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Color inversion and detail effects on face recognition

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Color Inversion and Detail Effects on Face Recognition

Two separate studies were completed to demonstrate the importance of color location and focus on face recognition. The first study manipulated Gaussian Blur (GB) and inversion (IN). GB is the process of taking an image out of focus, the higher the cycle the more out of focus the image will appear. IN is the process of changing the dark color with light color and the light color with dark color, like a colored photographic negative. In the study, twenty celebrity faces (10 female and 10 male) were exposed to six different manipulations: three levels of GB and two levels of IN (present and absent). Each of the 41 participants was exposed to all 120 images. Results showed that as the GB increased, there was a decrease in performance. When IN was present, there was also a decrease in performance. However, when GB and IN were used in combination, performance did not decrease further. The second study manipulated higher levels of GB and Glowing Edge (GE). GE is the process of highlighting the contours of the face in different colors. One hundred twenty participants were randomly exposed to one of the six conditions following one practice list. The results were measured using a between subjects design which showed an interaction between GB and GE, indicating both were a contributor to face recognition. It was demonstrated that facial recognition is contingent upon proper color location.

How is it that humans are able to recognize a face days and sometimes years after viewing it? What exactly are the components that contribute to face recognition? There is an abundance of research on various contributors to face recognition. Several studies (Haig, 1984; Hosie, Ellis, & Haig, 1988; Kemp, McManus, & Pigott, 1990) have been conducted to determine which facial features are the most important for accurate recognition.

Displacement of facial features

Haig (1984) aimed to determine how sensitive humans are to the slightest alteration in primary features of the face. In doing so, he kept the framework of the face but distorted the inner facial features such as the nose, eyes, and mouth. Haig performed the study by stretching the facial features horizontally or vertically. Results indicated that the eye was the strongest feature and the mouth was the weakest feature for facial recognition.

A later study (Hosie et al., 1988) indicated the eyes and mouth to be the most important features in face recognition of familiar faces. The study was conducted in a similar fashion to Haig's (1984) study, except that instead of using unfamiliar faces they used well-known faces. The faces of the well-known individuals had the facial feature of the nose, eyes, and mouth altered either vertically or horizontally.

Kemp et al. (1990) were also interested in facial features and their relevance to face recognition. They were interested in photographic negatives and inverted images (an image positioned upside down) on face recognition when facial features were repositioned. In the study, the facial features (eyes, nose, mouth, and chin) were removed from the face. Then the facial features were repositioned back into the original face they were removed from. Each facial feature was studied separately, first the eyes were removed and repositioned outward, upward, inward, or downward and placed back into the original face creating four images. Then the nose was removed from the image and repositioned creating another four images, and this procedure continued with the mouth, chin, and so on. Then each of the images including the original was exposed to a photographic negative, inversion, and both photographic negative and inversion. On a screen, three photos from the inversion condition appeared in a triangle. The top centered image was the original image that had no repositioning done to the eyes. One of the bottom two images was a match to the top centered image. The other image that was not a match had the eyes repositioned. Participants were instructed to indicate which picture from the bottom two matched the top center picture. Participants were exposed to four conditions: normal color, photographic negative, inversion, and photographic negative with inversion.

The results of Kemp et al.'s (1990) first experiment showed that the photographic negatives and inversion caused more difficulty for participants when trying to distinguish which image had the repositioning and which did not. However, the normal conditions did not hinder participants' ability to recognize the image with repositioning. Recognition performance was the worst when photographic negatives and inversion were combined. The results also showed that outward and inward positioning of the eyes were more noticeable than the upward and downward positioning of the eyes. This indicates that some facial features are not as important for face recognition.

Shading

Facial feature displacement is not the only manipulation studied in face recognition. Bradshaw and Wallace (1971) studied facial feature displacement but also examined photographic positive and negative images. They questioned whether serial or parallel processing took place when an image had a facial feature (eyes, mouth, eyebrows, chin, or hair) replaced with new facial features. Also, they wanted to know if inversion or the use of a photographic negative would create different results from those images viewed as a photographic positive and in an upright position. Bradshaw and Wallace used an Identi-Kit to change the facial features creating different faces. Participants were presented with paired faces and had to indicate whether the faces were the same or different. Pairs were presented in a photographic positive in upright or inverted positions and a photographic negative in upright or inverted positions as well.

Results indicated that the images that were presented upright and in a photographic positive produced lower response rates (amount of time it takes to process an image) with a larger percentage correct. Photographic negatives also produced the same results, indicating that they were processed the same way. Inverted faces were processed slower but over time they were processed just as fast as the upright ones. Results indicated that serial processing was taking place. Participants were processing the facial features one at a time, until a feature appeared different. When a facial feature appeared different, the processing stopped. Participants then took longer to scan the pair of faces. However, when there were more distinguishable differences among the two faces, scanning occurred faster.

In contrast to Bradshaw and Wallace (1971), Hayes, Morrone, and Burr (1986) found photographic positives and negatives to have an influence on face recognition. Hayes et al. (1986) examined which frequency bands; low, medium, or high, were the most beneficial for recognition in positive (colored photograph) and negative (black and white) images. The spatial frequency band filter is a process of gradually removing the detail from the face until there is almost no image appearing. High-spatial frequency shows the most detail and low-spatial frequency shows the least detail. Results indicated that positive and negative images at low-spatial frequency were unrecognizable. Low-spatial frequency negative images were the most difficult to recognize. Also, the photographic positive images were processed more accurately than the negative photographic images, which indicated that color may have an influence on face recognition. Specifically, colored images were more beneficial for accurate face recognition than black and white images.

Troje and Bülthoff's (1996) study examined texture and shading effects. Their study investigated the learning phase and the testing phase. The learning phase is considered to be more informational, in order for memorization to occur. The testing phase gives only half of the information, in order for proper recall from the learning phase to occur. The two phases were investigated by using shading, texture, poses, and resolutions. All the photographic images used were in 3-D and they had no hair, back, or shoulders. One set of images were textured, giving definition to the facial features of the 3-D face. The other set of images were shaded, creating a smooth outline of the facial features of the 3-D face. The images in the learning phase were shown at 0°, 22.5°, 45°, 67.5°, and 90° in rotation. The testing phase images were shown from -90°, -67.5°, -45°, -22.5°, 0°, 22.5°, 45°, 67.5°, and 90° in rotation. Those degrees mentioned in negatives were rotated in the opposite direction of the learning phase. The degrees in positives were rotated in the same direction as the learning phase. Participants were shown an image from the learning phase and then shown an image from the testing phase. Participants had to determine if the view in the testing phase was the same as the one in the learning phase. Results indicated that learning phase images at 20° and 70° are optimal for accurate recognition. Textured faces also yielded more accurate recognition in the frontal view. Shaded images yielded more accurate recognition in the side views.

Color

Color is another aspect of face recognition. Laughery, Alexander, and Lane's (1971) study dealt with positions and shading, but also briefly focused on color's importance to face recognition. The study was interested in what factors are essential when dealing with face recognition. Three experiments were performed. The first experiment dealt with time exposure. The study had two targets; both were Caucasian males. The first wore glasses and had a fair complexion; and the second did not wear glasses and had a dark complexion. Participants were allowed to study the target photos before being presented with a test list. During the test list, participants were instructed to pick out which individual was the correct target. One group of participants was allowed 10 seconds to view the target photos in the study list, and 2.5 seconds to view the photos in the test list. The second group of participants was allowed 32 seconds to view the target photos in the study list, and 8 seconds to view the photos in the test list. Results showed that those participants who were given longer exposure times performed better than participants who were given less exposure time.

The second experiment conducted in the Laughery et al. (1971) study dealt with pose positions. The four pose positions used were front, profile, right portrait, and left portrait. Each participant received 32 seconds to view the target photo. The task in experiment two was exactly the same as that of experiment one. Results indicated that pose position did not have an effect on face recognition.

The third experiment of Laughery et al.'s (1971) study focused on color. Photos were presented in color or black and white. All photos were presented in front view. Results indicated that color or absence of color was not significant for face recognition.

Yip and Sinha (2002) also examined the impact of color as a contributor to face recognition. Yip and Sinha used shading to determine if color was a contributor to face recognition. They used Gaussian blur to bring an image out of focus, and they presented the images in both gray and full color scale. They used four different cycles of the Gaussian blur 1.5, 2, 3, and 4. The same twenty-four celebrity photos were subjected to each cycle creating a total of 96 photos in the gray scale group and 96 photos is the full color scale group. However, the photos were presented in order of resolution (lowest to highest). The participants were asked to mark on a sheet of paper the celebrities' name, and an extra sheet of paper was given for changing the name as the resolution increased. Results indicated that the images presented in color produced more accurate responses than images presented in gray-scale. Further, results determined that when images were degraded, color was a more vital contributor to face recognition. In these situations, color provided boundaries for the facial features.

From previous research, we may conclude that certain facial characteristics have a greater influence on face recognition. The eyes and mouth play the greatest role in proper identification of a face (Haig, 1984; Hosie et al., 1988; Kemp et al., 1990). Frontal view of a face also leads to more accurate recognition (Troje & Bülthoff, 1996). However, longer exposure time to an image may reduce inaccuracies in later recall. (Laughery et al., 1971).

It is still up for debate whether a colored image leads to more accurate recall. While some researchers support the idea that colored images lead to more accurate recall (Yip & Sinha, 2002); other studies have shown that images, whether in color or black and white, are processed in the same manner (Laughery et al., 1971).

It has been suggested that color does have an influence on face recognition, but it has not been demonstrated how color influences face recognition (Yip & Sinha, 2002). Therefore, the present studies will show how color location is important for face recognition. Our studies will reinforce the idea that color aids in forming boundaries of the facial features. Our study will also address how the change in highlights of the face affects one's ability to distinguish the boundaries of the face, using a technique that inverts colors. Inverting colors is the process of substituting the darker colors of the face with lighter colors, and the lighter colors with darker colors, such as in a colored photographic negative. This technique distorts the color and the color location on the face. The present studies will also use a Gaussian blur effect to demonstrate the need for facial boundaries in order for accurate recognition to occur. In the second study, a Glowing Edge technique (GE) will be used in place of inversion. GE is the process of highlighting the contours of the face in different colors. This provides a more accurate measure of the importance of boundaries of the facial features.

Experiment 1

Method

Participants

There were 49 participants who were Minnesota State University Moorhead students enrolled in a psychology class. All participants were volunteers. Participants received extra credit in their psychology class for participating in the experiment. Eight of the participant results were not used in the study due to complications with the Media Lab program.

Materials

Twenty celebrity faces (10 female and 10 male) were selected from the Internet using the search engines Google and Yahoo. Adobe Photoshop CS2 software was used to cut and manipulate the faces of the celebrity images. The celebrities were cut from their backgrounds and placed on an all white backgrounds. Gaussian Blur (GB) was used on the celebrity faces using a 3 and 6 cycle; the larger the cycle the more blurred (or out of focus) the face appeared. Inversion (IN) was also used on the celebrity faces; IN involves the process of substituting the dark colors for light colors and the light colors for dark colors, such as in a colored photographic negative (see Appendix A for sample stimuli). All images were presented in color.

Procedure

The study used a 2 (inversion present vs. inversion absent) x 3 (Gaussian blur: 0, 3, 6) repeated measures design. The six conditions contained 20 images each, for a total combination of 120 images. The images were presented in a random order.

The six conditions consisted of the same 20 celebrity faces (10 male and 10 female). The practice session consisted of the same 20 celebrities, but different photos of them were used and their first and last names were included with the photos.

Participants were assigned to all of the six conditions. MediaLab was used to present the stimuli and record the responses. Participants were first exposed to the practice session, where they studied the celebrities and their names. This was done by using a Power Point slide show on the computer screen. The participants were allowed to study each photo as long as they wished in order to identify the celebrity. Following the practice session, the participants were exposed to a random presentation of 120 stimuli. Participants were given 15 seconds in the testing phase to study the photo and type in the celebrity's last name.

Results

This study involved a 2 (IN) X 3 (GB) factorial design. IN had two values, IN present and IN absent. GB had the values 0 GB, 1.5 GB, and 4 GB. A 2 (IN) X 3 (GB) analysis of variance (ANOVA) for a repeated measure was conducted on the dependent variable, face recognition. Zero was assigned to incorrect answers and 1 was assigned to correct answers.

There was a significant main effect for inversion, $F(1, 40) = 96.8, p = .0001, \eta^2 = .708$, and Gaussian blur, $F(2, 80) = 16.4, p = .0001, \eta^2 = .3$. However, the IN x GB interaction was not significant, $F(2, 80) = 1.938, p = .151, \eta^2 = .046$. Recognition performance with inversion absent was significantly higher than with inversion present ($p <$ .0001) as shown in Figure 1. Participants did better when inversion was absent. Pairwise *t*-tests showed that performance at Gaussian Blur level 0 was significantly higher than at level 3 ($p < .0001$) and at level 6 ($p < .0001$). Also, performance with Gaussian blur at level 3 was significantly higher than at level 6 ($p = .035$). As GB increased, recognition decreased as shown in Figure 2; therefore GB distorted recognition. When IN and GB were combined, performance did not decrease further.

Discussion

Color was hypothesized to be a contributor to face recognition. If color location was inaccurate, then face recognition was disrupted. Correct color location is also important in defining the boundaries of the facial features. There was no interaction between IN and GB, indicating that color did not appear to aid in forming boundaries of facial features when the features of the image were less clear with the GB. However, results did indicate IN to be a contributor to face recognition because participants performed better when images contained the correct colors. Therefore color was necessary for accurate recall. Performance decreased when the color of the celebrities' faces was shown inverted. Face recognition, then, depends on color.

Results also indicated that GB had an impact on face recognition. Participants' performance decreased as the level of GB increased. Therefore, we may conclude that boundaries of the facial features are also necessary for face recognition.

Our results demonstrated that proper pigmentation and color are necessary for face recognition. The ability to distinguish boundaries of the face is also necessary for face recognition. However, results failed to show that color aided in forming boundaries of facial features or location of facial features. The results of this study refute the results of Yip and Sinha's (2002) study. Yip and Sinha found color to be an aid in forming boundaries of facial features. The presentation of all images in the present study may have contributed to the results. The images were randomly shown to participants. Participants may have received the distorted images first or the image without manipulation. If the participants were shown the image without manipulation first, they may have found it easier to later identify the celebrity in the distorted image. This may have made overall recognition higher than if they had seen the distorted image first.

In order to control for this possible design weakness in Experiment 1, Experiment 2 was conducted. Experiment 2 utilized a between subjects design. Participants were not exposed to all conditions. By using this type of design, we were able to more accurately examine whether color is necessary for distinguishing boundaries of the facial features. A Glowing Edge technique (GE) was also used in place of inversion. The GE technique highlights the contours of the face, providing a more accurate measure of the importance of boundaries of facial features.

Experiment 2

In the second study, a Glowing Edge technique (GE) was used in place of inversion. GE is the process of highlighting the contours of the face in different colors. This provides a more accurate measure of the importance of boundaries of the facial features. A higher level of GB was also used. Blur was increased from levels of 0, 3, and 6, to 0, 4, and 8. The study implemented a between subjects design, rather than a within subjects design that was used in the first study. The aim of this study was to reconfirm that color is a contributor to face recognition; if color location is inadequate, face recognition would be disrupted. It is again hypothesized that correct color location is important in defining boundaries of the facial features.

Method

Participants

There were 120 participants who were Minnesota State University Moorhead students enrolled in a psychology class. All participants were volunteers. Participants received extra credit in psychology classes for participating in the experiment.

Materials

Stimuli were similar to those used in Experiment 1. Gaussian Blur (GB) was used on the celebrity faces using a 4 and 8 cycle; the larger the cycle, the more blurred (or out of focus) the face appeared. Glowing Edge (GE) was used on the celebrities' faces; GE is the process of highlighting the contours of the face in different colors (see Appendix B for sample stimuli). All images were presented in color.

Procedure

The study used a 2 (GE present vs GE absent) X 3 (Gaussian blur: 0, 4, 8) between subjects. The six conditions contained 20 images each, for a total of 120 images. The six conditions consisted of the same 20 celebrity faces (10 male and 10 female). The practice session was similar to that of Experiment 1.

Participants were assigned to one of the six conditions. Research Randomizer was used to randomly assign participants to conditions. Presentation was identical to that of Experiment 1. Participants were given 6 seconds in the testing phase to study each photo and 20 seconds to type in the celebrity's name on the following screen.

Results

This study involved a 2 (GE) X 3 (GB) factorial design. GE had two values, GE present and GE absent. GB had the values 0 GB, 4 GB, and 8 GB. A 2 (GE) X 3 (GB) analysis of variance (ANOVA) for between subjects was conducted on the dependent variable, face recognition, measured as in Experiment 1.

There was a significant main effect for GE, $F(1, 114) = 106.48, p = .0001, \eta^2 = .48$, and GB, $F(2, 114) = 14.12, p = .0001, \eta^2 = .2$. The GE x GB interaction was also significant, $F(2, 114) = 7.76, p = .001, \eta^2 = .12$. Tests of simple main effects were conducted in order to explore the interaction. The following results were found: for GE present, GB was found to be significant, $F(2, 53) = 15.28, p = .0001, \eta^2 = .366$; Bonferroni multiple comparisons showed that recognition was higher at 0 GB compared to 8 GB ($p < .001$). Also, recognition at 4 GB was higher compared to 8 GB ($p < .001$). For GE absent, GB was not found to be significant, $F(2, 61) = 2.417, p = .098, \eta^2 = .073$. For GB 0, GE produced a decrease in performance, $F(1, 40) = 31.86, p = .0001, \eta^2 = .443$. Similar results were found for GB 4, $F(1, 44) = 13.17, p = .001, \eta^2 = .23$; and for GB 8, $F(1, 30) = 100.63, p = .0001, \eta^2 = .770$. As GB increased, recognition decreased as shown in Figure 3. Therefore, GB distorted recognition when GE was present, but not when it was absent. It appears that GE caused a distortion in recognition which was further affected when GB was present as shown in Figure 3.

Discussion

Our hypotheses were as follows: color would contribute to face recognition; accurate face recognition would depend on proper color location; and correct color location would be important in defining boundaries of the facial features. All hypotheses were confirmed. In Experiment 1, there was a significant main effect for inversion although the interaction between GB and IN did not show that correct color location was important in defining the boundaries of the facial features. However, this was demonstrated in Experiment 2 with the use of GB and GE.

In Experiment 2, performance decreased when GE was present. GE was shown to be an independent contributor to face recognition, strengthening the idea that color location is important, especially when the image is not very clear, as in the presence of GB. GB was also shown to be a contributor to face recognition because performance decreased as GB increased. When GB was combined with GE performance further deteriorated. Therefore, color appears to aid in forming the boundaries of the facial features.

Our findings agree with the findings of Yip and Sinha (2002) in that color, and more specifically correct color location, aids in face recognition. Bradshaw and Wallace (1971) found that when a photo was presented incorrectly (i.e. upside down), it took participants longer to process the image. This relates to our study as well; when color location was incorrect and participants were not given added time to process the photo, participants may have been unable to correctly recognize the person in the photo. Kemp et al. (1990) distorted facial features, for example by stretching the nose, mouth, etc. of a face, or rotating the eyes of a face. The photo was presented in color, in a photographic negative, and inverted. Participants had more difficulty recognizing these distortions when the image was in a photographic negative or inverted. This also relates to our study because correct color location aided participants in face recognition.

Results from both experiments could be generalized to real life situations. Without proper color location to aid in our ability to define and distinguish boundaries of the facial features, things such as accurate eye witness testimony may not be possible.

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Figure 1
Mean identification scores for each level of Inversion in Experiment 1

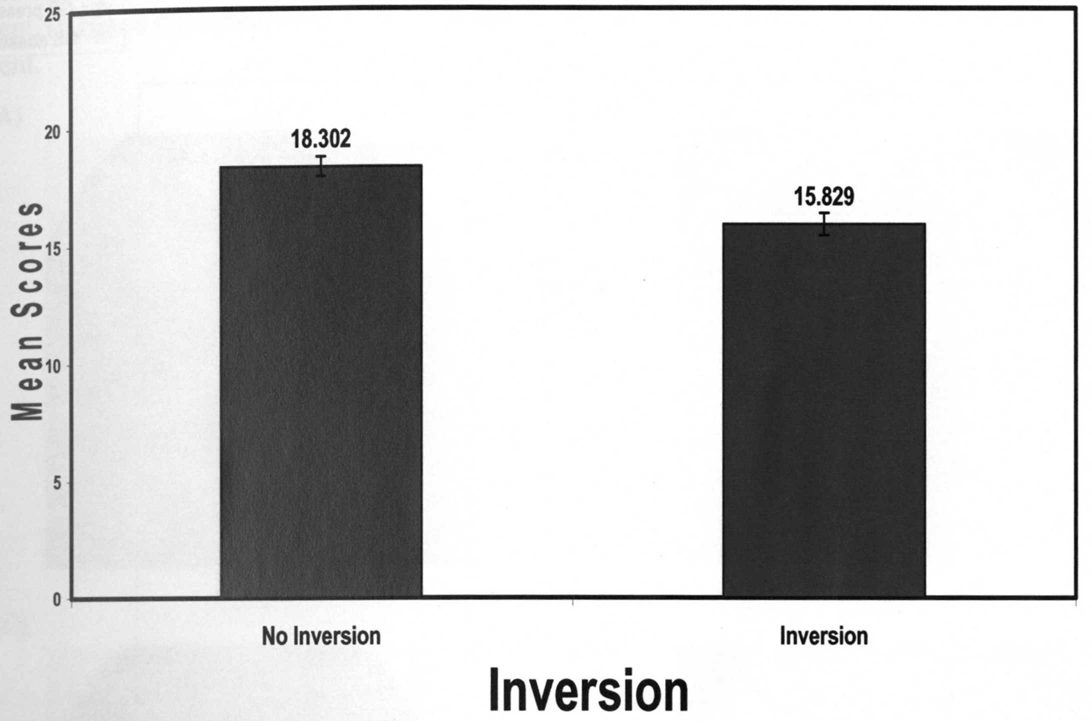


Figure 2
Mean identification scores for each level of Gaussian Blur in Experiment 1

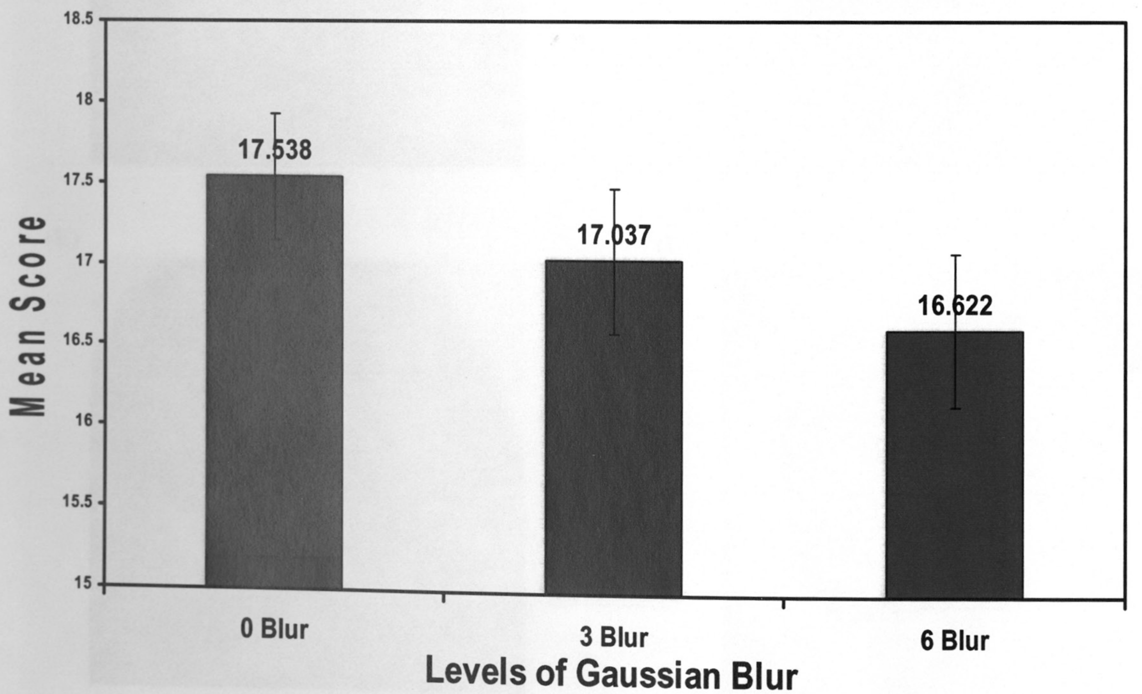
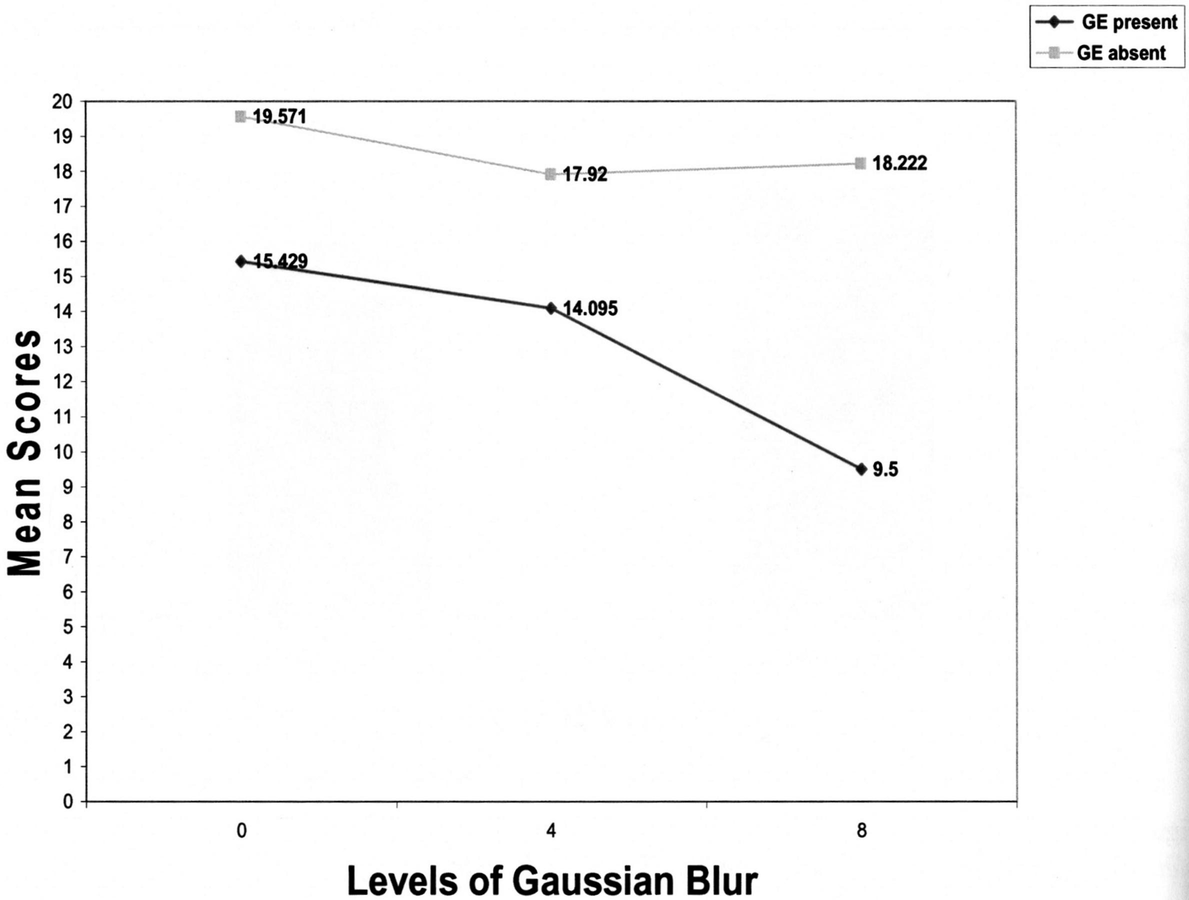


Figure 3

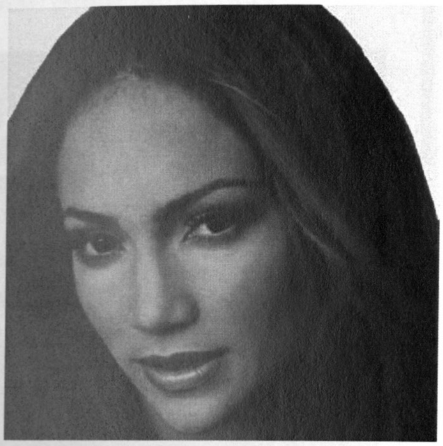
Mean identification scores for each level of Gaussian Blur and interaction between Gaussian Blur and Glowing Edge in Experiment 2



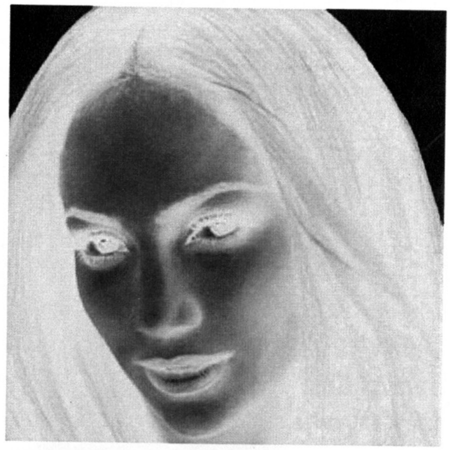
Appendix A

Jennifer Lopez picture (A) has a 0 Gaussian blur with Inversion absent, (B) has a 0 Gaussian blur with Inversion present, (C) has a 3 Gaussian blur with Inversion absent, (D) has a 3 Gaussian blur with Inversion present, (E) has a 6 Gaussian blur with Inversion absent, and (F) has a 6 Gaussian blur with Inversion present.

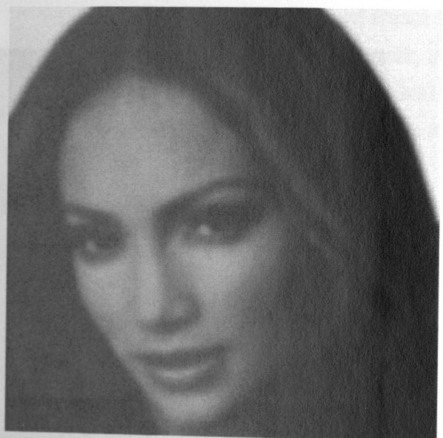
(A)



(B)



(C)



(D)

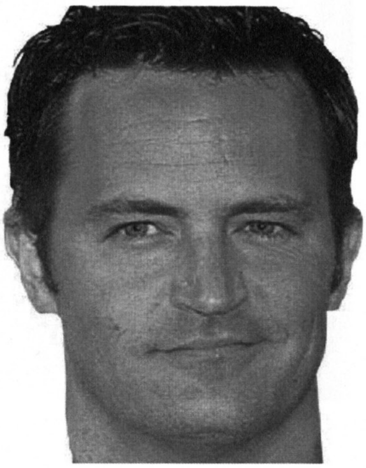
(E)

(F)

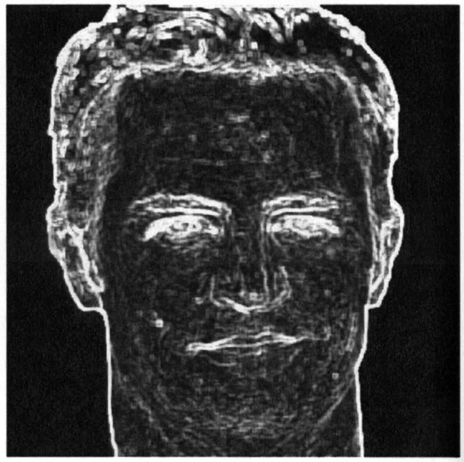
Appendix B

Mathew Perry picture (A) has a 0 Gaussian blur with Glowing edge absent, (B) has a 0 Gaussian blur with Glowing edge present, (C) has a 4 Gaussian blur with Glowing edge absent, (D) has a 4 Gaussian blur with Glowing edge present, (E) has an 8 Gaussian blur with Glowing edge absent, and (F) has an 8 Gaussian blur with Glowing edge present.

(A)



(B)



(C)

(D)

(E)

(F)