Effects of the Hollow Mask Illusion on Children

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We experience the world via the interaction between sensory input and the brain's ability to organize and interpret that input. Some people perceive the same things in different ways, and sometimes our perceptions are not accurate representations of that with which we interact. One example of an inaccurate representation is the optical illusion, a stimulus that deceives the visual system by appearing to be something that it is not. Gregory (1997) highlights the issues regarding how we recognize the present without confusing it with our past, arguing that it is regulated by the present being signaled by real-time sensory inputs. But what happens when these systems stop working, and how do they develop?

Illusions, whether they are caused physically (via obstructions to light or a disturbance of sensory signals to the eye) or cognitively (via misapplication of knowledge), allow these questions to be studied by psychologists in various areas. For example, illusions have been used to examine perceptual phenomena in individuals with schizophrenia, including identifying differences in top-down versus bottom-up processing and neural responses as compared to healthy controls (Dima et al., 2009). In addition to psychopathology, illusions allow us to examine how visual pathways and perception change over time, specifically by looking at the differences between adults (who have fully developed visual systems) versus infants and children (who are still developing). These differences in perception allow researchers to map the progression of development across the lifespan.

One example of varying perceptions can be seen in the differences between children and adults. Even when children's visual systems are fully developed and functional, they still perceive the world from a fundamentally different angle than adults, even when viewing the same objects. For example, children are less likely to be susceptible to certain optical illusions, such as the Ebbinghaus Illusion (Doherty, Campbell, Tsuji, & Phillips, 2010). The Ebbinghaus Illusion manipulates context clues in order to distort the perception of the size of two objects which are actually the same size (see Figure 1). For this 2-dimensional illusion, context effects the accuracy in which individuals identify the similarity in size between two objects. When given misleading context, children were more likely to make correct decisions than adults. The opposite was found to be true when context was helpful. Illusions like the Ebbinghaus highlight key differences in different samples of people, including between psychologically impaired individuals and healthy controls, as well as between adults and children. Research examining these differences has contributed to literature regarding brain development from infancy to adulthood, with specific regard to how visual pathways develop and can malfunction over time. Optical illusions are especially helpful in this area, as they rely on discrepancies between the senses, visual pathways, and the brain. When the eyes receive information from their surroundings, that information travels from the retina and to the visual cortex of the brain via circuits of neurons sending neural impulses to one another that convey the information. This information is processed and encoded, creating an image of a given stimulus. However, not all the information originally sent from the retina reaches the processing center of the brain (Pafundo, Nicholas, Zhang, & Kuhlman, 2016). The information that does not reach the brain is sent backwards to the first stage of processing, creating a feedback loop. (Pafundo, Nicholas, Zhang, and Kuhlman (2016) determined that 20% of the activity in the first processing stage in the visual cortex is actually a result of this feedback loop, which indicates that the information coming from this region is not actually a direct response to stimuli, but a response to how the stimuli was perceived by other, higher, cortical areas. This feedback loop could potentially explain how the brain processes stimuli that is not complete, highlighting underlying mechanisms that could be involved in top-down processing when viewing optical illusions.

One illusion that has been used to this effect is the depth inversion illusion (Gregory, 1997), a perceptual phenomenon in which a concave object appears to be convex to its viewer. The hollow mask illusion is an example of the depth inversion illusion, using a mask of a human face painted on the concave side to mimic what the convex side would show (i.e., a normal human face) using shading and other monocular depth cues. A regular mask is inverted, and the concave portion is painted in a manner that reflects the shading one would see when viewing a face under normal conditions, which in addition to familiarity, and characteristic surface color, enhances the illusion (Hill & Bruce, 1993; Hill & Johnston, 2007; Ramachandran, 1988). Lighting conditions also play a role in the perception of this illusion. Adults use the assumption that light comes from above, while young children tend to assume that it does not and assume the stimulus is convex, highlighting a change in perception bias over development (Ramachandran, 1988; Thomas, Nardini, & Mareschal, 2010). Research using this type of illusion has found that infants (Corrow, Granrud, Mathison, & Yonas, 2011; Tsuruhara et al., 2011) and those who have been diagnosed with schizophrenia (Dima et al., 2009) are less likely to perceive inverted masks of human faces as being concave, even when the context tells them otherwise. Considering that top-down processing allows those with healthy, fully developed visual systems fall for the illusion, the data suggesting that children and those with Schizophrenia do not fall for the illusion could mean that the visual pathways and underlying mechanisms of top-down processing are not fully developed in these individuals or at some point in time, for those with schizophrenia, the pathways could be disrupted by other means which can cause lapses in perception (Frith & Dolan, 1997).

The reason the Hollow Mask Illusion is so robust is not conclusively understood, but there are postulations regarding the way the mask is perceived. Gregory (1970) suggests that the reason individuals perceive the mask as being convex (even when told it is concave) is due to the brain having to make up for any visual information that is lost while traveling to the brain from the eyes. Therefore, the brain must use past experiences in order to construct a face when the information is not available, via top-down processing, a mechanism in which the human brain uses prior knowledge in order to form perceptions about specific stimuli. This supposes, in essence, that for the visual system, if an individual is viewing a face that is somewhat ambiguous, the brain would use prior knowledge of larger concepts and past experiences with faces, thus influencing how the individual perceives this stimulus. Top-down processing is further examined via inversion effects in the hollow mask illusion, where inversion of the stimulus weakened the illusion (Papathomas & Bono, 2004). The weaker illusion of an inverted face would suggest that when viewing a stimulus in an unfamiliar context, top-down processing is interrupted to such a degree that the brain cannot use previous knowledge of faces to perceive the facial stimulus as one would perceive the face of another individual they are interacting with.

Interacting with individuals is important to survival, making the ability to recognize similar others important to infants, who are able to distinguish between familiar and unfamiliar faces almost immediately after birth (Bushnell, Sai, & Mullin, 1989). Studies involving the removal of cataracts in children highlights critical periods, like that of facial perception, of the visual system (Billson, Fitzgerald, & Provis, 1985; Ganesh, Arora, Sethi, Gandhi, Kalia, Chatterjee, & Sinha, 2014; Rogers, Tishler, Tsou, Hertle, & Fellows, 1981). In addition to facial recognition, other areas of visual perception are equally, if not more, important to human development and navigation of the world. Depth perception, for example, is a critical component that keeps mobile children from traveling off high areas that would result in injury. As demonstrated by the visual cliff illusion (Gibson & Walk, 1960), this ability is fully developed by the time children usually gain the ability to walk (24 months, approximately). However, there is evidence suggesting infants as young as 6 months are able to perceive which objects are closer to them (Updegraff, 1930). By using illusions to draw conclusions about differences in perception, we can get a better sense of when certain cortical networks are established. Using this information, we can examine what happens when development fails or lags behind, and potentially how to fix errors in the visual system when it becomes problematic (Gori, Molteni, & Facoetti, 2016).

The current study examines the difference in the effects of the Hollow Mask Illusion on children and adults. To our knowledge, this is the first study to examine this phenomenon in children (ages ranging from 4 to 6-years-old), as opposed to studies examining infant perception. Additionally, this study presents a new mask type which may be more familiar to children than the masks previously used for this illusion. Given that children are less efficient in using context clues in their perception of the environment (Doherty, Campbell, Tsuji, & Phillips, 2010), we hypothesize that children will be more likely to report the concave side of the mask as concave, as opposed to adults who will be more likely to report the concave side as convex. The character mask created for this experiment will be compared to the effectiveness of the traditional hollow mask, as well as examining if the mask was more palatable to the presented audience. This study aims to add to current literature regarding critical brain area in regards to vision and perception, specifically in regards to development between preschool aged children (which have yet to be studied, to our knowledge) and adults. This study has the potential to highlight the key leaps in development from infancy to adulthood.

Method

Participants

Participants were recruited from Albright College and the Albright Early Learning Center. Participation in the study was completely voluntary, and adult participants could receive course credit and/or extra credit in their psychology classes for their participation in this study at the discretion of their professors or monetary compensation. Parental consent was obtained for the child participants along with demographic information via forms sent out from the Albright Early Learning Center, and the children were compensated with a toy of their choosing. All procedures were approved by the local Institutional Review Board.

There were a total of 33 participants in the current study. Participants were excluded if they did not appear to understand directions or appeared distracted during the time of the experiment, which was operationalized by checking for random responses. Additionally, a new variable was calculated, in which the proportion in the illusion (during the concave right side up condition) was subtracted from the proportion in illusion for the control (convex side right side up condition). Anything below -.5 was excluded on the basis that this would indicate they were not paying attention or did not understand the directions (as this would indicate they were reporting the convex mask as concave, which is unlikely in normal circumstances).

After applying the exclusion criteria 4 participants were excluded. The total number of participants included in analyses was N = 29. Of these participants, there were 14 children (M = 4.12, SD = .56) and 15 adults (M = 20.4, SD = .828). In the child group, 57.1% were male and 42.9% were female. Additionally, 92.9% of participants in this group identified as Caucasian, with 7.1% identifying as

Hispanic/Latino. In the adult group, 80% were female and 20% were male. Additionally, 53.3% identified as Caucasian, 6.7% as Asian, 13.3% as African America, and 26.7% as Hispanic/Latino.

Materials and Procedure

This was an in-person study examining the effects of the Hollow Mask Illusion. First, participants gave their informed consent and were then given instructions regarding the procedure. Participants were asked to remain relaxed and report what they were perceiving honestly. Additionally, participants were told that the object they were viewing can appear ambiguous, and that if their percept changed at any point, it was normal for it to happen. Second, participants were shown a Necker Cube (see Figure 2) and were asked to point out which face of the cube they perceived to be closer to them. Participants were then asked to continue looking at the cube, and to alert researchers when their percept changed (when the opposite face appeared closer). Next, participants were shown a sample stimulus of a blank mask and asked to focus on the fixation point (a green dot on the nose). Both the concave and convex side were shown to participants, and the researcher explained that the concave side appears to be caving in (pointing to the wall), whereas the convex side appears to be popping out (pointing at the participant). For the child group, participants were instructed to tell the researcher (when prompted) that if the mask was pointing at the participant, they should say “at me”, and if the mask was pointing at the wall, they should say “at the wall”. Participants were then shown each side and asked whether it was caving in or popping out. The experiment took place in two different rooms. In the room for children, a black trifold was set on a table with two black boards attached on each side, lining either side of the visual field, with lights set up on each side such that the lighting negated shadows cast by the mask contours. The masks were attached to the board via push pins. In the room for adults, the mask was hung on a black wall, with black curtains and flood lights lining each side of the visual field. In both setups, participants were situated approximately 80 inches away from the stimulus.

Two hollow masks were created as inverted versions of a human face and Elmo face, and were painted such that they reflected the same stimulus under normal, unedited viewing conditions. Each of these were shown the participants in multiple orientations: A concave Elmo mask placed right side up, upside down, and the unpainted front (see Figure 3b), and a human concave mask placed right side up and upside down (see Figure 3a). Participants were instructed to focus on the fixation point (a green dot on the nose), and to report what they were perceiving each time the researcher asked. Each mask was viewed for approximately 90 seconds, and participants were asked what they were perceiving at intervals of 10 seconds. The strength of the illusion was calculated as the proportion of time spent in the illusion (viewing the mask as convex instead of concave). The order in which participants viewed the masks was counterbalanced.

Children were given a small survey in which they rated each mask on a scale of 1-5 on friendliness and scariness. The children’s demographics were completed by parents with the consent forms. Adult participants completed a demographic form at the end of the experiment.

Results

To test the hypothesis that children be more likely to report the concave side of the mask as concave and that adults would be more likely to report the concave side as convex, a 3-way mixed model ANOVA was conducted on a sample of 33 participants to compare the main effects of age (child x adult), orientation (right side up x upside down), and mask type (human x character), on proportion of time spent in the illusion (See Table 1, Figure 4). There was a significant main effect of mask type on the strength of the illusion. The human mask ($M = .472$, $SD = .057$) showed a stronger illusion than the Elmo mask ($M = .307$, $SD = .051$) [$F(1,27) = 6.405$, $p = .018$, $\eta^2 = .192$]. There was also a significant main effect of age group on the strength of the illusion. Children ($M = .480$, $SD = .062$) perceived a stronger illusion than adults ($M = .300$, $SD = .060$) [$F(1,27) = 4.402$, $p = .045$, $\eta^2 = .140$]. There was no main effect of orientation on the strength of the illusion, nor were there any significant interactions, although the interactions between orientation and age group ($p = .058$), as well as between orientation and mask type approached significance ($p = .059$). These results suggest that children are more perceptible to the hollow mask illusion than adults, and that the Elmo mask was not as efficient in producing a strong illusion.

To examine if children preferred the novel character mask compared to the human mask, paired sample t-tests were conducted comparing the ratings of how scary and how friendly the participants perceived each mask. There was no significant difference in friendliness ratings between the two mask types [$t(12) = 1.806$, $p = .096$]. These results suggest that Elmo mask may be a suitable substitute for studying the hollow mask illusion in terms of likability, that is, it may not produce aversive effects when viewed by children. Another t-test was conducted for quality control purposes, which compared the strength of the illusion between the Elmo mask (right-side up condition) and the control (right side up, unpainted, convex side of the Elmo mask). There was a significant difference between the Elmo mask ($M = .287$, $SD = .312$) and the control ($M = .804$, $SD = .298$) [$t(28) = 6.265$, $p < .001$]. The results of this t-test suggest that participants viewed the concave side as significantly different from the unpainted convex side of the Elmo mask.

Additional 3-way ANOVAs were run to examine potential confounding effects of gender and race on the strength of the illusion. A 2(Mask type) x 2(Orientation) x 2(Gender) ANOVA revealed there were no main effects of gender, $F(1, 27) = 1.37$, $p = .252$. The findings for orientation and mask type were consistent with previous analyses. These results suggest that gender does not affect the strength of the hollow mask illusion.

A 2(Mask type) x 2(Orientation) x 4(Race) ANOVA revealed no main effects of Race, $F(3, 25) = .833$, $p = .489$, Mask Type, $F(1, 25) = 2.442$, $p = .131$, or Orientation, $F(1, 25) = .379$, $p = .544$. There was a significant interaction between Mask Type and Orientation, $F(1, 25) = 4.47$, $p = .045$, where for the Elmo Mask, the upside down ($M = .288$, $SD = .115$) orientation showed a stronger illusion than the right side up ($M = .181$, $SD = .104$) orientation. For the human mask, the right side up ($M = .514$, $SD = .106$) orientation showed a stronger illusion than the upside down ($M = .348$, $SD = .117$) orientation (see Figure 5). These results suggest that while race has no main effects on illusion strength, when controlling for this variable, the mask type and orientation also do not have any significant effects, suggesting that there may be cultural differences that only minimally effect the illusion strength. Additionally, the results suggest that when viewing the Elmo mask, the strength of the illusion is stronger than viewing it right side up, which is the opposite of the human mask.

Discussion

The current study aimed to examine the effects of the Hollow Mask Illusion on children. More specifically, this study examined the differences in the strength of this illusion between adults and children when viewing two different masks of varying orientations.

The hypothesis that adults would be more likely to report the concave side as convex was not supported. The data analyses show the opposite effect: children were more likely to report the concave side of both masks as convex, as opposed to the adult participants, suggesting that children perceive a stronger illusion. This is not consistent with previous findings concerning infants, suggesting they are less susceptible to perceiving the illusion, which is to say they are more likely to veridically perceive the concave side (Corrow, Granrud, Mathison, & Yonas, 2011; Doherty, Campbell, Tsuji, & Phillips, 2010; Tsuruhara et al., 2011).

Though not originally hypothesized, the illusion strength of each mask was compared to test the effectiveness of our novel mask. The human mask showed a stronger illusion than the Elmo mask, which would suggest that the mask created for this experiment did not produce as strong of an illusion as expected.

Limitations and Future Directions

When controlling for confounds, analyses did not reveal significant effects of gender, suggesting male and female perceptual capabilities are similar. This insignificant finding could be due to the disproportion between the number of male and female participants across both groups. Additionally, when analyzing race, the effect of mask type became insignificant, which could be due to potential cultural differences in how illusions are perceived. A larger and more diverse sample size could alter these results.

It is well known that children's visual systems are not as developed as adult's. Facial recognition is a skill that develops at birth and is improved and maintained over time with experience (Nelson, 2001). Over the course of development, it is not until age 6 that children view the face as a whole (Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998). It is possible that children spent more time in the illusion by looking at parts of the face, such as the eyes or the fixation point, the nose, which could have led to a stronger illusion.

The disparity between adult and child perceptual abilities with this illusion could be due to a familiarity bias for completing facial stimuli (Buttle & Raymond, 2003; Johnston & Edmonds, 2009), which would explain why the human face was stronger in its illusory capabilities overall, especially considering the amount of time spent looking at faces as compared to a fictional character. However, adults did spend less time in the illusion for the Elmo mask than children. This character is likely more familiar to children, which, as explained by the familiarity bias, could explain the higher strength of the illusion for the child group.

In addition to the familiarity bias, it is important to note that although the display setups were set to mimic one another, each age group was tested in a different room with a different type of setup, including different types of light sources. Further research into this topic should take into account the differences in display types, as well as the implications regarding gender, race, and sample size. Additionally, it may be beneficial to examine the parts of the masks children and adults are looking at the most. The current study was unable to determine the adherence to looking at the fixation points on each mask, but eye-tracking equipment could help to fix this issue.

The current study provides additional measures which can be used to study the hollow mask illusion in children, as is seen by the lack of difference in friendliness ratings between each mask. Additionally, though not as strong, the mask created can potentially be used in further research regarding developments in perception of optical illusions in children as it relates to development and further understanding of how brain regions develop at specific times across the lifespan.

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Tables and Figures

Table 1.

Means and Standard Deviations of illusion strength across age groups and mask types.

	Children		Adults	
	M	SD	M	SD
Elmo Mask	0.428	0.322	0.155	0.24
Human Mask	0.523	0.352	0.533	0.282

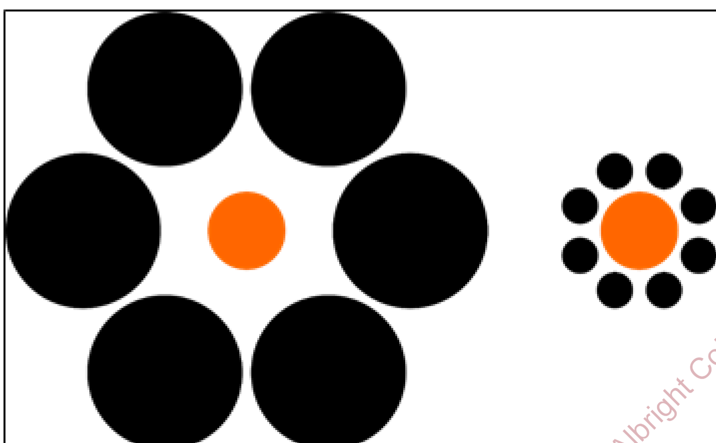

Figure 1. The Ebbinghaus Illusion, which examines visual perception in relation to helpful and unhelpful context.

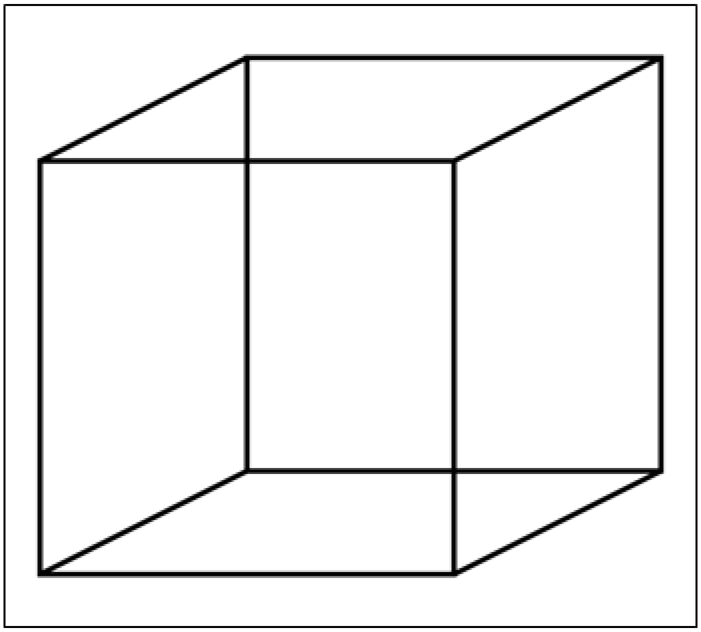

Figure 2. Necker cube used to demonstrate changes in percepts.

A

B

Figure 3. The human (a) and Elmo (b) masks shows to participants.

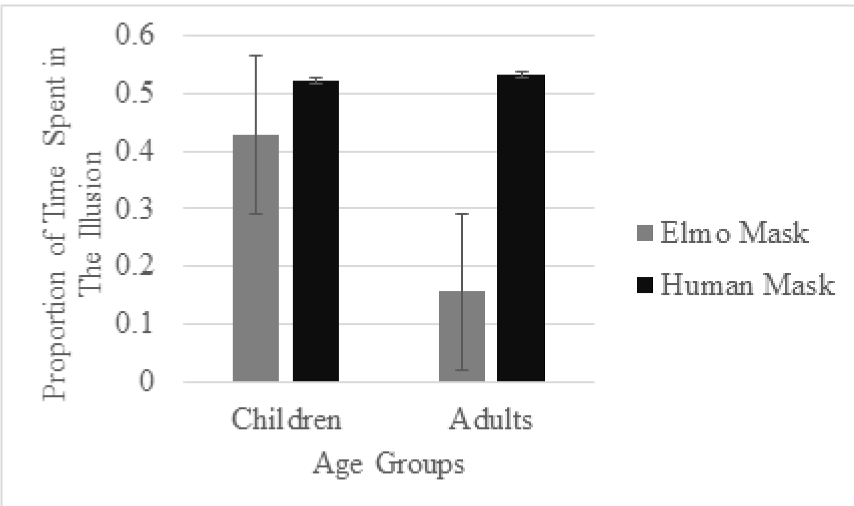

Figure 4. Effects of Age group and Mask Type on proportion of time spent in the illusion (strength of illusion)

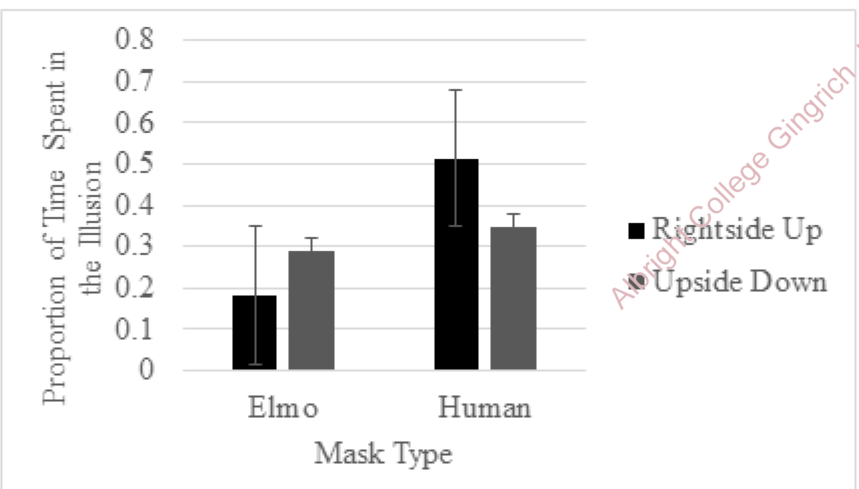

Figure 5. Interaction between Mask Type and Orientation.