 and N400 ERPs. However, both stimuli types produced classical N170 and N400 responses as indicated by visual inspection of the waveforms, indicating that while these types of images were often found to be unexpected in their mismatched features, they were recognized as uniquely human in nature.

5 LIMITATIONS AND FUTURE DIRECTIONS

The current study has several potential limitations. Participants' ages, ethnicities, and education levels are largely homogenous. Future research in this area would ideally ensure a more diverse sample of participants across these demographic variables.

Interstimulus perceptual variances (ISPVs) were likely different between the *shape* and *material* conditions. This may have influenced differences in N170 response between the two stylizations that were not accounted for or controlled for.

The N400 results indicated that the relatively infrequent inclusion of unaltered images amongst a majority of digitally manipulated images may have unduly influenced the ERP response. While the intention was to view the N400 within the context of manipulated features, it appears that it instead it showed greater sensitivity to the unexpected nature of real, unaltered human face presentation. Future studies interested in the N400 ERP may include more numerous presentations of the unaltered face stimuli or exclude it entirely.

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Chapter 4. Discussion

This dissertation focused on digital manipulation and stylization forms across human and human-like stimuli. Both studies were designed to address different types of phenotypical displays to better understand best-fit methods and commonalities between commonly used digital alterations to images. The incorporation of subjective measures designed to capture salient emotional responses to these stimuli was intended to grant additional insight into the objective, electrophysiological measures used.

While different adjectives were used to prompt subjective responses in S*tudy 1* and *Study 2* (grotesque and off-putting, respectively), both describe similar qualities and reveal commonalities between perceptions of thatcherized images. Overall, the valence of thatcherized images was rated as more emotionally negative than non-thatcherized images. This occurred despite different iterations of featural manipulations across studies, indicating a robust effect of thatcherization. This is consistent with prior studies that have found similar effects of thatcherization on participant perception of stimuli. Interestingly, there did exist a discrepancy between studies and interactions of thatcherization on the levels (or conditions) of manipulation. In S*tudy 1*, there was no significant interaction effect between thatcherization and condition (color, black and white, cutout) on grotesque ratings. However, in S*tudy 2*, a significant interaction was found between thatcherization and the individual stylizations of shape and material. Such a discrepancy may have occurred for several reasons.

First, and most obviously, different descriptors were used between studies. “Grotesque” may describe fundamentally different emotional aspects that are not described by “off-putting.” Grotesque is defined as comically or repulsively ugly or distorted, while off-putting is defined as unpleasant, disconcerting, or repelling. “Repulsive” and “ugly” are semantically strong

adjectives that describe a particularly negative valent emotional reaction. In contrast, the definition of off-putting contains relatively less negatively valent emotional language and instead appears to emphasize a mix of negative emotionality with the behavioral quality to stay away or maintain distance from the object of description.

Despite these differences, the author believes that the lack of consistency of thatcherization by image manipulation between studies is more likely due to the disparate nature of the stimuli manipulation itself. Across shape and material manipulations in S*tudy 2*, a significant main effect was found on the level of stylization and off-putting ratings. However, in S*tudy 1*, there was no main effect of condition on grotesque ratings. In other words, differences in face presentation, whether color, black and white, or cutout conditions, did not produce any measurable change in subjective perception.

Conversely, face stimuli used in *study 2* varied predominantly along levels of mismatch between head shape and skin material. The result was a more focused and intentional alteration of face stimuli in regards to unpleasant features based on the uncanny valley theory (Mori, 1970; Schindler et al., 2017). This, in combination with increased degrees of perceptual variance along larger continuums in S*tudy 2*, likely accounts for the differences in significant interactions of thatcherization and featural manipulation between studies.

Findings regarding N170 amplitude also varied across studies. In *Study 1*, thatcherization was associated with a significantly larger peak N170 amplitude than non-thatcherized images. This effect was not found for *Study 2*. This discrepancy lends insight into a unique effect produced by uncanny entities. Peak N170 amplitude has been seen to increase in the presence of thatcherized images (Carbon et al., 2005), believed most frequently to be a result of an increase in the cognitive effort needed to process human faces with this manipulation. Since this effect is

absent in uncanny entities, it may suggest that due to the nature of their manipulated features, a higher degree of cognitive effort is required at baseline to process these images that do not show any meaningful additive effect of thatcherization. Indeed, the overall N170 mean peak amplitude seen in *Study 1* is nearly 45% smaller than that seen in *Study 2*.

Further support is added to this rationale when considering that inverted images are associated with an enhanced N170 effect (Civile et al., 2020). *Study 1* included the use of inverted images, and results indicated that indeed there was an enhanced N170 deflection for these stimuli. However, S*tudy 2* did not use inverted images, yet there remained a larger overall mean peak N170 amplitude.

Results from these two studies largely support many of the qualities inherent to N170 waveform presentation seen in the extant literature. Based on the overall findings, several recommendations can be made for the use of similar stimuli in future studies. If future methodology is designed to examine the effects of human face featural manipulations on N170 deflection, a cutout presentation of stimuli is likely the best fit method. This condition removes visual noise in the form of reduced differentiation between head sizes and shapes. However, it is important to note that the cutout condition, as used in *study 1*, is defined by a greyscale image. If future studies were to examine the effects of different textural, lighting, or skin material manipulations, color inclusion on the cutout should be used. Maintaining the greyscale aspect otherwise may reduce otherwise salient differences across these areas.

Additionally, it was found that of all of the non-thatcherized stimuli used in S*tudy 2*, *shape* level 1 was associated with the highest participant rating of off-putting. This suggests that stimuli with a cartoon-shaped head (large and oval-like) with mismatched features of realistic skin textures produce the most unappealing character designs. This provides further support for

similar findings from Schindler et al. (2017). This result can help to inform future researchers on which elements to manipulate when attempting to create uncanny, unappealing stimuli for study. Additionally, this has implications for industry in regards to stylistic considerations. The end goal in the entertainment industries would be to avoid unappealing character design, as this can detract from viewer immersion and create negative associations with the work.

While it was not the intent of this study to directly measure elements of pathogen-avoidance (likelihood of interaction with pathogen-laden materials/objects, pathogen avoidance motivations via disgust scales, etc.), this theory helped conceptualize matters related to stimuli construction and interpretation of results. The specific digital manipulations of stimuli in both *study 1* and *study 2* possess features that are inhuman, mismatched, and unexpected. However, a balance needed to be struck between the incorporation of such features and maintaining a distinct human quality of the images. After all, if the elements of manipulation were so great that the participant no longer perceived the images as human, then the results would have no longer been applicable to facial processing.

Across both studies, thatcherized images produced higher ratings of negative perception than non-thatcherized images. Furthermore, based on the presence of distinct N170 waveforms, it is clear that participants were perceiving these faces as being inherently human. This effect persisted at even the most heavily altered or stylized levels of presentation. While participants did not specifically rate their perception of such images possessing a communicable disease, these findings are in line with tenets of pathogen-avoidance. Thatcherized images, with their misshapen eyes and mouths, may evoke negative feelings as a means to safeguard the viewer from contact. This can also be seen when considering the results associated with stimuli with misshapen heads (*study 1* cutout condition and *study 2* shape continuum), and unexpected skin

materials (*study 1* cutout condition and *study 2* material continuum). In conclusion, participants' overall negative emotional response was similar across studies in regards to thatcherized images. This shows that, short of inversion, thatcherized stimuli produce a robust subjective effect that is largely unaffected by digital manipulation. Additionally, differences across the two studies in N170 amplitude show that there exists a functional difference or specific quality to uncanny imagery. Schindler et al. (2017) suggested that this is likely driven by a mismatch of key elements of the head and face. Simply altering the appearance of a stimulus in order to appear less realistic does not produce the same effect as altering said stimuli to contain incongruous features. This provides additional insight into uncanny valley research, and suggests that the response curve originally suggested by Mori (1970) may be better explained by salience of incongruous features, rather than simply "human-likeness."

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