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Cognitive Modeling of Smile Perception Using Reaction Time and PCA-Based Feature Selection

**Abdullah Bin Queyam¹, Sanjay Dhanka^{2*}, Debasmita Ghosh Roy³, Ramesh Kumar⁴,
Manish Kumar Singla⁵**

^{1,3}*School of Automation, Banasthali Vidyapith, Rajasthan, 304022, India,*

²*Department of Electrical Engineering, Graphic Era Deemed to be University, Clement Town, Dehradun, India,*

⁴*Chitkara University Institute of Engineering & Technology, Chitkara University, Punjab, India,*

⁵*Department of Biosciences, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai, India-602105,*

¹abdullahbinqueyam@banasthali.in, ^{*2}sanjaykumar506070@gmail.com,

³debasmitaghoshroy@banasthali.in, ⁴rameshkumarmeena@gmail.com,

⁵msingla0509@gmail.com

***Corresponding Author**

Abstract

The study describes a novel framework, which uses the human cognitive response data in terms of reaction times (RT) to simulate the perception of smile intensity. The authors transcend the use of traditional binary categorization by proposing a continuous smiling index (SI) based on human RTs and binary rating of a mixed 200-image dataset of faces. We also combine this psychophysical information with a machine learning pipeline that uses Principal Component Analysis (PCA) and feature selection in sequence in a unique manner. This enables us to produce artificial facial expression continua with perceptually based control smile differences. One of the contributions is the fact that RTs present a strong, implicit measure of expression ambiguity and intensity. Our model delivers more perceptually realistic smile progressions as compared to baseline methods through comparative evaluation. The model is proven to be effective through human validation experiments which identify a logarithmic pattern of perception that is consistent with psychological models. The proposed work advances facial expression analysis by: (1) establishing a cognitive data-driven continuous intensity metric, (2) demonstrating the untapped value of reaction time in expression modeling, and (3) providing an effective synthesis method for generating realistic facial expression continua for HCI and psychological research.

Keywords. Cognitive Modeling, Smile Perception, Reaction Time, Principal Component Analysis, Facial Expression Synthesis.

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1. INTRODUCTION

One of the most important components of the process of sharing thoughts and social signals with people is facial expressions. Of all expressions smiling is the most researched one since it is evident in every culture with varying degrees of intensity. Calder et al. [1] were pioneers in applying PCA to the facial expression. They checked its fit in face memory models of the brain. Their conclusion is that PCA does not always do a good job of identifying tiny changes such as small smiles. This work was expanded by Beltran and Calvo [2], who examined the brain activity when smiling. They obtained PCA and brain wave data to follow the initial signs in the behind brain. Their findings revealed that the brain reacts very fast to smiles in a manner that emphasizes on significant changes. The reaction time or RT is also significant in the perception of smiles by people. Li et al. [3] applied brain tests to observe the variation in the speed or slowness of response on the way we detect smiles. They demonstrated that attempting to respond quickly may impair the capacity of the brain to detect gentle smiles. This will be significant in developing superior models of our face reading. Elsewhere Jones and Kramer [4] employed PCA and one more technique known as factor analysis. They discovered that smiles are likely to cause individuals to feel safe and open. These are the faces that are prominent in PCA. In Cowen et al. [5], PCA was used to reconstruct brain signal faces. Their work is based on the fact that PCA can be used to learn the manner in which the brain stores the description of faces such as smiling.

2. METHODOLOGY

The methodology section outlines the systematic approach employed in this study to investigate the "smiling strength" of faces using cognitive modeling techniques.

2.1. *Dataset Selection and Preprocessing*

The approach used in this experiment started with the close selection and pre-processing of the facial images in order to explore the phenomenon of smiling strength as both a dichotomous variable (smiling and not smiling), and as a continuous measure that will be able to detect the subtle variations of the facial expressions. The analysis targeted such important parameters of the face as smile line (curvature of the lips), smile arc (position of the teeth in relation to the lower lip), the shape of the upper lip, and the presentation of teeth that are included in such parameters to contribute to the apparent infertility of the smile. Calculation of Continuous Smile Index

2.2. *Feature Selection Using Sequential Forward Selection*

The criterion used to select the features was sequential forward selection to determine the most effective subset of principal components to estimate the continuous smile index (CSI). The main aim was to identify the most efficient combination of features derived using PCA, which would be the best predictor of the smile intensity and at the same time be parsimonious in nature. It was done through the SequentialFS function of MATLAB as it was used to apply an iterative selection method based on the performance measures. The algorithm selected the subsets by feature through mean squared error (MSE) of linear regression as the main performance measure that guaranteed that the features chosen would give rise to the lowest prediction error.

3. RESULTS AND DISCUSSION

The study investigated smile perception using cognitive modeling techniques on a curated dataset of 200 facial images (100 individuals, with smiling and neutral expressions). Images were standardized for background and orientation to minimize irrelevant variations. Reaction time data from three participants was processed to create a continuous smile index ranging from -1 (definite non-smile) to +1 (definite smile), after removing outliers (<200ms or >2s) and normalizing for individual response speeds.

Human validation with two participants confirmed all continua maintained monotonic smile progression as shown in Figure 1. The regression model's continuum showed superior logarithmic alignment with human ratings ($R^2=0.92$ vs 0.85/0.84 for alternatives), particularly in distinguishing subtle smile intensities. Table 1 summarizes a study on smile perception, finding that regression modeling best predicts human ratings by using mid-level PCA features.

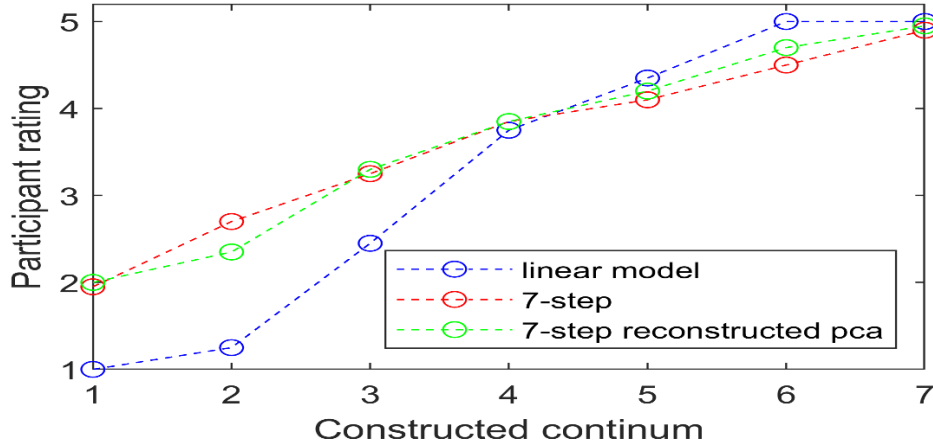


Figure 1. Human Perception of Constructed Continuum.

Table 1 Key Experimental Outcomes.

Component	Metric	Finding	Implication
Dataset	Image selection	200 images (100 pairs)	Controlled pose/variability balance
Smile Index	Distribution range	-1 to +1 continuum	Effective expression quantization
PCA	Variance explained (Top 3 PCs)	52.19% total	Gender/race dominate facial variance
Feature Selection	Optimal features	10 PCA components (up to PC47)	Smile perception uses mid-level features

Regression Model	Prediction accuracy (Human rating)	$R^2=0.92$	Best perceptual alignment
Continuum Generation	Methods compared	Regression vs. two averaging techniques	Regression preserves perceptual linearity
Human Validation	Rating consistency	All methods monotonic ($p<0.01$)	General method robustness

4. CONCLUSION

The research has been able to come up with a cognitive modeling method to measure and synthesize facial expression with respect to the intensity of smile. The best sources of facial variance with the aid of PCA were gender and race, whereas sequential feature selection was used to optimize the identification of smile-related features. A continuous smile index, which was obtained by adding reaction times and binary classifications, was useful in capturing perceptual differences between smiling and non-smiling faces. Training a linear regression model on these features yielded high-quality syntactic facial continua that were better than more basic weighted-averaging schemes on perceptual alignment.

5. REFERENCES

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