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Top down processing of faces in human brain: A Behavioral Study

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Abstract— Notwithstanding the extensive research effort has gone into understanding face perception by human brain. The concept of face recognition is established yet is selectively impaired relative to recognition of faces of equivalent difficulty. The objective of present study is to develop a theoretical model and a set of stipulations for understanding and discussing how we distinguish familiar faces, and the relationship between recognition and other aspects of face processing. Top down imagery stimuli of familiar and unfamiliar faces were shown to healthy individuals and were asked to recognize them as quickly and accurately as possible. The stimuli were formulated in such a manner that semantic memory and cognitive training does not play a significant role during the task execution. The responded stages by the subjects were recorded. Results obtained from the nonparametric analysis of the multivariate data recorded indicate that process of structural decoding of unfamiliar faces occurring inside the brain is delayed in comparison to familiar faces. It is speculated that brain structures, which have been associated with face recognition task countenance difficulty while identifying unfamiliar faces. Several distinctive information that we derive from seen faces appear to influence the processing performance of the brain during the task.

Keywords: Face recognition; Nonparametric analysis; Multivariate.

I. INTRODUCTION

Human faces are amongst the most significant social signals in everyday life. It is widely acknowledged that face recognition is subserved by highly specialized processes that are qualitatively different from processes underlying the identification of other kind of objects [1]. Several studies on this subject further confirm that face recognition is a dedicated process which is different from general object recognition [2, 3].

Many studies on human face perception have identified an interhemispheric difference is more dominant for face processing. In physiological studies using fMRI, right FFA was activated more than left FFA [4, 5]. Using ERP and MEG most subjects evoked larger components for face in the right hemisphere than the left [6, 7, 8, 9].

Neuropsychological studies have established that people use different brain areas for face recognition and other object recognition [10]. Evidence from ERP study, [11] has also confirmed that processing of facial affect relies on the interplay of several distinct brain areas. This seems to be evident because recognition of known faces involves a match between the products of structural encoding and previously stored structural codes describing the appearance of known faces, held in face recognition units. Impaired structural encoding can result in the disruption of face identification [12]. It is also proposed that cognitive system plays an active role in deciding whether or not the preliminary match is sufficiently close to indicate true recognition or merely a similitude to the true recognition. Several factors are seen to influence such decisions.

In the latest unanimous study [13], investigating face recognition by humans, it is evident that humans can recognize faces in extremely low resolution images which nicely fit in the present experimental protocol.

Neuropsychological investigations of visual imagery and representations have led to a deeper understanding of the face perception, representation and memory. But how each individual perceives face's structural properties, is there any discrepancy when it comes to distinguishing familiar and unfamiliar faces, and does recognition has any correlation with face processing aspects is still unclear. The aim of this present study is to shed light on these questions.

II. METHODOLOGY

A. Subjects

Eighteen healthy subjects equally from either gender participated in this study. The mean age was 23.37 years for female subjects and 23.14 years for male subjects. All the subjects had normal or corrected to normal visual acuity. Every subject was totally naïve to experiment on face perception.

B. Stimuli and apparatus

Participants were seated in a light attenuated room. A 19 inch computer screen was placed 20 cm in front of the participant's eyes. Stimuli were images of familiar and unfamiliar faces processed on graphics software, and presented on a computer monitor in front of a black background. To overcome variability of object appearance caused by extrinsic factors [14] intensity level of each stimulus was kept fixed and all face images showed a frontal view, with opened eyes having a neutral expression. All the images were edited to a same format and sizes were kept fixed as 5.2x4cm on the computer screen. The familiar faces consisted of two categories of faces. The first category consisted of well known politicians, movie stars, sportsmen and other celebrities and the second category consisted of common friends and colleagues known personally to all the subjects. The unfamiliar faces were of people that the subject had never seen previously. Each category consisted of fifteen images. The low-resolution images were created by applying Gaussian filter using graphics software. Each image was blurred and was arranged in ten top-down stages in the order of decreasing intensity of the Gaussian filter. Then each set of the face image was randomly arranged in the experimental protocol. In order to remove role of episodic memory blank image was placed at the end of each set.

C. Preparation

Brief medical history and written consent was taken from each participant. They were then given a brief description about the experiment and setup in the laboratory.

D. Experimentation

Each experimental session lasted for about 25 minutes. Participants were instructed to respond orally as quickly and accurately as possible to the respective stimuli, and to maintain central eye fixation during the trials. They were however asked not to guess, but only respond once they were fairly certain about the identity. Participant had to judge the familiarity of each face by classifying them into one of the three categories: (1) Familiar celebrity face (name and profession known); (2) Personally familiar face of colleague or friend (name and profession known); (3) Unfamiliar face (never seen before). The same face remained on the screen, though shifted through stages of progressively lower blurring, the last stage being the unmodified original face, until a response was made. The particular stage where response was elicited was noted for each subject. While showing the blank image, subjects were asked to give feedback describing the distinctive characteristics observed in the previous set of images. Stimulus repetition was not allowed. Responses were classified as correct when a category 1, 2 and 3 was chosen for celebrity faces, personally familiar faces, and unfamiliar faces, respectively.

III. DATA ANALYSIS AND RESULTS

Using the recorded data respective frequencies for each stimulus were evaluated. Then, cubic spline interpolates for each frequency points were traced. Interpolates were validated by satisfying cubic spline interpolant conditions [15]. Then, Curve fitting of the validated interpolates were performed and

respective frequency polygons were plotted for each subject per category and for all subjects per category.

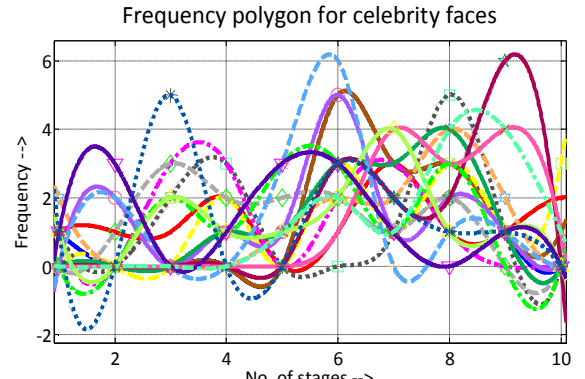


Figure 1: Frequency vs No. of stages graph for response of subjects during celebrity faces.

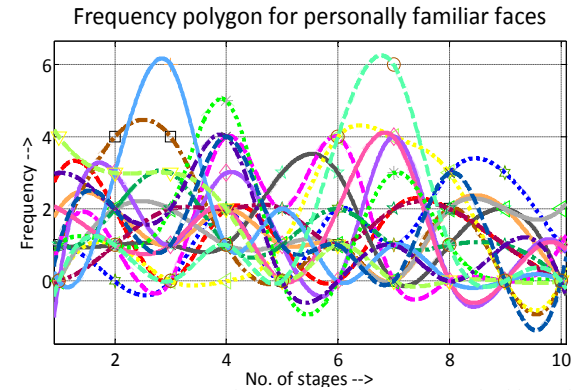


Figure 2: Frequency vs No. of stages graph for response of subjects during personally familiar faces.

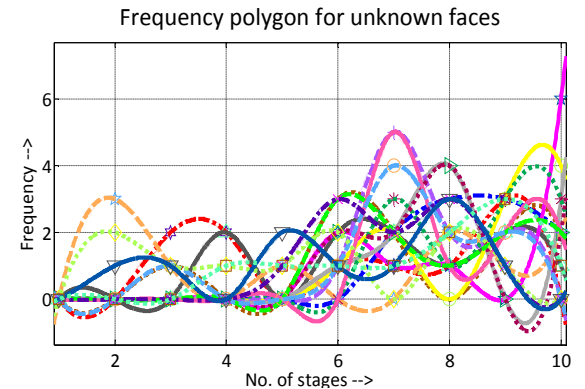


Figure 3: Frequency vs No. of stages graph for response of subjects during unknown faces.

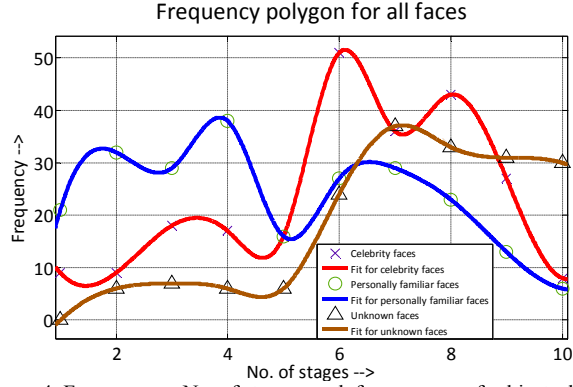


Figure 4: Frequency vs No. of stages graph for response of subjects during all faces.

It can be seen from the frequency polygon results that the stage which corresponded to the maximum correct responses for familiar celebrity faces is 6 and 4 for personally familiar category. Response was however slightly delayed in case of unfamiliar faces with 7 being the maximum responded stage. Thus, it is observed from the experiment that subjects showed good ability to identify familiar faces and to discriminate between the familiar and unfamiliar faces used in this experiment.

Nonparametric density estimation technique was applied to reveal the basic ingredients of multivariate frequency data obtained. It has been proved by earlier comparative studies on nonparametric density estimation techniques that kernel density estimation is an effective tool to reveal structure of multivariate samples [16, 17]. For the d -variate random samples X_1, X_2, \dots, X_n drawn from a density f , the kernel density estimate (KDE) is defined by

$$\hat{f}(x; H) = n^{-1} \sum_{i=1}^n K_H(x - X_i)$$

where x is independent and identically distributed (i.i.d.) collection of random variables [18] given by

$$x = (x_1, x_2, \dots, x_d)^T \text{ and } X_i = (X_{i1}, X_{i2}, \dots, X_{id})^T,$$

$i = 1, 2, 3, \dots, n$. H is the bandwidth matrix which is symmetric and positive-definite [19],

$$K_H(x) = |H|^{-1/2} K(H^{-1/2}x)$$

and K is a d -variate kernel function satisfying the condition

$$\int K(x) dx = 1$$

Gaussian kernel has much longer effective support than other kernels [20], hence it was used as kernel function. It is given by

$$K(x) = (2\pi)^{-d/2} \exp(-\frac{1}{2}x^T x)$$

KDE of each subject per category and for all subjects per category was evaluated and respective kernel smoothing curves were plotted. Then, maximum value of kernel densities for all the plots was evaluated.

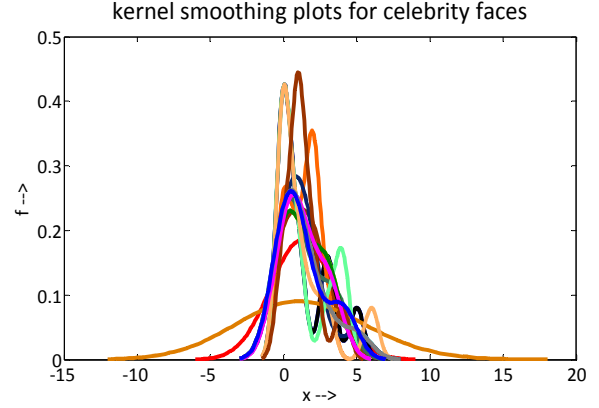


Figure 5: KDE 'f' vs i.i.d. random variables 'x' graph for response of subjects during celebrity faces.

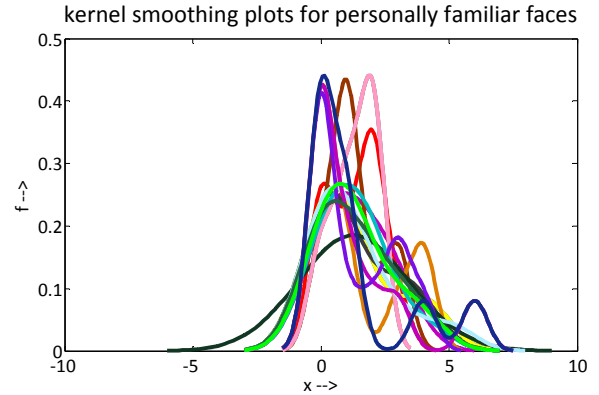


Figure 6: KDE 'f' vs i.i.d. random variables 'x' graph for response of subjects during personally familiar faces.

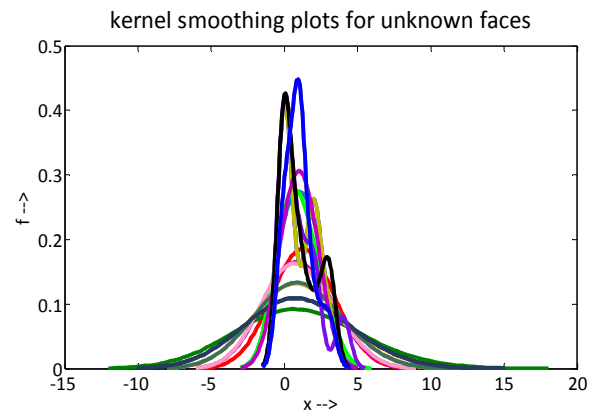


Figure 7: KDE 'f' vs i.i.d. random variables 'x' graph for response of subjects during unknown faces.

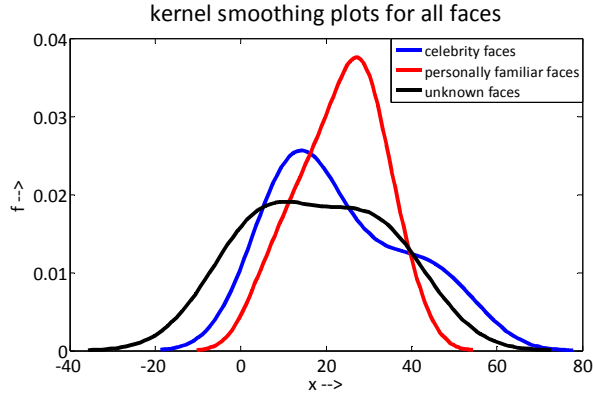


Figure 8: KDE 'f' vs i.i.d. random variables 'x' graph for response of subjects during all faces.

Sl. No. of Subjects	Maximum Kernel density estimate 'f' during different categories of stimuli		
	Celebrity faces	Personally familiar faces	Unknown faces
1	0.1855	0.3547	0.1855
2	0.4261	0.2523	0.1653
3	0.4261	0.2610	0.4138
4	0.2627	0.4346	0.2740
5	0.2306	0.2610	0.0922
6	0.2306	0.4263	0.1319
7	0.2343	0.4410	0.2776
8	0.3547	0.4410	0.1319
9	0.2837	0.2518	0.1093
10	0.2518	0.1855	0.1629
11	0.0905	0.4410	0.1334
12	0.4263	0.2663	0.1093
13	0.2306	0.2627	0.4138
14	0.4263	0.4263	0.4264
15	0.4444	0.4129	0.3061
16	0.2560	0.2403	0.4261
17	0.2627	0.2681	0.4480
18	0.2610	0.4402	0.4480

Table 1: Maximum KDE for each subject during different categories of stimuli.

From the KDE graphs, it can be observed that steeper curve is formed during personally familiar faces while the curve is slightly broader in response to celebrity faces. In the case of unknown faces, roughly flat topped curve is obtained.

The maximum kernel density estimate for all subjects during celebrity faces, personally known faces, and unknown faces is 0.0256, 0.0376, and 0.0191, respectively.

These results provide evidence that probability density is maximum in case of personally familiar faces, comparatively less for celebrity faces and least for unfamiliar faces. Hence, it can be concluded that brain tend to show superior ability when it comes to identifying familiar faces whereas comparatively, predicament occur when it comes to identifying unknown faces.

IV. DISCUSSION AND CONCLUSION

The aim of this experiment was to probe the processing model underlying familiar and unfamiliar faces in the human brain. This report describes a series of processing stages and correlation addressing the recognition of low resolution images arranged in top down manner. Various frequencies of responses and nonparametric constraints are investigated to find out the way and mode of interaction between recognition and other characteristics of face processing.

Our results agree with earlier studies [21, 22], that both holistic and feature information are crucial for the perception and recognition of faces. Study suggests the possibility of global descriptions serving as a front end for finer, feature based perception. If dominant features are present, holistic descriptions may not be used. Significance of facial features is ranked in the order as: face outline, hair, skin color, eyes and eyebrows, mouth, and other features.

The skin tone and color of the faces was observed to place a noteworthy impact. Subjects showed a poor performance against faces with evenly toned skin whereas, performance was better with unevenly toned skin. It is proposed that unevenly toned skin might improve the definition of the facial outlines and hence augmenting the precision of recognizing facial aspects. The aesthetic attributes such as beauty, attractiveness, etc. also play a role with the conclusion that the more attractive the faces are, the better is their recognition rate; the least attractive faces come next, followed by the mid-range faces. All faces are not recognized equally [23], this seems to be apparent because distinctive faces are better retained in memory and are recognized better and faster than typical faces. These inferences are also correlated with the rate recognition shown by subjects to the different categories of faces as concluded from the analysis results. The better performance with the known faces gives an account that ability of the brain to tolerate degradations in the image increases with familiarity.

Previous studies [24, 25], concluded that information contained in low spatial frequency components plays a dominant role in face recognition. During the recognition task it was found that low frequency and high frequency components impart different information. For example, the sex judgment task can be successfully accomplished using low frequency components only, while the identification task requires the use of high frequency components.

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REFERENCES

- [1] G. M. Davies, H. D. Ellis, J. W. Shepherd, "Face recognition accuracy as a function of mode of representation," *Journal of Applied Psychology* 63, pp. 180-187, 1978.
- [2] I. Biederman, P. Kalocsai, "Neural and psychological analysis of object and face recognition," *Face recognition: From theory to applications* (H. Wechsler, P. J. Phillips, V. Bruce, F. F. Soulie, T. S. Huang, eds.), Berlin: Springer-Verlag, pp.3-25, 1998.
- [3] H. D. Ellis, "Introduction to aspects of face processing: Ten questions in need of answers," *Aspects of Face Processing* (H. Ellis, M. Jeeves, F. Newcombe, A. Young, eds.), Dordrecht: Nijhoff, pp.3-13, 1986.
- [4] N. Kanwisher, J. McDermott, M. M. Chun, "The fusiform face area: a module in human extrastriate cortex specialized for face perception," *Journal of Neuroscience* 17, pp.4302-11, 1997.
- [5] G. McCarthy, A. Puce, J. C. Gore, T. Allison, "Face specific processing in the human fusiform gyrus," *Journal of Cognitive Neuroscience* 17, pp.605-10.
- [6] R. J. Itier, M. J. Taylor, "Effects of repetition learning on upright, inverted and contrast-reversed face processing using ERPs," *Neuroimage*, pp.1518-1532, 2004.
- [7] R. J. Itier, M. J. Taylor, "Source analysis of the N170 to faces and objects," *Neuroreport* 15, pp.1261-1265, 2004.
- [8] S. Watanabe, R. Kakigi, S. Koyama, E. Kirino, "Human face perception traced by magneto- and electro-encephalography," *Cognitive Brain Research* 8, Elsevier, pp.125-142, 1999.
- [9] S. Watanabe, R. Kakigi, S. Koyama, E. Kirino, "It takes longer to recognize the eyes than the whole face in humans," *Neuroreport* 10, pp.2193-2198, 1999.
- [10] M. J. Farah, K. L. Klein, K. Levinson, "Face recognition and within-category discrimination in prosopagnosia," *Neuropsychologia*, Elsevier, 2000.
- [11] K. Werheid, G. Alpay, I. Jentsch, W. Sommer, "Priming emotional facial expressions as evidenced by event-related brain potentials," *International Journal of Psychophysiology*, Elsevier, pp. 209-219, 2005.
- [12] M. Eimer, "Event-related brain potentials distinguish processing stages involved in face perception and recognition," *Clinical Neurophysiology*, Volume 111, Issue 4, pp. 694-705, 2000.
- [13] P. Sinha, B. Balas, Y. Ostrovsky, R. Russell, "Face recognition by humans: 20 results all computer vision researchers should know about," *Proceedings of the IEEE*, 2006.
- [14] S. Duvdevani-Bar, S. Edelman, "Visual recognition and categorization on the basis of similarities to multiple class prototypes," *International Journal of Computer Vision* 33(3), pp.201-228, 1999.
- [15] J. Lambers, Math 105A Summer Session I Lecture 10 Notes, 2003-04.
- [16] M. P. Wand, M. C. Jones, *Kernel Smoothing*, Chapman & Hall/CRC press, 1995.
- [17] J. Ćwik, J. Koronacki, "Multivariate Density Estimation: A Comparative Study," *Neural Computing and Applications*. Springer-Verlag London Limited, pp.173-185, 1997.
- [18] http://en.wikipedia.org/wiki/Independent_and_identically-distributed_random_variables.
- [19] T. Duong, "kks: Kernel Density Estimation and Kernel Discriminant Analysis for Multivariate Data in R," *Journal of Statistical Software*, vol. 21, 2007.
- [20] J. Fan, Q. Yao, *Nonlinear time series: Nonparametric and Parametric methods*, "Nonparametric density estimation," Springer, 2005.
- [21] V. Bruce, P. J. B. Hancock, A. M. Burton, "Human face perception and identification," *Face recognition: From Theory to Applications* (H. Wechsler, P. J. Phillips, V. Bruce, F. F. Soulie, T. S. Huang, eds.), Berlin: Springer-Verlag, pp.3-25, 1999.
- [22] J. N. Tanaka, M. J. Farah, K. D. Wilson, M. Drain, "What is "special" about face perception?," *Psychological Review* Vol. 105, No. 3. American Psychological Association Inc., pp.482-498, 1998.
- [23] A. J. O'Toole, "Handbook on face recognition," *Psychological and Neural Perspectives on Human Face Recognition*, Springer, 2004.
- [24] L. D. Harmon, "The recognition of Faces," *Scientific American*, vol.229, no. 5, pp. 71-82, 1973.
- [25] A. P. Ginsburg, "Visual information processing based on spatial filters constrained by biological data," *AMRL Technical Report*, pp. 78-129, 1978.