# Fatigue-related differences in human facial dimensions based on static images

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# Fatigue-related differences in human facial dimensions based on static images

**V Triyanti[1,2], Yassierli[1] and H Iridiastadi [1]**

[1]Faculty of Industrial Technology, Institut Teknologi Bandung, Bandung 40132, Indonesia
[2]Department of Industrial Engineering, Atma Jaya Catholic University of Indonesia, Jakarta 12930, Indonesia
vivi.triyanti@student.ti.itb.ac.id[1]; vivi.triyanti@atmajaya.ac.id[2]

**Abstract.** Automatic fatigue recognition based on eye and mouth movements has been widely researched and used to detect human fatigue. However, there were only few studies that quantitatively examining fatigue status based on static images. This study was a pilot study that aimed to examine differences in human facial dimension between fresh and fatigue condition, based on photos. 4 photos from 8 subjects were taken, each photo depicted the subject in fresh condition with a neutral expression, fresh condition with a happy expression, fatigue condition with neutral expression, and fatigue condition with happy expression. Each photo was analyzed using Face Reader 7.1 software to detect the coordinates of the points around the eyes and mouth. 10 dimensions around the eyes were calculated for each situation. In neutral expressions, paired t-test with significance value of 0.05 proved that in 8 dimensions, value in fresh conditions were different from ones in fatigue conditions. But these results were not proven in the picture with happy expressions. Although further research is needed, this finding could be a first step for developing the knowledge to detect fatigue based on facial static images.
**Keywords**: Human fatigue, human facial dimension, static images

## 1. Introduction

Fatigue is a suboptimal condition of the body caused by exertion, where the context of fatigue depends on the condition and form of exertion, can be in the form of physical energy or mind [1]. Fatigue can be physical or mental. Conditions of fatigue can lead to changes in strategy in the use of resources so that the level of mental processing or physical activity can be maintained or can also be reduced [2]. The short-term effects of fatigue on individuals are performance disruptions including reduced ability to concentrate, make decisions, maintain alertness, and control emotions [3]. Fatigue can also increase error rates, slow down reactions, and thus increase the likelihood of accidents and injuries [4].

A subjective study states that the face when fatigue was different from the face in normal conditions and can be recognized from a photo. Hanging eye lid, glazed eyes, red eyes, dark circles under the eyes, pale skin, gloomy lips, and fine lines were signs of fatigue that appear in a collection of photos [5]. From this study, we may infer that there is possibilities that single or series of static images can be used to examine the status of a person's fatigue condition.

In addition to subjective research, so far there were not many researches related to facial recognition that uses quantitative measurements to detect fatigue based on a person's photos or static facial images. So far most studies used facial movement behaviors to detect fatigue, such as eye or mouth movements, or pupil size [6]. When humans were fatigue, especially when sleepy, the eyes tended to have specific movement behavior. For example, a faster rate of blinking, longer eye closure, slow eye gaze [7], and decreased levels of eye openness [8]. In drowsiness, sudden nodding movements occurred [9-11]. Some studies were also suggested that when fatigue, people had "declined" facial expressions [12-13]. However, quantitative explanations about these expressions have not been stated clearly.

In this paper, a pilot study was conducted to examine fatigue facial expressions based on static images. Detection of face points were done automatically using the facial expression analysis software FaceReader 7.1 from Noldus (www.noldus.com), in which one of the outputs of the software was XY coordinates for several points of the face. By processing the coordinates, we may analyze whether there were any differences in facial dimensions between fresh and fatigue conditions. This research can be an initial study for research related to fatigue detection using human photos, which can be used to detect worker's fatigue.

## 2. Methods

### *2.1. Data processing*

All images were processed using Face Reader 7.1 software. Face Reader software generally aims to classify people's emotions into different basic emotional categories, namely happy, angry, sad, surprised, fear, disguised, and neutral [15]. In addition to the recognition of basic facial expressions, the Face Reader 7.1 outputs are X-Y coordinates for several points of the face (Figure 1) around the eyes, nose and mouth. There are a total of 49 coordinates (denoted by light blue dots). The coordinates have units of pixels and the values are measured from the upper left corner of the face image. From 49 coordinates, only 12 coordinates from points around eyes, eyebrows, and mouth that were used in this research, denoted by dark blue dots in Figure 1. Table 1 defined the position of each dot.

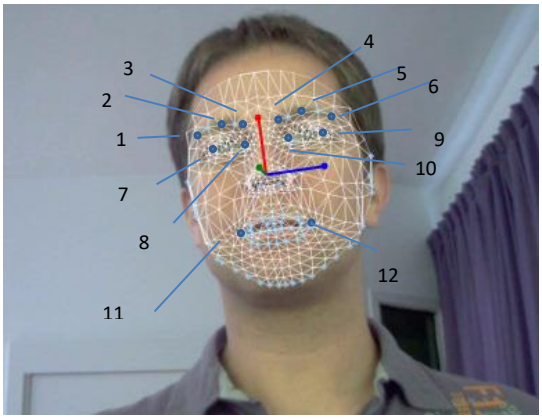
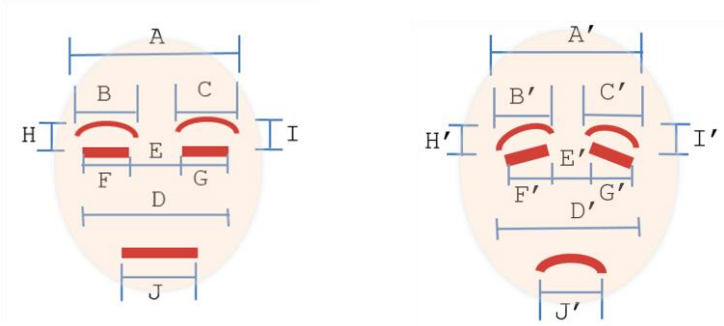



**Figure 1**. Coordinates of facial points, based on output from Software Face Reader 7.1

**Table 1.** Location of x,y coordinates on Face Reader 7.1 software based on Figure 1

| Points | Facial parts |
|---|---|
| 1-3 | left eyebrow |
| 4-6 | right eyebrow |
| 7-8 | corners left eye |
| 9-10 | corners right eye |
| 11-12 | Mouth |

Because in previous studies, one sign of fatigue was a "declined" face [12][13], there were several hypotheses were tried in this study. The calculation formula was determined based on the 12 points in Figure 1. The coordinates output from the 12 points were used to calculate 10 specific face dimensions, especially around eyebrows, eyes, and mouth (Figure 2), which were marked with capital letters.




(a) Neutral expression (b) Fatigue expression

**Figure 2.** Face illustration and measured dimension
a) Neutral expression, illustrated with straight brow, eye, and mouth position
b) Fatigue expression, illustrated with declining brow, eye, and mouth position

The 10 face dimensions (Figure 2) could be categorized into 4 hypotheses, which were:

1. Horizontal distances of eyebrows in fresh conditions were higher than in fatigue conditions. The related dimensions were:
   A. Distance between outer points of eyebrows (P6 – P1)
   B. Left eyebrow length (P3-P1)
   C. Right eyebrow length (P6-P4)
2. Horizontal distances of eyes in fresh conditions were higher than in fatigue conditions. The related dimensions were:
   D. Horizontal distance between outer points of eyes (P10 – P7)
   E. Horizontal distance between inner points of eyes (P9 – P8)
   F. Left eye length (P7-P6)
   G. Right eye length (P10-P9)
3. In fatigue eyes, the eyelids tended to be more closed, therefore the vertical distance between the eye brow and upper eyelid was hypothesized further in fatigue than in fresh conditions. However, because Face Reader output did not display the coordinates of the eye lids, the eye points were approached with the coordinates of the eye tip. Based on this explanation, the related dimensions and the formula were
   H. Avg. of left eye-eyebrow vertical distance ((P7 – P2)+(P8-P2))/2
   I. Avg. of right eye-eyebrow vertical distance ((P9 – P5)+(P10-P5))/2
4. Horizontal length of mouth in fresh conditions was higher than in fatigue conditions.
   J. Length of mouth (P12 – P11)

For dimension A-G and J, with the hypotheses that the dimensions in fresh condition were greater than ones in fatigue condition, the differences were calculated as follows:

Difference = distance of two points when fresh - distance of two points when fatigue (1)

For dimension H and I, the expected condition is the opposite, so the formula was:

Difference = distance of two points when fatigue - distance of two points when fresh (2)

*2.2. Data collection*

The subjects were 8 persons from various ages, where they were asked to stand or sit upright facing the camera. Then the subject was asked to show a neutral expression and continued with a happy expression with a smile [14]. At the time of measurement, a ruler was placed above the subject's head horizontally, to indicate the actual size relative to the image. All static facial images were taken using a smartphone. Images were taken in two times: in the morning (after the morning bath) and at night (just before going to bed at night). Both times were chosen to represent the state of fresh face (in the morning) and tired face (at night). In total there were 4 static images taken from each subject, which were:

a. Neutral expression – fresh condition (in the morning)
b. Neutral expression – fatigue condition (at night)
c. Happy expression – fresh condition (in the morning)
d. Happy expression – fatigue condition (at night)

In the initial data, the coordinates obtained were in pixel units, therefore they had to be converted into centimeters. Each distance data listed at point A-J of section 2.2 was calculated for each image. With the help of the distance obtained from the ruler, all images were interpolated into the same unit and measurement, so that all images could be compared. In this study, the images were taken from the fresh and fatigue condition in each expression. Based on the difference, the average and standard deviation values were calculated. A series of one way paired t-tests were performed to test that the average of difference between both values was more than 0 (it means that the distance of object in normal condition was higher than in fatigue condition).

## 3. Result and Discussion

*3.1. Neutral expression*

After all subjects performed neutral expression in fresh and fatigue conditions (Figure 3), each picture then was processed using Face Reader 7.1 software. Based on the output of the software, the eight subjects confirmed have been performed a neutral expression, although in all photos of subjects, neutral expression mixed with other expressions (Figure 4). The magnitudes of the 10 facial dimensions then were calculated and the difference between both conditions were further analyzed. The average and standard deviation of the differences, and the *p*-value of paired t-test are shown in table 2.

(a) Fresh (b) Fatigue

**Figure 3**. Example of subject's neutral expression in the fresh and fatigue condition

When the subject did not do any expression, or was called a neutral expression, the average differences in values of all measured dimensions showed positive values. There was even one participant who had a very large difference value between fresh and fatigue conditions, especially for the outer point of the eyebrow (P1) and the outer point of the eye (P7). These condition caused the difference value

between fresh and fatigue conditions of the dimension "Distance between outer points of eyebrows (A)" and the dimension "Horizontal distance between outer points of eyes (D)" were also very large. As a result, for these two dimensions, the standard deviation of the eight samples became very high.

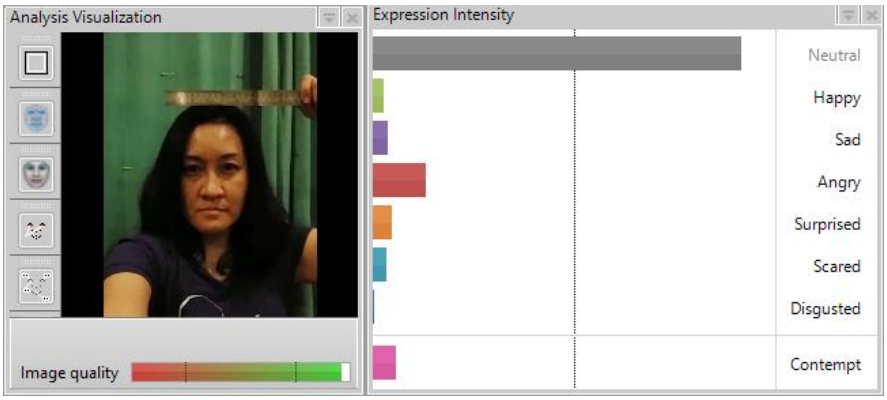



**Figure 4.** Example of software output for neutral expression and the expression intensity

**Table 2.** Average and Standard Deviation of dimension difference, and p-value of one way paired t-test for fresh and fatigue conditions in neutral expression

| Measurement | Diff. Avr | SD | p value |
|---|---|---|---|
| **Eye Brow** | | | |
| A. Distance between outer points of eyebrows | 2.000 | 2.117 | 0.016 |
| B. Left eyebrow length | 0.520 | 0.530 | 0.014 |
| C. Right eyebrow length | 0.678 | 0.696 | 0.014 |
| **Eye** | | | |
| D. Hor. distance between outer points of eyes | 1.491 | 1.562 | 0.015 |
| E. Hor. distance between inner points of eyes | 0.641 | 0.015 | 0.641 |
| F. Left eye length | 0.422 | 0.375 | 0.008 |
| G. Right eye length | 0.427 | 0.404 | 0.010 |
| **Eye brow-eye distance** | | | |
| H. Avg. of left eye-eyebrow vertical distance | 0.621 | 0.907 | 0.047 |
| I. Avg. of right eye-eyebrow vertical distance | 0.641 | 0.920 | 0.045 |
| **Mouth** | | | |
| J. Length (horizontal) of mouth | 0.599 | 0.905 | 0.052 |

The positive average differences value indicates that the value of the face dimension measured in fresh condition is higher than in fatigue condition, meaning that the eyes and eyebrows when in fatigue did look decline than when in fresh. When they were tested using a paired t-test, all dimensions showed significant differences, except the dimensions "Horizontal distance between inner points of eyes (E)" and the dimension "Horizontal length of mouth (J)". This results inferred that the difference between the closest distance of the eyes when in fresh and fatigue was not much different, likewise the length of the mouth. Originally it was predicted that when fatigue, the mouth tended to bend downward. Therefore it was hypothesized that the horizontal length of the mouth of fresh condition was greater than of fatigue condition. However, apparently this hypothesis was not proven. Although there was difference in mouth length, it could not be proven that the difference was significant.

*3.2. Happy expression*

In addition to neutral expressions, subjects were also asked to demonstrate happy expressions both at fresh condition (in early morning) and at fatigue (at night). Based on the Face Reader 7.1 software output, all objects were confirmed have made happy expressions in both conditions (Figure 5).

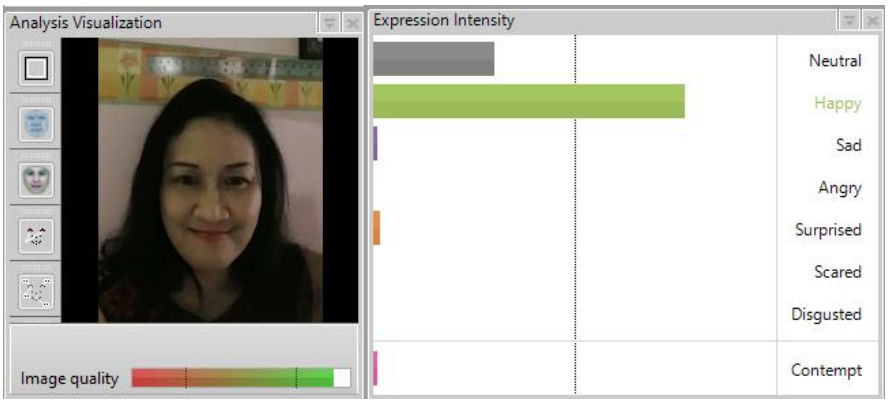


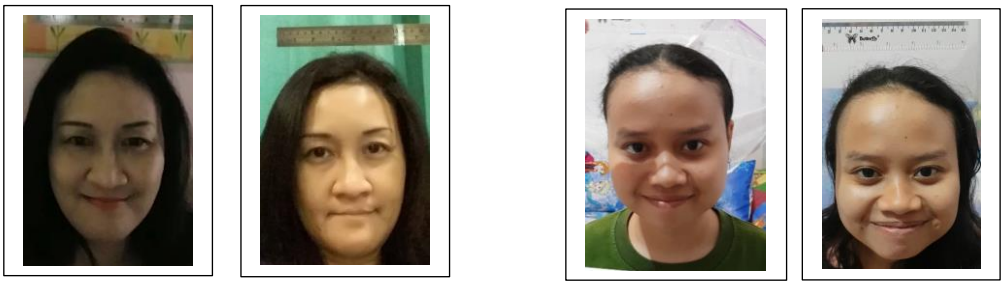

**Figure 5.** Example of software output for happy expression and the expression intensity

In contrast to neutral expressions, the results for happy expressions indicated dissimilarity. Of the ten dimensions calculated, all dimensions showed negative values. So it can be said that the dimensions value in fatigue were greater than in fresh conditions (and vice versa for dimensions H and I) (Table 3). However, based on the *p*-value it can be concluded that the differences is not significant. Values that tended to be greater when fatigue might be due to the subject's efforts to make happy expressions when in fatigue condition were greater than when in fresh conditions. This resulted in an unnatural expression from the subjects because of the perforce smile. The various happy expression might cause the location of the face points (and also the value of the measured dimensions) to be incompatible with the hypothesis.

**Table 3.** Average and Standard Deviation of dimension differences, and *p*-value of one way paired t-test for fresh and fatigue condition in happy expression

| **Measurement** | **Diff. Avr** | **SD** | ***p*-value** |
|---|---|---|---|
| **Eye Brow** | | | |
| A. Distance between outer points of eyebrows | -0.877 | 3.939 | 0.274 |
| B. Left eyebrow length | -0.488 | 1.288 | 0.160 |
| C. Right eyebrow length | -0.316 | 1.323 | 0.260 |
| **Eye** | | | |
| D. Hor. distance between outer points of eyes | -0.867 | 3.175 | 0.233 |
| E. Hor. distance between inner points of eyes | -0.347 | 1.466 | 0.262 |
| F. Left eye length | -0.283 | 0.872 | 0.194 |
| G. Right eye length | -0.236 | 0.857 | 0.231 |
| **Eye brow-eye distance** | | | |
| H. Avg. of left eye-eyebrow vertical distance | -0.084 | 0.797 | 0.387 |
| I. Avg. of right eye-eyebrow vertical distance | -0.100 | 0.762 | 0.361 |
| **Mouth** | | | |
| J. Length of mouth | -0.527 | 2.573 | 0.290 |

For happy expression, almost all subjects had a small difference average values, but had a large standard deviation. This meant the original data difference varied greatly, but was almost evenly distributed on the top and bottom of the average (resulting in a small average value). It can be said that there were subjects who gave large smile that affected the dimensions of the eyes and mouth, but there were also those who only smile slightly, so that the dimensions of the eyes tend to be the same as in neutral expression (Figure 6).



(a) Happy-fresh (b) Happy-fatigue (a) Happy-fresh (b) Happy-fatigue

**Figure 6.** Example of subject's happy expression in the fresh and fatigue condition

*3.3. Discussion*

This study indicated that fatigue face recognition based on static images (not video) was possible to be done automatically using software, especially if the subject only shows a neutral expression. This was a significant finding, considering that so far most studies had emphasized the facial movements (such as mouth and eye movements) to indicate fatigue and drowsiness. Furthermore, the results of this study could be used to gain more knowledge about the parameter and threshold of fresh and fatigue condition related to human facial. The knowledge would be valuable to the development of fatigue detection system based on static images that did not need continuous monitoring of object movements. For example by taking pictures of workers periodically (not continuously), we could assess the condition of their fatigue. Further study also could be done by analysing fatigue compared to varied expression (sad, anger, scared, etc.) and psychologies condition (stress, depressed, anxiety, etc.).

In spite of the positive finding, this pilot study still had many shortcomings. The main limitation was the small number of samples. More samples were needed to prove that for most population, the facial points were indeed changing according to fatigue conditions. In addition, there were also factor of cosmetics. In this study, subject was not restricted in the use of cosmetics. So in some subjects, pictures in fresh conditions were taken when they have used cosmetics. This might cause the software recognition of the facial point's location to be different. Another limitation that could not be ignored was the limitation of dimension measurement. In this study, most of measured dimensions were horizontal dimensions. Since the location of the facial points displayed by the software was very limited, there were limitations in measuring vertical dimensions. An example is the eye area. The software does not display the location of the eyelids or eyelids, so that the width of the eyes cannot be measured.

## 4. Conclusion

This research was a pilot study to examine the ability of software in recognizing the differences in facial points of subjects when in fatigue and fresh conditions, based on photos or static facial images. The results showed that of 10 dimensions, 8 dimensions around the eyes and mouth did show significant differences (using significance value of 0.05), especially if the subject only showed a neutral expression. Due to the faces appearance that tended to look "declined" when in fatigue condition, the value of the dimensions tended to be smaller when fatigue. However the same conclusion could not be generalized for other conditions. If the subject showed a happy expression, the differences in dimensions when fresh

and fatigue were not significant. Because this study was still in early stages, further research is needed to validate these findings.

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