Evolutionary Psychology

www.epjournal.net – 2011. 9(2): 137-146

Original Article

Preliminary Evidence that the Limbal Ring Influences Facial Attractiveness

Darren Peshek, Department of Cognitive Sciences, University of California Irvine, Irvine, CA, USA. Email: dpeshek@uci.edu (Corresponding author).

Negar Semmaknejad, Department of Cognitive Sciences, University of California Irvine, Irvine, CA, USA.

Donald Hoffman, Department of Cognitive Sciences, University of California Irvine, Irvine, CA, USA.

Pete Foley, Innovation Science, Procter & Gamble, Cincinnati, OH, USA.

Abstract: The limbal ring of the eye appears as a dark annulus where the iris meets the sclera. Both width and opacity of the limbal ring are influenced by iris pigmentation and optical properties of the region. With age the limbal ring becomes less prominent, making it a probabilistic indicator of youth and health. This raises the question: Are judgments of facial attractiveness sensitive to this signal in a potentially adaptive way? Here we show that the answer is yes. For male and female observers, both male and female faces with a dark and distinct limbal ring are rated as more attractive than otherwise identical faces with no limbal ring. This result is observed not just for upright faces but also for inverted faces, suggesting that the limbal ring is processed primarily as a local feature rather than as a configural feature in the analysis of facial beauty. We also discuss directions for future research that can clarify the role of the limbal ring in the visual perception of facial attractiveness.

Keywords: mate preference, sexual selection, facial attractiveness, configural processing

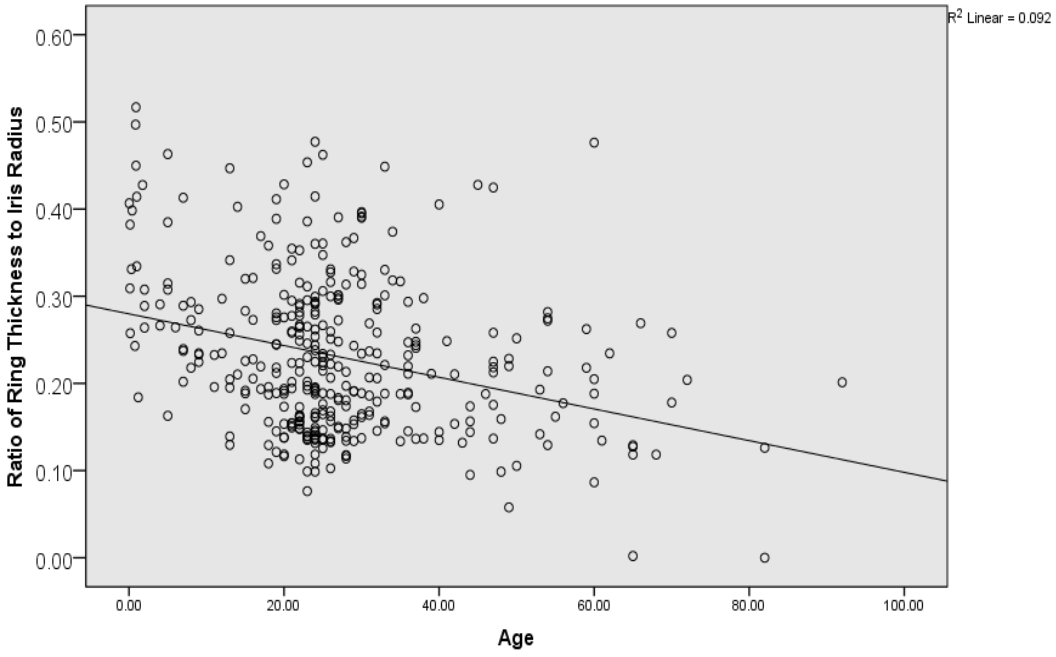
Introduction

Most human observers can quickly evaluate facial attractiveness. In fact it takes only 100 ms to determine the attractiveness of a face (Willis and Todorov, 2006). Faces that are more symmetrical, closer to the norm, or show greater evidence of estrogen or testosterone are generally perceived as more attractive (Cunningham, 1986; Grammer and Thornhill, 1994; Perrett et al., 1998; Perrett et al., 1999; Ramachandran and Hirstein, 1999; Rhodes, 2006; Wong et al., 2008). The eyes receive greater attention than any other feature of the face (Althoff and Cohen, 1999; Davies and Hoffman, 2002) and provide important cues that influence attraction during social interactions. Dilated pupils indicate emotional

arousal (Bradley, Miccoli, Escrig, and Lang, 2008) and are rated more attractive by males and females (Tombs and Silverman, 2004). Observers prefer a direct gaze when judging the attractiveness of a happy face, more than when judging the attractiveness of a disgusted face, and this difference in preference is greater when viewing a face of the opposite sex (Conway, Jones, DeBruine, and Little, 2008). Here we show that a feature of the eye called the limbal ring also affects facial attractiveness.

The limbal ring appears as a dark annulus outlining the iris. This outline can be caused by pigmentation of the peripheral iris or by the internal optics of the eye (Shyu and Wyatt, 2009). The visibility of the limbal ring can be decreased or completely removed by a variety of medical conditions that affect the transparency of the peripheral cornea. These include neovascularization and Pterygium related to unhealthy stem cells at the corneo-sclearal limbus (Ang et al., 2010; Mort, Ramaesh, Kleinjan, Morley, and West, 2009; Sangwan, 2001; Zheng and Xu, 2008) and cloudiness caused by corneal edema or corneal arcus (Fernandez et al., 2009; Khurana, 2007). The limbal ring also becomes less visible due to conditions more closely related to advanced age such as glaucoma and arcus sinilis (Cavallotti and Cerulli, 2008). As demonstrated in Figure 1, the thickness of the limbal ring is negatively correlated with age, $r(362) = -.303$, $p < .001$. As seen in this figure, the thickness of limbal rings begins to decline even in youth, before degenerative diseases usually begin. Thus a clearly visible limbal ring is a probabilistic indicator of both health and age.

Figure 1. Limbal-ring thickness decreases as a function of age



Note: Ellipses were drawn to fit the inner and outer boundaries of the limbal ring on faces chosen randomly from www.Facity.com. Thickness was computed as the mean difference of the major and minor axes of the two ellipses. The thickness of the limbal ring in this graph is reported as a proportion of the radius of the iris, to provide a scale invariant measure.

This raises the question: Are judgments of facial attractiveness shaped to use the information within the limbal ring in a potentially adaptive way? To answer this question, we showed observers, on each trial, two faces that were identical except that the eyes of one had dark limbal rings and the eyes of the other had no limbal rings. Observers chose which face was more attractive, and indicated the degree of their preference.

Materials and Methods

Face stimuli

Ten male and nine female faces were selected from the PUT Face Database (Kasiński, Florek, and Schmidt, 2008). One additional female face from the Radboud Faces Database (Langner et al., 2010) was used to create the final set of male and female stimuli. Only faces with neutral or slightly smiling expressions were used. The stimuli were edited in Adobe Photoshop to create versions with and without dark limbal rings. In order to remove any limbal ring already present in the iris, while preserving acceptable image quality, irises from the Database of Human Iris Images (Dobeš and Machala, 2002) were used in place of the original iris and pupil. One unique iris was chosen for each face by selecting a lightly colored iris close to the eye color of the original face. Each iris image was cropped to remove any limbal ring already present, and distinctive pigmentation was removed that so that iris patterns would not be obviously identical in each eye. Next, a circle with a radial gradient was imported from Adobe Illustrator and placed within the iris at fifty percent opacity to create images with dark limbal rings. Faces within each final pair were identical besides the presence or absence of the limbal rings. Figure 1 shows examples of male and female stimulus pairs. The final stimulus set also included mirror-reversed pairs to prevent confounds caused by head direction, and inverted (upside-down) pairs to determine whether the limbal ring is processed as a local feature or a configural feature. There were a total of 80 stimulus pairs. All faces had blue or light-colored eyes.

Figure 1. Examples of stimulus pairs, with dark limbal ring faces to the right

Procedure

Forty-five observers (25 females, mean age = 20.90 years, *SD* = 4.48) completed a forced-choice face preference test. Each was seated approximately 30 inches from a 27" Apple iMac display, and directed to read the instructions displayed onscreen explaining how to use a slider adjustment to indicate their face preference for each stimulus pair. The slider was moved to the left if the left face was more attractive and to the right if the right face was more attractive. The distance of the slider away from center indicated how much more attractive one face appeared than the other. The slider could move 6 degrees in either direction from center; the units used to record the slider position were 16.67 units per degree.

Each trial began with a fixation cross at the center of the screen for 750 milliseconds before the stimulus pair was presented. Then the observer was allowed as much time as needed to enter a rating with the slider at the bottom of the screen. Each image subtended 18.8 degrees vertical visual angle and 14.1 degrees horizontal visual angle. The images of the pair were presented side by side, spaced 200 pixels apart, and subtended a total horizontal visual angle of 28.3 degrees. Stimulus pairs were presented in randomized order in two blocks separated by a 30 second break. If the limbal rings image of a pair appeared on the left in the first block, then it appeared on the right in the second block, and vice versa. Trials were randomly mixed with an equal number of distracter trials in which faces varied in iris size rather than in limbal ring strength. This created a total of 320 trials that were completed in an average time of about 30 minutes.

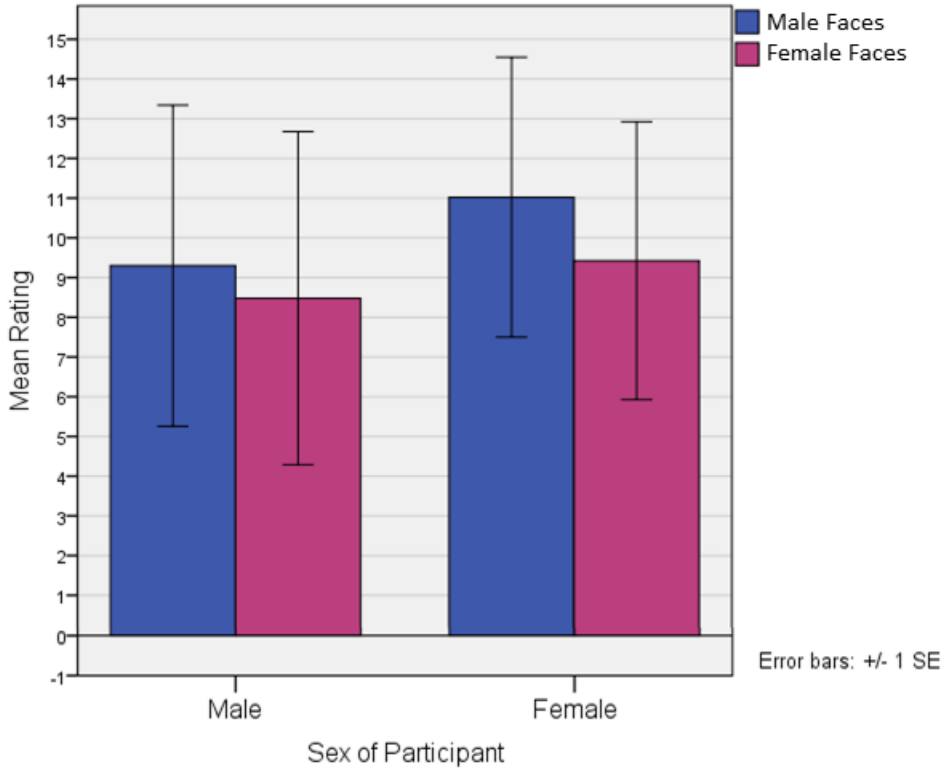
Results

Observers' ratings were assigned positive values if they moved the slider toward the dark limbal ring image, or negative values otherwise; mean values of zero indicate no preference. Right-tailed *t*-tests were used to determine if male and female observers preferred dark limbal rings in male and female stimuli. Mean ratings of all stimuli across male and female observers were significantly greater than zero ($t(44) = 3.68$, $p < .001$), as were mean ratings across observers when viewing only male ($t(44) = 3.90$, $p < .001$) or female ($t(44) = 3.38$, $p = .001$) faces. Male observers preferred the limbal ring in both male ($t(19) = 2.30$, $p = .016$) and female ($t(19) = 2.02$, $p = .029$) stimuli, as did female observers ($t(24) = 3.13$, $p = .002$ for male faces; $t(24) = 2.70$, $p = .006$ for female faces). Two-tailed independent-sample *t*-tests revealed no significant difference between male and female observers when viewing only male ($t(43) = -0.323$, $p = .749$) or female ($t(43) = -0.174$, $p = .863$) faces. Paired-samples *t*-tests showed that there was also no significant difference when viewing male and female stimuli for male observers ($t(19) = -0.6558$, $p = .520$) or female observers ($t(24) = -1.621$, $p = .118$).

Right-tailed *t*-tests demonstrate preference for the limbal ring in both upright faces ($t(44) = 3.99$, $p < .001$) and inverted faces ($t(44) = 3.28$, $p = .001$). This was the case for both male observers (upright: $t(19) = 2.42$, $p = .0129$; inverted: $t(19) = 1.91$, $p = .0357$) and female observers (upright: $t(24) = 3.13$, $p = .00225$; inverted: $t(24) = 2.67$, $p = .00676$). A paired samples *t*-test demonstrates that the preference for the limbal ring was greater in

upright than inverted faces ($t(44) = 2.76$, $p = .00845$). A mixed design ANOVA confirmed these findings with significant main effects for face inversion ($F(1,43) = 7.41$, $p = .009$) and presence of the limbal ring ($F(1,43) = 12.89$, $p = .001$).

Figure 2. Male and female ratings of attractiveness for male and female faces



Note: Positive values indicate preference for faces with a dark limbal ring.

Discussion

The limbal ring is caused by anatomical and optical components and becomes less visible with age or poor health. Male and female participants rated faces with clearly visible limbal rings as more attractive, suggesting that both sexes have been shaped by natural selection to use the limbal ring as a probabilistic indicator of reproductive fitness.

Inverted stimuli were included in the study to test if limbal rings are processed as local features or configural features of the face. When viewing upright faces, we exploit spatial relationships among facial features (i.e., their configuration), but when a face is presented upside-down we rely primarily on local features (e.g., the shape or color of the eye; Diamond and Carey, 1986; Maurer, Le Grand, and Mondloch, 2002; Murray, Yong, and Rhodes, 2000; Rossion and Gauthier, 2002). Our finding that inverted faces are rated more attractive when they have a dark limbal ring suggests that the limbal ring is processed as a local feature in the analysis of facial beauty. Our further finding that a dark limbal ring enhances attractiveness of upright faces more than of inverted faces could be interpreted as

indicating that the limbal ring also has some role in the configural analysis of facial beauty (see, e.g., Bäuml, 1994). However, a more likely explanation is simply that the eyes, and therefore the limbal rings, receive fewer fixations and less attention when faces are inverted (Barton, Radcliffe, Cherkasova, Edelman, and Intrilligator, 2006; Davies and Hoffman, 2002).

When rating attractiveness of the opposite sex, men typically place more emphasis on signals of youth than do women (Buss, 2007; Buss and Barnes, 1986; Etcoff, 1999). In principle, the limbal ring could serve as a signal of youth: Thickness of the limbal ring declines with increasing age, as shown in Figure 1. Our data show no evidence that the limbal ring affects male ratings of attractiveness differently than it affects female ratings. This might indicate that the limbal ring is used as a signal of health but not of youth. Or it might indicate that our experiment did not detect real differences in male and female ratings. Our stimuli have only a dark limbal ring or no limbal ring; perhaps adding more subtle variations to the limbal rings would lead to more nuanced results. It would be interesting to test directly whether the limbal ring affects judgments of age. One could, for instance, have observers estimate the ages of faces shown one at a time, and have each face appear twice at random in the sequence, once with a dark limbal ring and once with a minimal limbal ring. If the versions with dark rings are estimated to be significantly younger, this would be good evidence that the limbal ring can affect judgments of age.

One might argue that the preference for a dark limbal ring in our experiment is due to an artifact in our stimuli: One face in each pair has no limbal ring at all, and one might argue that this is so unnatural that it makes the face unattractive. However, eyes with faint or nonexistent limbal rings are common, and there are many attractive faces with faint limbal rings.

It may be that the preference for a dark limbal ring in our experiment is due not simply to its signaling of corneal clarity and iris pigmentation, but also to enhancing of the apparent whiteness and brightness of the sclera by increased local contrast. The relative contributions of these two factors to attractiveness can be tested in future experiments by using stimuli in which the scleras have been adjusted to have equal apparent brightness and whiteness. Even after such an adjustment, the luminance contrast between the sclera and iris plays a vital role in social interactions by indicating gaze direction (Ando, 2002; Sinha, 2000). The direction of gaze is interpreted more quickly for opposite sex faces with exaggerated sex-typical features, suggesting that detecting the gaze of potential high-quality mates was an important selection pressure (Jones, Main, DeBruine, Little, and Welling, 2010). A dark limbal ring provides an additional contrast boundary and may further enhance gaze-dependent social interactions.

In principle, the limbal ring could be a rich source of probabilistic information about youth and health. Our experiment shows that a dark limbal ring is more attractive than no limbal ring; however, it is an interesting and open question whether human vision has been shaped to exploit subtle differences in limbal rings, or whether we have been shaped to use simple heuristics such as “dark is better” or “thick is better.” The results could have practical application: Colored contact lenses are now commercially available that mimic the appearance of a limbal ring.

The faces in our experiment had lightly colored irises; however, the limbal ring is more difficult to detect in darker irises. Therefore the limbal ring might have less influence on attractiveness in faces with dark irises. This is an interesting topic for further experiments.

Acknowledgements: We thank Naveen Hothi and Shane Johnston for help creating the stimuli, and David Buss, Shannon Cuykendall, Nancy Etcoff and Marjan Farid for helpful comments on an earlier draft of this paper. We also thank Claudia Gavrilescu, Alysha Kassam, Samantha Kiel, Faizan Memon, Ian Merion, Matt Richardson and Jessica Wong for making the limbal ring measurements displayed in Figure 1. This research was supported in part by a grant from Procter & Gamble.

Received 23 February 2011; Revision submitted 29 March 2011; Accepted 31 March 2011

References

Althoff, R.R., and Cohen, N.J. (1999). Eye-movement-based memory effect: A reprocessing effect in face perception. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*, 997-1010.

Ando, S. (2002). Luminance-induced shift in the apparent direction of gaze. *Perception, 31*, 657-674.

Ang, L.P.K., Tanioka, H., Kawasaki, S., Ang, L.P.S., Yamasaki, K., Phuc Do, T., ... Kinoshita, S. (2010). Cultivated human conjunctival epithelial transplantation for total limbal stem cell deficiency. *Investigative Ophthalmology and Visual Science, 51*, 758-764.

Barton, J.J.S., Radcliffe, N., Cherkasova, M.V., Edelman, J., and Intriligator, J.M. (2006). Information processing during face recognition: The effects of familiarity, inversion, and morphing on scanning fixations. *Perception, 35*, 1089-1105.

Bäuml, K. (1994). Upright versus upside-down faces: How interface attractiveness varies with orientation. *Perception, 56*, 163-172.

Bradley, M.M., Miccoli, L., Escrig, M.A., and Lang, P.J. (2008). The pupil as a measure of emotional arousal and autonomic activation. *Psychophysiology, 45*, 602-607.

Buss, D.M. (2007). The evolution of human mating. *Acta Psychologica Sinica, 39*, 502-512.

Buss, D.M., and Barnes, M. (1986). Preferences in human mate selection. *Journal of Personality and Social Psychology, 50*, 559-570.

Cavallotti, C.A.P., and Cerulli, L. (2008). *Age-related changes of the human eye*. Dordrecht: Springer.

Conway, C.A., Jones, B.C., DeBruine, L.M., and Little, A.C. (2008). Evidence for adaptive design in human gaze preference. *Proceedings of the Royal Society B: Biological Sciences, 275*, 63–69.

Cunningham, M. (1986). Measuring the physical in physical attractiveness: Quasi-

experiments on the sociobiology of female facial beauty. *Journal of Personality and Social Psychology, 50*, 925-935.

Davies, T.N., and Hoffman, D.D. (2002). Attention to faces: A change-blindness study. *Perception, 31*, 1123-1146.

Diamond, R., and Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology: General, 115*, 107-117.

Dobeš, M., and Machala, L. (2002). The database of human iris images, http://www.inf.upol.cz/iris.

Etcoff, N. (1999). *Survival of the prettiest*. New York: Doubleday.

Fernandez, A., Keyes, M., Pencina, M., D'Agostino, R., O'Donnell, C., and Thompson, P. (2009). Relation of corneal arcus to cardiovascular disease (from the Framingham heart study data set). *American Journal of Cardiology, 103*, 64-66.

Grammer, K., and Thornhill, R. (1994). Human (homo sapiens) facial attractiveness and sexual selection: The role of symmetry and averageness. *Journal of Comparative Psychology, 108*, 233-242.

Jones, B.C., Main, J.C., DeBruine, L.M., Little, A.C., and Welling, L.L.M. (2010). Reading the look of love: Sexually dimorphic cues in opposite-sex faces influence gaze categorization. *Psychological Science, 21*, 796-798.

Kasiński, A., Florek, A., and Schmidt, A. (2008). The PUT face database. *Image Processing and Communications, 13*, 59-64.

Khurana, A. K. (2007). *Comprehensive ophthalmology*. New Delhi: New Age International Publishers

Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., and van Knippenberg, A. (2010). Presentation and validation of the Radboud Faces Database. *Cognition and Emotion, 24*, 1377-1388.

Maurer, D., Le Grand, R., and Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences, 6*, 255-260.

Murray, J.E., Yong, E., and Rhodes, G. (2000). Revisiting the perception of upside-down faces. *Psychological Science, 11*, 492–496.

Mort, R.L., Ramaesh, T., Kleinjan, D.A., Morley, S.D., and West, J.D. (2009). Mosaic analysis of stem cell function and wound healing in the mouse corneal epithelium. *BMC Developmental Biology, 9*, 4-17.

Perrett, D. I., Burt, D., Penton-Voak, I., Lee, K., Rowland, D., and Edwards, R. (1999). Symmetry and human facial attractiveness. *Evolution and Human Behavior, 20*, 295-307.

Perrett, D.I., Lee, K.J., Penton-Voak, I.S., Rowland, D.R., Yoshikawa, S., Burt, D.M., Henzi, S.P., Castles, D.L., and Akamatsu, S. (1998). Effects of sexual dimorphism on facial attractiveness. *Nature, 394*, 884–887.

Ramachandran, V.S., and Hirstein, W. (1999). The science of art: A neurological theory of aesthetic experience. *Journal of Consciousness Studies, 6*, 15-51.

Rhodes, G. (2006) The evolutionary psychology of facial beauty. *Annual Review of Psychology, 57*, 199-226.

Rossion, B., and Gauthier, I. (2002). How does the brain process upright and inverted

faces? *Behavioural and Cognitive Neuroscience Reviews, 1*, 62-74.

Sangwan, V.S. (2001). Limbal stem cells in health and disease. *Bioscience Reports, 21*, 385-405.

Shyu, B.P., and Wyatt, H.J. (2009). Appearance of the human eye: Optical contributions to the "limbal ring." *Optometry and Vision Science, 86*, 1069-1077

Sinha, P. (2000). Here's looking at you, kid. *Perception, 29*, 1005–1008.

Tombs, S. and Silverman, I. (2004). Pupillometry: A sexual selection approach. *Evolution and Human Behavior, 25*, 221-228.

Willis, J., and Todorov, A. (2006). First impressions: Making up your mind after a 100-ms exposure to a face. *Psychological Science, 17*, 592–598.

Wong, B.J.F., Karimi, K., Devcic, Z., McLaren, C.E., and Chen, W. (2008) Evolving attractive faces using morphing technology and a genetic algorithm: A new approach to determining ideal facial aesthetics. *The Laryngoscope, 118*, 962-974.

Zheng, T., and Xu, J. (2008). Age-related changes of human limbus on in vivo confocal microscopy. *Cornea, 27*, 782-786.