Lighting for Good Facial Modeling

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Abstract

The need for lighting that provides attractive modeling of faces has long been recognized in the entertainment industry. There, the problem has been solved by providing energy-intensive forms of theater lighting and the extensive use of make-up. However, the need for good facial modeling is becoming more urgent in many other business settings given the increasing use of teleconferencing, but the use of dedicated sets and make-up is unrealistic. This lighting update describes a pilot study undertaken with the objectives of determining what lighting conditions give satisfactory facial modeling for different facial types, viewed directly and by video; of determining how different were peoples' reactions to the same person see directly or on video, for a range of different lighting conditions; and identifying a metric of light distribution that could be related to the modeling of the face, in both media.

1. Introduction

Communication between people is more than a matter of the spoken word. Who has not been guided in the interpretation of what has been said by facial expression and body language? Given the importance of facial expression to communication, the lighting of the face is likely to be a factor in determining what is communicated. This has long been recognized in the entertainment industry (McCandless, 1958; Bellman, 1967). The solution there has been to use photogenic people, high quality camera / imaging systems, energy-intensive, theater-style lighting and make-up. Such an approach is unlikely to be widely accepted for everyday communication by teleconference where many of the people taking part are not photogenic and do not wear make-up. These limitations place additional emphasis on the way the people are lit if poor communication is to be avoided.

This paper describes a pilot study of the effect of lighting on facial modeling undertaken under the aegis of the IESNA / IALD Quality of the Visual Environment / Metrics of Quality committee. The first objective of the pilot study was to determine what lighting conditions give satisfactory facial modeling for different facial types, viewed directly and by video. The second objective was to determine how different were peoples' reactions to the same person seen directly or on video, for a range of different lighting conditions. The third objective was to identify a metric of light distribution that could be related to the modeling of the face, in both media.

2. Method

The pilot study took place in a large windowless room lit by several rows of continuous pendant uplights and a continuous cove uplighting system, both systems being fitted with fluorescent lamps. A chair was positioned in the middle of the room facing a large 4 ft by 4 ft mirror (Figure 1). Behind the chair was blue fabric-covered screen. The model to be evaluated was asked to sit in the chair. The model was lit by various combinations of GE 60 - 100 W halogen infrared lamps in clamp-mounted LSI spotlights in addition to the room ambient lighting. The spotlights were mounted on two frames in the positions shown in Figure 1. The distribution of light achieved at the model's head was measured by replacing the model's head with a cubic illumination meter (Cuttle, 1997). In all, ten different lighting conditions were used, for each of three models. Table 1 identifies the ten different lighting conditions and the associated cubic illuminance readings.

The three models were very different in appearance. Model 1 was an older Caucasian man, with a lined face and receding hairline, who wore glasses. Model 2 was a young Caucasian woman, with smooth skin, who wore make-up but no glasses. Model 3 was a young Asian man, with smooth skin, who did not wear make-up or glasses. Figure 2 shows views of the three models under lighting condition 3: front lighting

A variable number of observers sat either side of the mirror and completed questionnaires which asked their level of agreement with five different statements, for each model lit by each lighting condition. The model answered the same questions by reference to his / her appearance in the mirror, and the level of agreement with the statement "The lighting is comfortable". Just behind and above the top of the mirror were a Sony CCD-VX3 video camera and an IQCam imaging photometer. These devices were used to record the model's face, the video camera for future replay and the IQ Cam for photometric purposes.

After data had been collected for three models, each directly viewed under the ten different lighting installations, the video recordings of the models' faces were shown to many of the same observers on a GE Stereo Monitor, Model 31GT660. The order in which the models' faces were shown on the video was the same as the order in which they were seen when viewed directly. The observers answered the same questions when viewing the face on the monitor as when viewing the face directly.

The number of observers making the ratings varied over the course of the experiment because many were also acting as subjects in another experiment. The number of observers for the direct viewing trials ranged from 5 to 10. For viewing the video recordings, the number of observers ranged from 12 to 13. All the subjects were experienced in lighting, being members of the QVE/MOQ committee or people from the Boston area interested in its work.

3. Results

3.1 Preferred lighting conditions

Tables 2 - 6 show the mean levels of agreement with the statements, for the three models, the ten lighting conditions and the two viewing conditions. A simple way to examine this data is to identify the lighting conditions for which the observers most strongly agree and most strongly disagree with each statement, for both direct and video viewing. In Tables 2 - 6 the lighting conditions producing the highest level of agreement are printed in bold and those giving the lowest level of agreement are printed in italics in Tables 2 - 6.

An examination of Tables 2 and 3, which cover the holistic statements " I like the way the face is lit" and "The appearance of the face looks natural" respectively, reveals that the lowest level of agreement with these statements most frequently occurs for the lighting condition 2 which is the top light only. As for the highest level of agreement and hence the most preferred lighting, these occur for different lighting conditions for different models and different viewing modes, but all involve the ambient lighting.

Examination of Tables 4 - 6, which cover the statements " Parts of the face are in shadow"; " The lighting of the face is very even" and " Facial blemishes and wrinkles are clearly visible" provide a rationale for the responses given in Tables 2 and 3. Lighting condition 2 produces high levels of agreement that parts of the face are in shadow and low levels of agreement that the lighting of the face is very even. Further, the lighting conditions in which the ambient lighting is on (conditions 7 - 10) provide low levels of agreement that parts of the face are in shadow and high levels of agreement that the face is very evenly lit. The mean levels of agreement with the statement "Facial blemishes and wrinkles are clearly visible" were close to neutral, probably because two of the models had very few facial blemishes and wrinkles. However, the responses are consistent in that highest level of agreement occurs for lighting conditions without any ambient lighting while the lowest levels of agreement occur for conditions where the ambient lighting is present.

To identify the relative preference for the different lighting conditions, the level of agreement with the statements " I like the way the face is lit" and "The appearance of the face looks natural" are averaged over all three models, for direct viewing and video viewing separately. The resulting grand average levels of agreement are listed in Table 7, together with their rank order. Table 7 shows that *for both direct and video viewing, the more diffuse and symmetrical the lighting is, the more likely* it is that people will consider the face well lit and natural in appearance. Table 8 shows the levels of agreement with the statement " The lighting is comfortable" given by the three models. Again it is apparent that the more diffuse the lighting is the more comfortable it is seen to be.

3.2 Relationship between direct and video viewing
The rank orders given in Table 7 suggest that there is a definite relationship between direct and video viewing because the rank orders for the direct and video viewing are similar. A more sensitive examination of the relationship between direct and video viewing is given by plotting the mean level of agreement for each statement, for direct viewing against video viewing, for each model seen under all lighting conditions. Figures 3 – 7 show this relationship and indicate a close relationship between the levels of agreement for the two viewing modes, for the statements " I like the way the face is lit"; "The appearance of the face looks natural"; "Parts of the face are in shadow" and "The lighting of the face is very even". The relationship for the statement "Facial blemishes and wrinkles are clearly visible" is much less clear because of the limited range of responses. One feature of particular note is the tendency, evident in Figure 3, for video viewing to exaggerate the observers response to the statement "I like the way the face is lit" for a given model / lighting combination relative to direct viewing of the same model / lighting combination.

3.3 A metric for facial modeling
There are a number of possible photometric metrics for facial modeling. Hargroves and McFadden (1997) used a simple ratio of the horizontal illuminance falling on the top of the head and the vertical illuminance falling on the front of the face and showed it was related to peoples' evaluation of suitability of the lighting for facial modeling as seen on a video. The lower was the value of the metric, the better was the quality of the video image. This is not unreasonable given that illumination from immediately above will tend to produce strong shadows and illumination from directly in front will tend to wash them out.

An alternative approach, with the advantage of established criteria, is to use the vector / scalar ratio proposed more than thirty years ago by Cuttle et al. (1967). The idea behind this metric is that the greater the magnitude of the vector illumination relative to the scalar illuminance, the stronger will be the shadows and vice versa. Of course, the vector illumination has a direction as well as a magnitude, so the distribution of shadows on a face can be different for two lighting installations having the same vector / scalar ratio.

Table 9 shows the Hargroves and McFadden metric and the vector scalar ratio calculated for each of the lighting conditions. Figure 8 shows the mean ratings of agreement with the statement "I like the way the face is lit" for direct and video viewing, plotted against the Hargroves and McFadden metric. Examination of Figure 8 suggests an inverse u-shaped relationship for the direct viewing, although the arms of the U are implied by only a limited number of data. For high values of the metric the lighting of the face of all three subjects was not liked. At the lowest value of the metric, the lighting of the face of model 1 was not liked but the lighting of models 2 and 3 was. This is probably because model 1 was wearing glasses and the strong front lighting necessary to produce a low value of the metric would create shadows around the eyes from the frame of the glasses (see Figure 2). Models 2 and 3 did not wear glasses. For video viewing, there is no clear relationship between the level of agreement and the Hargroves and McFadden metric.

Figure 9 shows the mean ratings of agreement with the statement "I like the way the face is lit" for direct and video viewing, plotted against the vector / scalar ratio. Also shown are the linear regression lines for each model separately. All three models show similar trends. Extrapolating these regression lines suggests a high level of liking of the lighting of the face would occur for a vector / scalar ratio of about 1.0. This is slightly less than the preferred vector / scalar ratio found by Cuttle et al (1967) of 1.3 but they were using larger fluorescent light sources to produce the lighting distribution rather than the point sources used here. Point sources produce sharper edged shadows than larger area light sources, so it is likely that a lower vector / scalar ratio will be preferred for point sources than for area sources.

Another feature of note is the tendency for video viewing to show greater variability in response. This is probably due to the limited dynamic range of the video system enhancing the contrast of any shadows cast on the face by the lighting. Also, it might be thought odd that the vector / scalar ratio, which takes no account of the direction of the vector illuminance and hence no account of the distribution of shadows, would be consistently related to the level of agreement with the statement " I like the way the face is lit". However, it seems likely that when evaluating the lighting of a face, any strong shadows are disliked, no matter where they occur, and the face, particularly one wearing glasses, has several features capable of casting shadows for a wide range of illumination vector directions.

4. Discussion

The results presented here were collected from a group of people interested in lighting, taking part in a pilot study. Therefore, these results should be taken as indicative rather than conclusive. Nonetheless, the results do suggest a number of provisional conclusions. These are:

Conventional office lighting is capable of producing good facial modeling (see Table 7) without discomfort to the person being lit (see (Table 9)

Diffuse lighting is most likely to produce good facial modeling.

Vector / scalar ratio is a useful metric for determining the suitability of a lighting installation for facial modeling. Vector / scalar ratios of greater than 3.0 should be avoided (see Figure 9)

Similar responses will be obtained when a face is viewed directly or on video (see Figures 3 7) although video viewing tends to produce greater variability in response

Clearly, to determine the best form of lighting for teleconference facilities requires a more refined study using a wider range of realistic lighting installations, more observers representative of the users of such facilities, and tighter experimental control. It would also be of interest to determine if the nature of the communication achieved during teleconferencing was altered by changing the lighting. These studies are something that we hope to address in the future.

5. Acknowledgements

It is a pleasure to acknowledge the contribution of Litecontrol, who supported this study by making their staff and facility available. Also appreciated is the volunteer participation of all the observers, particularly those who accepted the inevitable mockery associated with being a model.

6. References

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Table 1. The illuminances (lx) on the six faces of a cube placed at the model's head position, for each lighting condition

Lighting	Description	x = full face	-x = back of head	y = model's right side	-y = model's left side	z = top of head	-z = under chin
1	Two opposing sidelights, no ambient	661	13	1238	960	1092	12
2	Toplight, no ambient	952	30	14	5	2390	31
3	Frontlight, no ambient	276	15	5	4	173	13
4	Frontlight, no ambient, white reflector on lap	302	17	9	8	178	67
5	Frontlight, right sidelight, no ambient	634	21	1235	9	767	19
6	Frontlight, right sidelight, no ambient, white reflector on lap	672	25	1263	19	779	112
7	Ambient only	383	241	370	473	680	60
8	Ambient, frontlight	664	263	383	494	868	73
9	Ambient, frontlight, right sidelight	985	272	1454	504	1384	79
10	Ambient, frontlight, two opposing sidelights	1326	276	1632	1446	1951	86

Table 2. Mean level of agreement for with the statement " I like the way the face is lit" for the different lighting conditions and models. For each model the lighting conditions giving the highest level of agreement with the statement is marked bold and the lowest level of agreement is marked in italics

Lighting	Model 1 Direct	Model 1 Video	Model 2 Direct	Model 2 Video	Model 3 Direct	Model 3 Video
1	-0.4	-2.8	0.1	-4.5	0.8	-1.0
2	-4.3	*-4.8*	*-3.6*	*-4.7*	*-1.8*	*-4.4*
3	*-4.6*	-2.3	-0.3	-1.5	0.6	1.9
4	-3.8	-2.9	2.0	-0.1	0.9	2.3
5	-1.5	-3.4	-0.7	-3.1	-1.7	-2.3
6	-1.4	-2.7	-0.7	-2.8	-0.8	0.0
7	1.6	2.6	1.9	2.1	2.4	1.4
8	1.9	1.8	3.3	**2.4**	**3.3**	2.7
9	**3.0**	**3.1**	1.3	2.2	-0.1	1.6
10	1.8	2.4	**4.3**	-0.7	1.7	**3.4**

Table 3: Mean level of agreement with the statement "The appearance of the face looks natural" for the different lighting conditions and models. For each model the lighting conditions giving the highest level of agreement with the statement is marked bold and the lowest level of agreement is marked in italics

Lighting	Model 1 Direct	Model 1 Video	Model 2 Direct	Model 2 Video	Model 3 Direct	Model 3 Video
1	-1.1	-1.6	1.4	-4.1	0.3	-0.2
2	*-3.9*	*-4.3*	*-4.5*	*-4.8*	-1.9	*-4.0*
3	-3.0	-1.5	1.6	-1.5	0.9	2.1
4	-2.8	-2.8	1.1	-0.5	1.6	2.7
5	-2.1	-2.1	-0.3	-1.3	*-2.1*	-2.2
6	-0.9	-2.6	-0.7	-2.7	-1.3	-0.8
7	**3.4**	**3.5**	2.9	2.3	2.6	0.9
8	0.6	1.4	2.7	**2.9**	**3.5**	3.0
9	0.1	0.7	0.1	1.7	-0.2	1.2
10	2.0	2.2	**4.5**	-1.0	2.4	**3.4**

Table 4. Mean level of agreement for with the statement " Parts of the face are in shadow" for the different lighting conditions and models. For each model the lighting conditions giving the highest level of agreement with the statement is marked bold and the lowest level of agreement is marked in italics

Lighting	Model 1 Direct	Model 1 Video	Model 2 Direct	Model 2 Video	Model 3 Direct	Model 3 Video
	2.3	2.3	-1.5	-0.5	1.6	2.0
2	3.0	**4.8**	**4.5**	**4.8**	1.8	**4.6**
3	3.0	-1.9	1.5	2.2	-2.4	-0.6
4	**4.0**	0.7	-0.1	-0.8	-2.5	-1.1
5	2.5	3.7	2.9	3.2	**3.7**	3.4
6	1.9	3.5	3.0	3.2	2.8	2.0
7	*-1.8*	*-3.4*	*-2.3*	-1.0	*-3.5*	*-4.5*
8	1.1	-0.3	-2.7	-1.9	-2.4	-2.5
9	3.0	3.1	3.1	-1.0	2.2	1.4
10	0.6	1.2	-2.5	*-2.5*	-0.7	-1.2

Table 5. Mean level of agreement for with the statement " The lighting of the face is very even" for the different lighting conditions and models. For each model the lighting conditions giving the highest level of agreement with the statement is marked bold and the lowest level of agreement is marked in italics

Lighting	Model 1 Direct	Model 1 Video	Model 2 Direct	Model 2 Video	Model 3 Direct	Model 3 Video
1	-1.0	-1.1	*-4.5*	*-4.5*	1.3	-1.5
2	-1.9	*-4.6*	-2.1	-0.3	-2.7	*-4.7*
3	-1.6	-1.9	0.6	-0.3	2.3	0.3
4	-2.8	0.2	0.9	**3.4**	2.1	1.6
5	-2.3	-3.0	-3.7	-3.7	*-3.4*	-3.4
6	-0.4	-2.9	-3.2	-2.8	-2.6	-3.1
7	**4.0**	**3.3**	**2.7**	1.6	**4.2**	**4.4**
8	-0.6	1.6	3.1	2.6	3.6	2.7
9	*-3.3*	-2.6	-2.1	1.5	-2.5	-2.0
10	0.1	-1.1	2.3	3.9	0.5	1.2

Table 6. Mean level of agreement for with the statement " Facial blemishes and wrinkles are clearly visible" for the different lighting conditions and models. For each model the lighting conditions giving the highest level of agreement with the statement is marked bold and the lowest level of agreement is marked in italics

Lighting	**Model 1 Direct**	**Model 1 Video**	**Model 2 Direct**	**Model 2 Video**	**Model 3 Direct**	**Model 3 Video**
1	1.9	0.6	-2.3	*-3.2*	-0.3	1.8
2	**2.3**	-0.7	-0.1	-1.3	**1.8**	0.2
3	-1.1	0.3	0.0	**-0.5**	-2.2	-0.7
4	-1.0	0.0	-0.1	-1.2	*-2.4*	-0.8
5	-0.4	**1.8**	**1.0**	-0.8	0.7	**2.3**
6	-1.1	0.1	-0.2	-1.8	-0.2	1.1
7	*-1.6*	*-1.3*	-1.7	-1.2	-1.2	-1.0
8	-0.3	-0.9	*-2.4*	-1.2	-1.2	*-1.9*
9	1.4	-0.3	0.1	-2.2	0.6	1.6
10	1.1	-0.7	-0.7	*-3.2*	-0.1	0.3

Table 7. Grand mean level of agreement with the statements "I like the way the face is lit" and " The appearance of the face looks natural", averaged over all three models, for each lighting condition and direct and video viewing separately.

Lighting	**Description**	**Direct: Grand mean**	**Direct: rank order**	**Video: grand mean**	**Video: rank order**
1	Two opposing sidelights, no ambient	0.2	5	-2.4	8.5
2	Toplight, no ambient	-3.3	10	-4.5	10
3	Frontlight, no ambient	-0.8	7	-0.5	6
4	Frontlight, no ambient, white reflector on lap	-0.2	6	-0.2	5
5	Frontlight, right sidelight, no ambient	-1.4	9	-2.4	8.5
6	Frontlight, right sidelight, no ambient, white reflector	-1.0	8	-1.9	7
7	Ambient only	2.5	3	2.1	2
8	Ambient, frontlight	2.6	2	2.4	1
9	Ambient, frontlight, right sidelight	0.7	4	1.8	3
10	Ambient, frontlight, two opposing sidelights	2.8	1	1.6	4

Table 8. Level of agreement with the statement " The lighting is comfortable" given by the three models, for every lighting condition.

Lighting	Description	Model 1	Model 2	Model 3
1	Two opposing sidelights, no ambient	-5	-3	-5
2	Toplight, no ambient	-5	-5	3
3	Frontlight, no ambient	-5	-3	1
4	Frontlight, no ambient, white reflector on lap	-5	-3	1
5	Frontlight, right sidelight, no ambient	-5	-5	-3
6	Frontlight, right sidelight, no ambient, white reflector on lap	-5	-3	-1
7	Ambient only	5	3	5
8	Ambient, frontlight	-1	1	5
9	Ambient, frontlight, right sidelight	-3	-1	3
10	Ambient, frontlight, two opposing sidelights	-5	-3	3

Table 9. The Hargroves and McFadden metric, defined as the ratio of the horizontal illuminance on the top of the head to the vertical illuminance on the front of the face; and the vector / scalar ratio developed by Cuttle et at (1967), for the ten lighting conditions.

Lighting	Description	Hargroves and McFadden metric	Vector / Scalar ratio
1	Two opposing sidelights, no ambient	1.65	1.37
2	Toplight, no ambient	2.51	3.87
3	Frontlight, no ambient	0.63	3.51
4	Frontlight, no ambient, white reflector on lap	0.58	2.85
5	Frontlight, right sidelight, no ambient	1.21	3.84
6	Frontlight, right sidelight, no ambient, white reflector on lap	1.16	3.53
7	Ambient only	1.78	1.67
8	Ambient, frontlight	1.31	1.93
9	Ambient, frontlight, right sidelight	1.41	2.43
10	Ambient, frontlight, two opposing sidelights	1.47	1.88

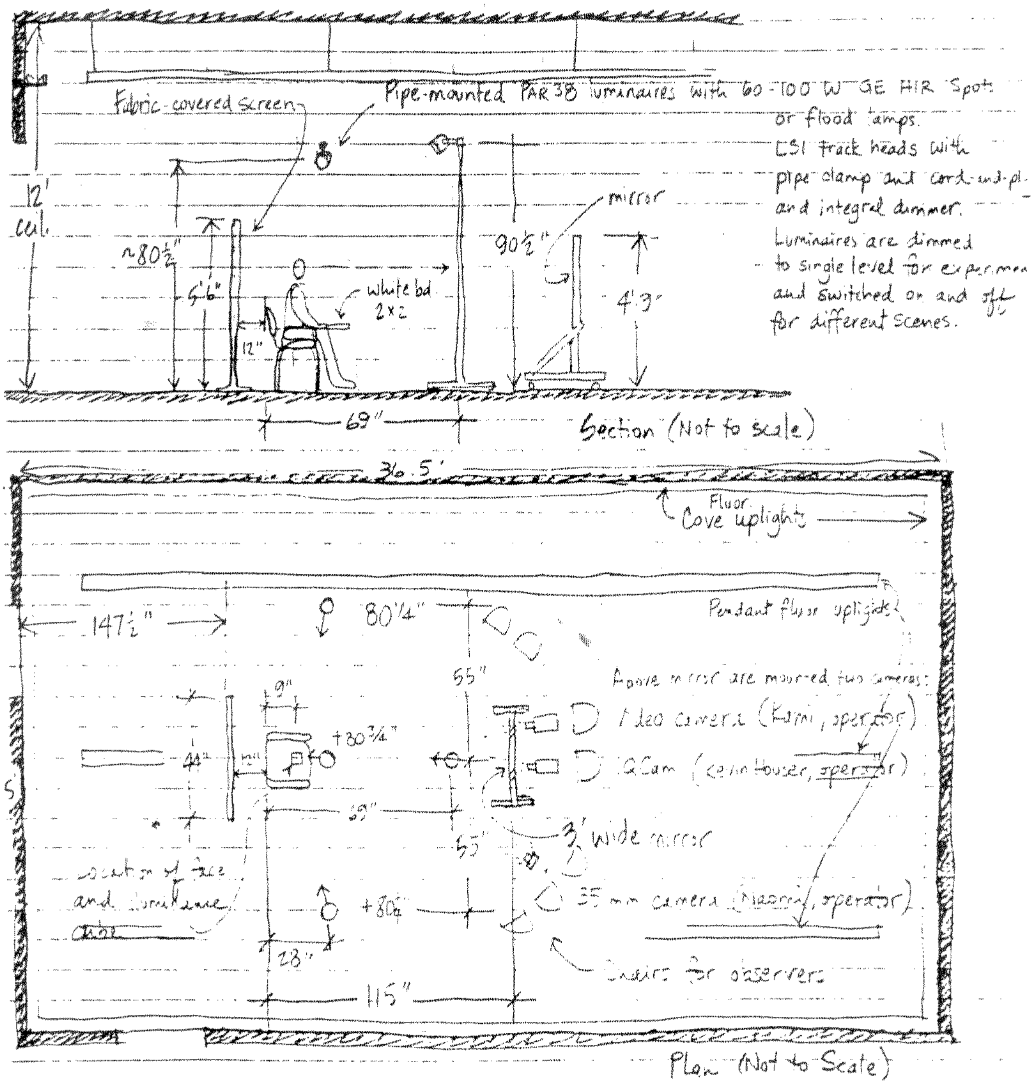


Figure 1. Sketch of the experimental arrangement:

Model 1 | Model 2 | Model 3

Figure 2. Photographs of the three models under lighting 3: Front lighting

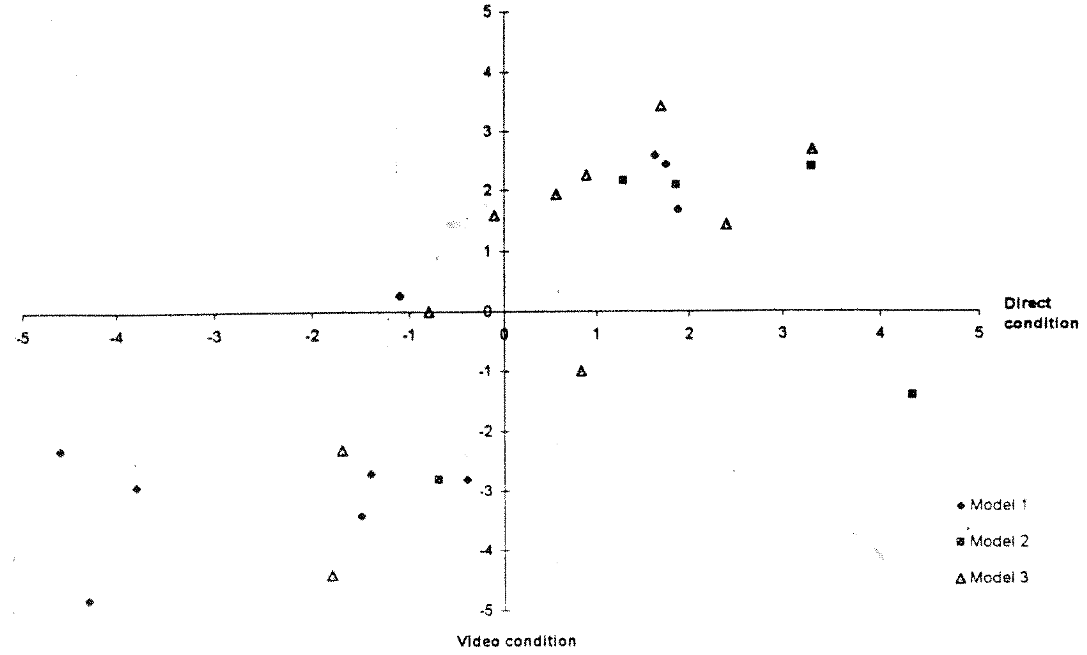


Figure 3. Mean levels of agreement with the statement "I like the way the face is lit" for each model and lighting combination, seen directly, plotted against the mean levels of agreement for the same conditions seen on video.

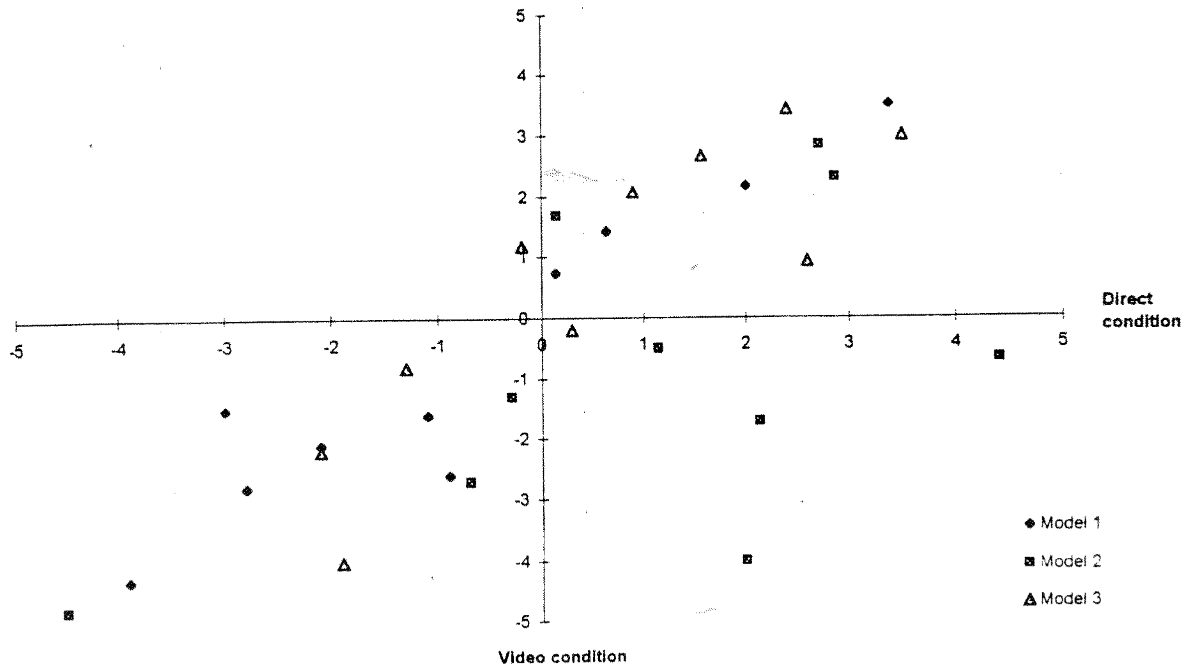


Figure 4. Mean levels of agreement with the statement "The appearance of the face looks natural" for each model and lighting combination, seen directly, plotted against the mean levels of agreement for the same conditions seen on video.

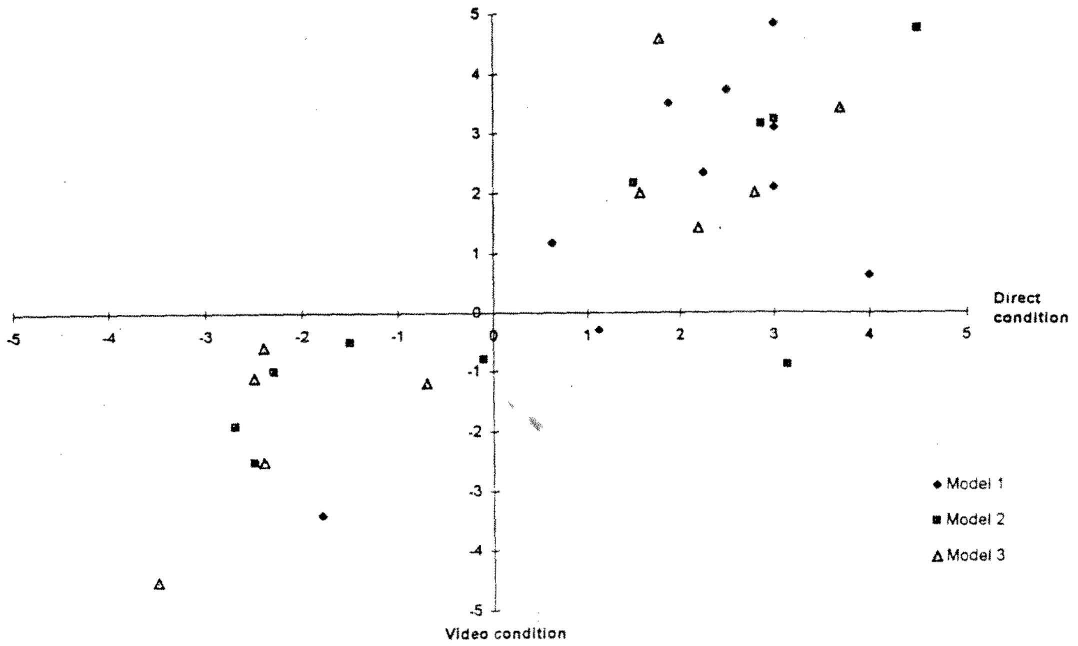


Figure 5. Mean levels of agreement with the statement "Parts of the face are in shadow" for each model and lighting combination, seen directly, plotted against the mean levels of agreement for the same conditions seen on video.

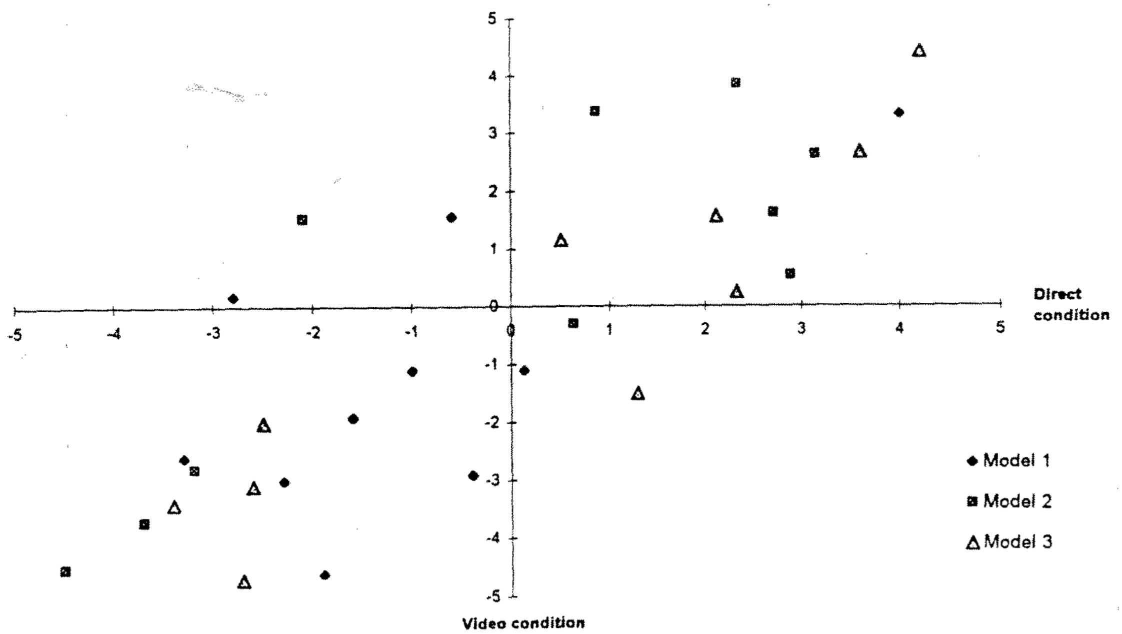


Figure 6. Mean levels of agreement with the statement "The lighting of the face is very even" for each model and lighting combination, seen directly, plotted against the mean levels of agreement for the same conditions seen on video.

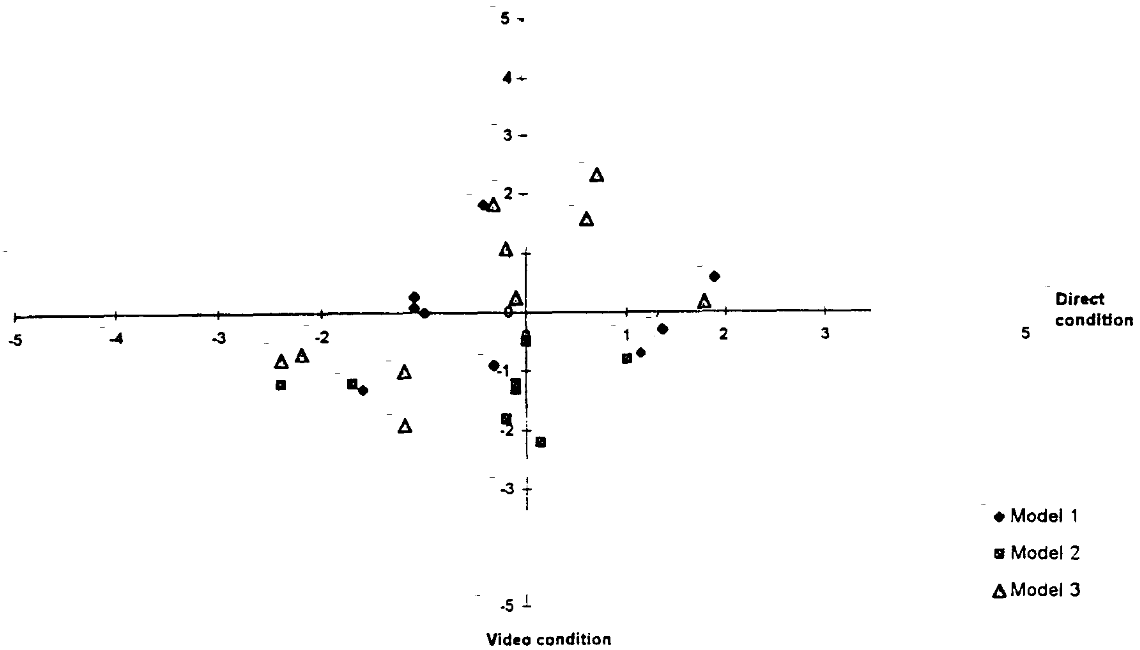
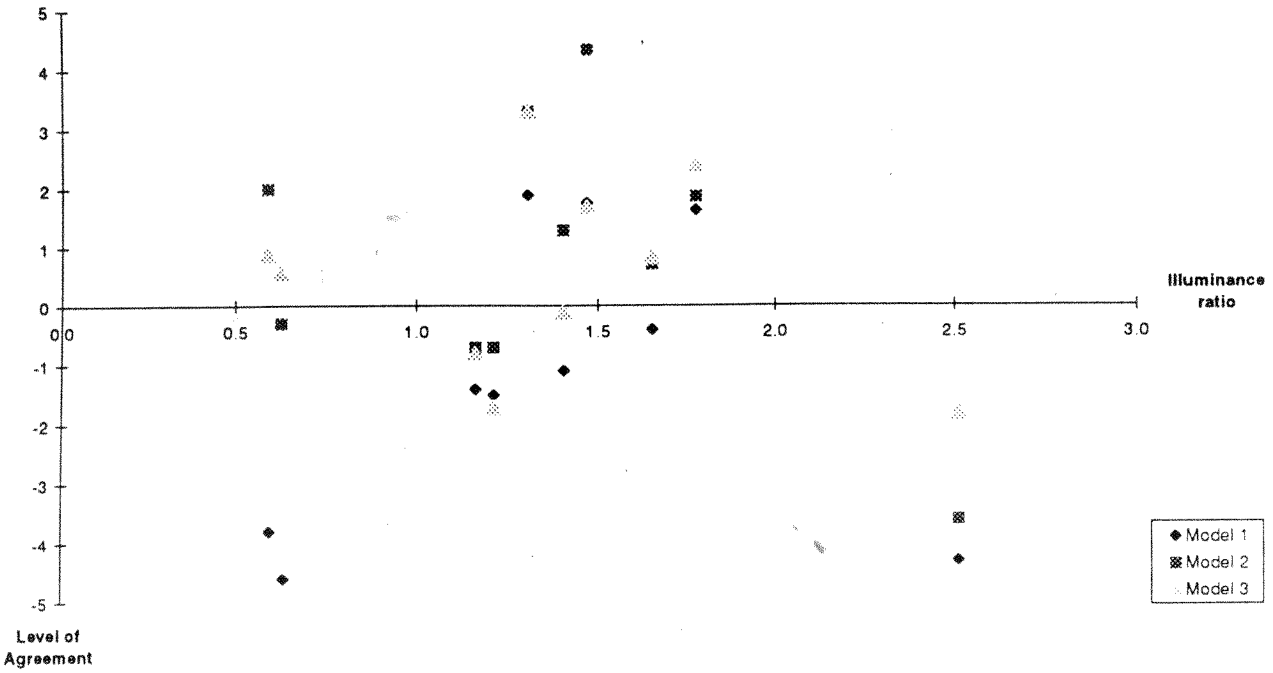
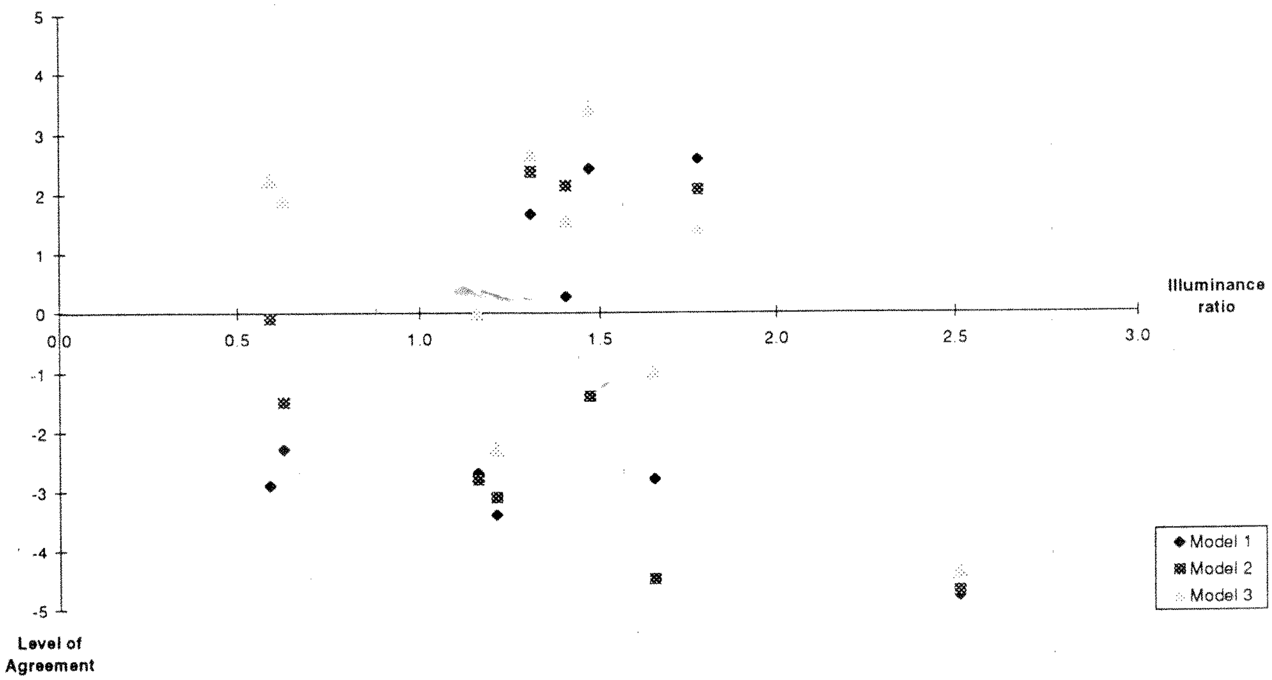


Figure 7. Mean levels of agreement with the statement "Facial blemishes and wrinkles are clearly visible" for each model and lighting combination, seen directly, plotted against the mean levels of agreement for the same conditions seen on video.

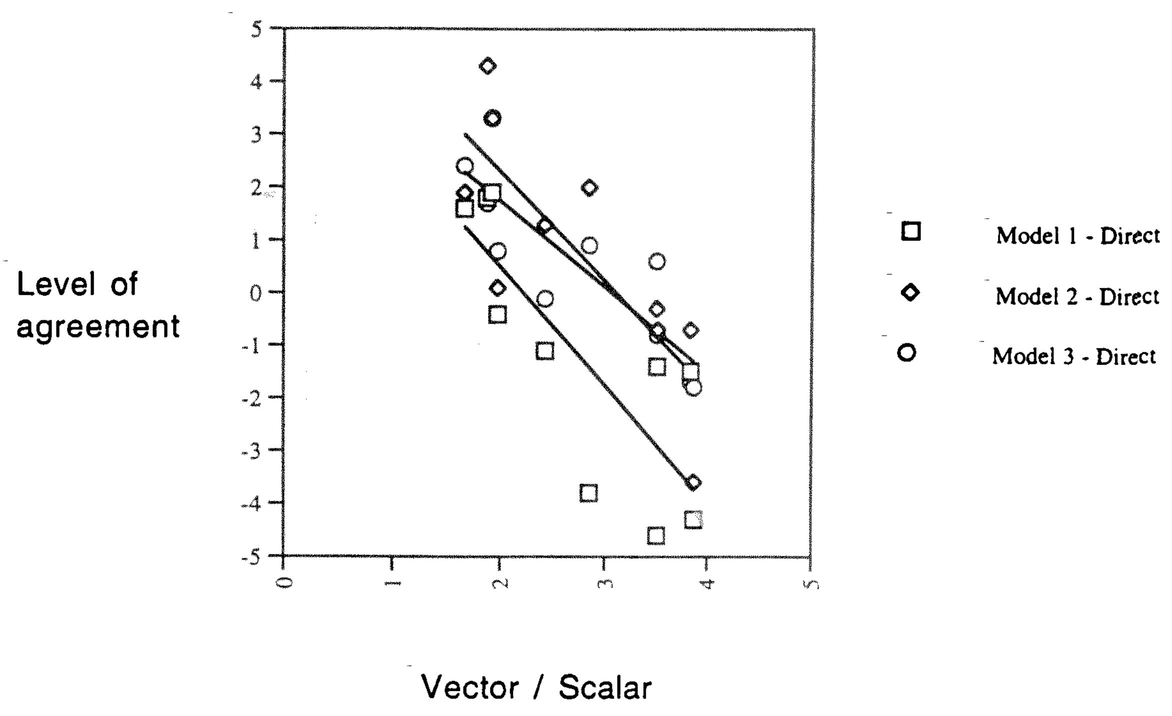


Direct condition



Video condition

Figure 8. Mean levels of agreement with the statement "I like the way the lighting is lit" for every model and lighting combination, plotted against the Hargroves and McFadden (1997) metric, for direct and video viewing separately.



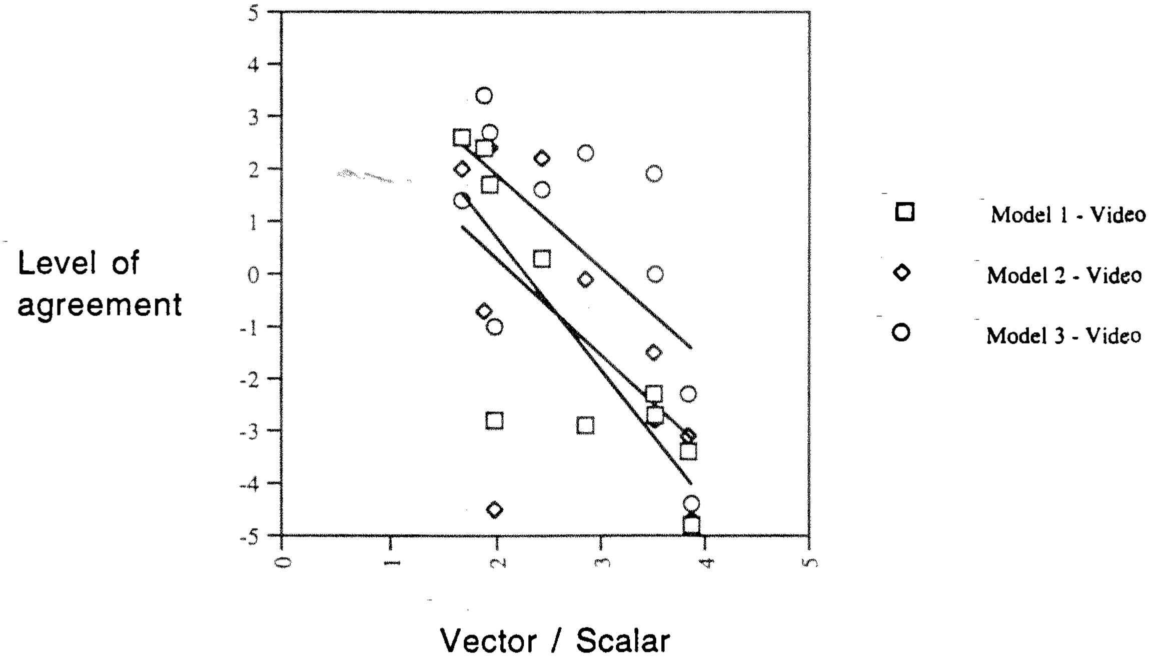


Figure 9. Mean levels of agreement with the statement "I like the way the lighting is lit" for every model and lighting combination, plotted against the vector / scalar ratio, for direct and video viewing separately. Also shown are the linear regression equations for each model.