

# Can Gloss and Translucency Be Captured in an Explainable Low-Dimensional Space?

Hassan Askary, Muhammad Hamza Zafar, and Davit Gigilashvili

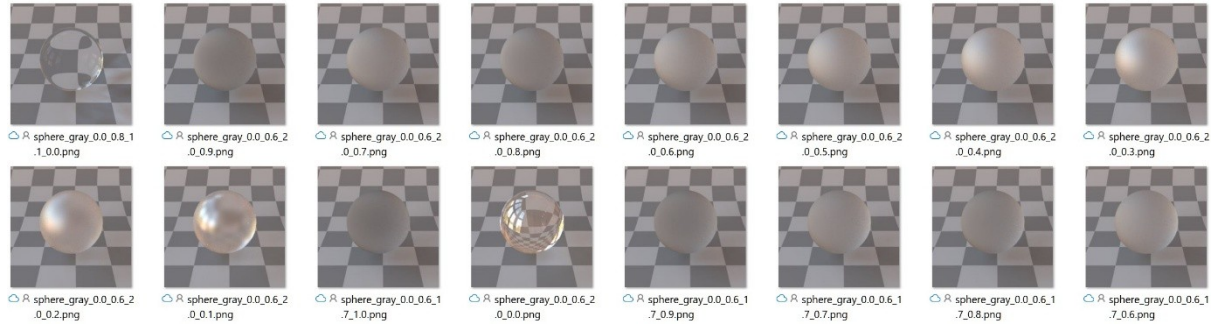
Colourlab, Dept. of Computer Science, Norwegian University of Science and Technology. Gjøvik, 2815, Norway

## Supplementary Materials

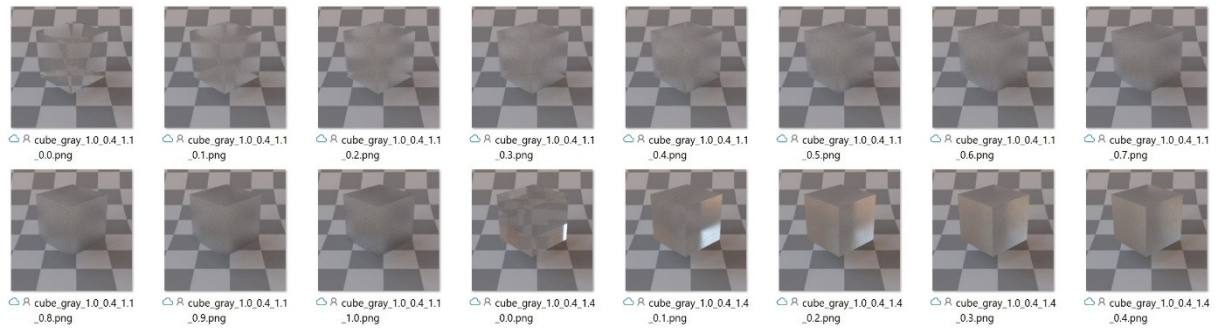
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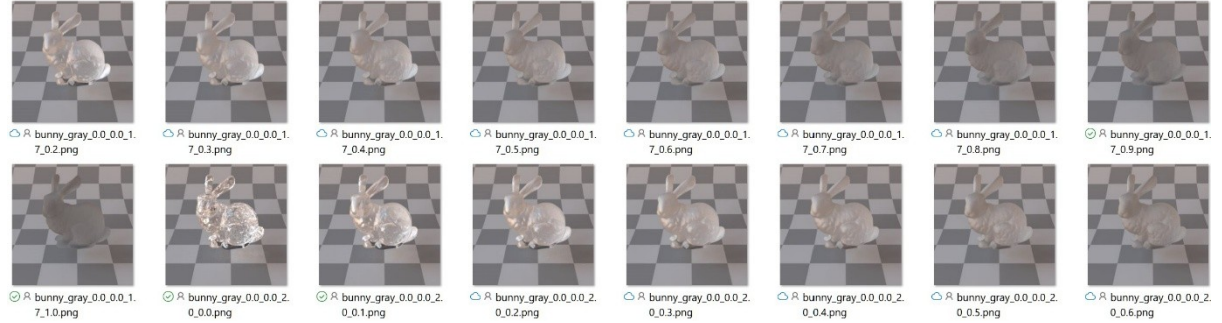
## S1. Examples of the Rendered Stimuli



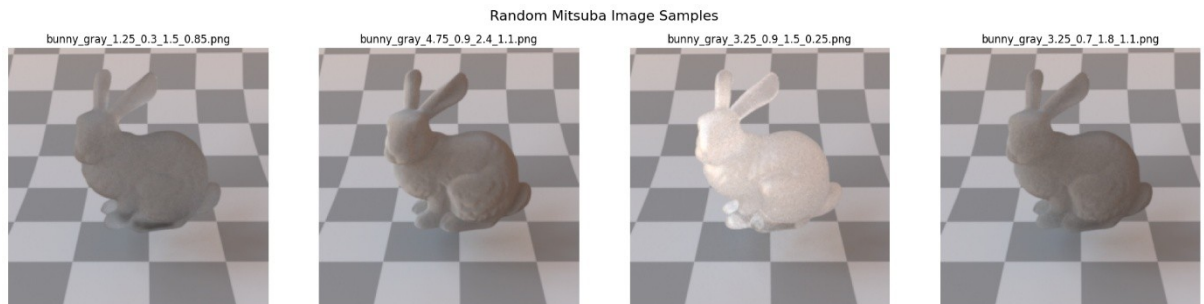
(a) Random samples from the sphere dataset with fixed lighting.



(b) Random samples from the cube dataset with fixed lighting.



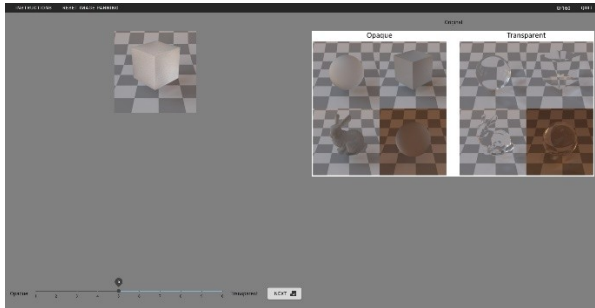
(c) Random samples from the bunny dataset with fixed lighting.



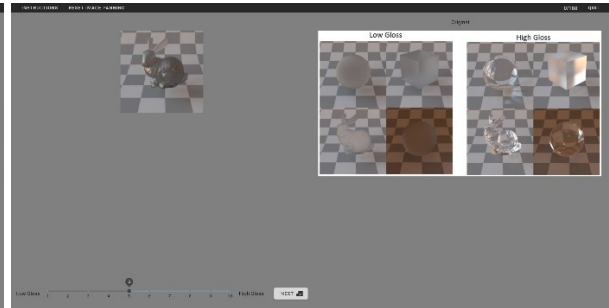
(d) Additional Mitsuba-rendered dataset samples for model generalization testing.

**Figure S.1.1. Random samples from the rendered dataset. The filename indicates the optical parameters in the following format: ( $\sigma_T$ ) (albedo) ( $l_oR$ ) ( $\alpha$ ).**

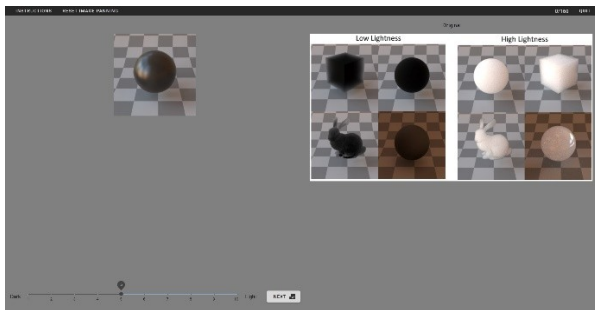
## S2. Experimental Interface



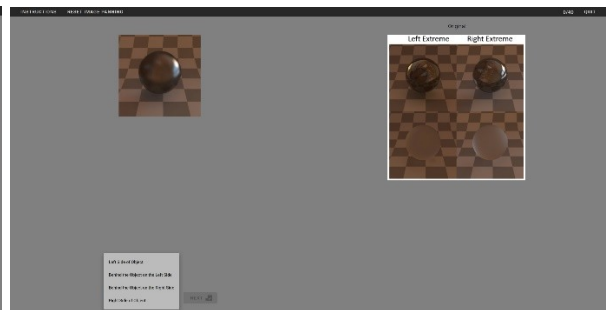
(a)



(b)



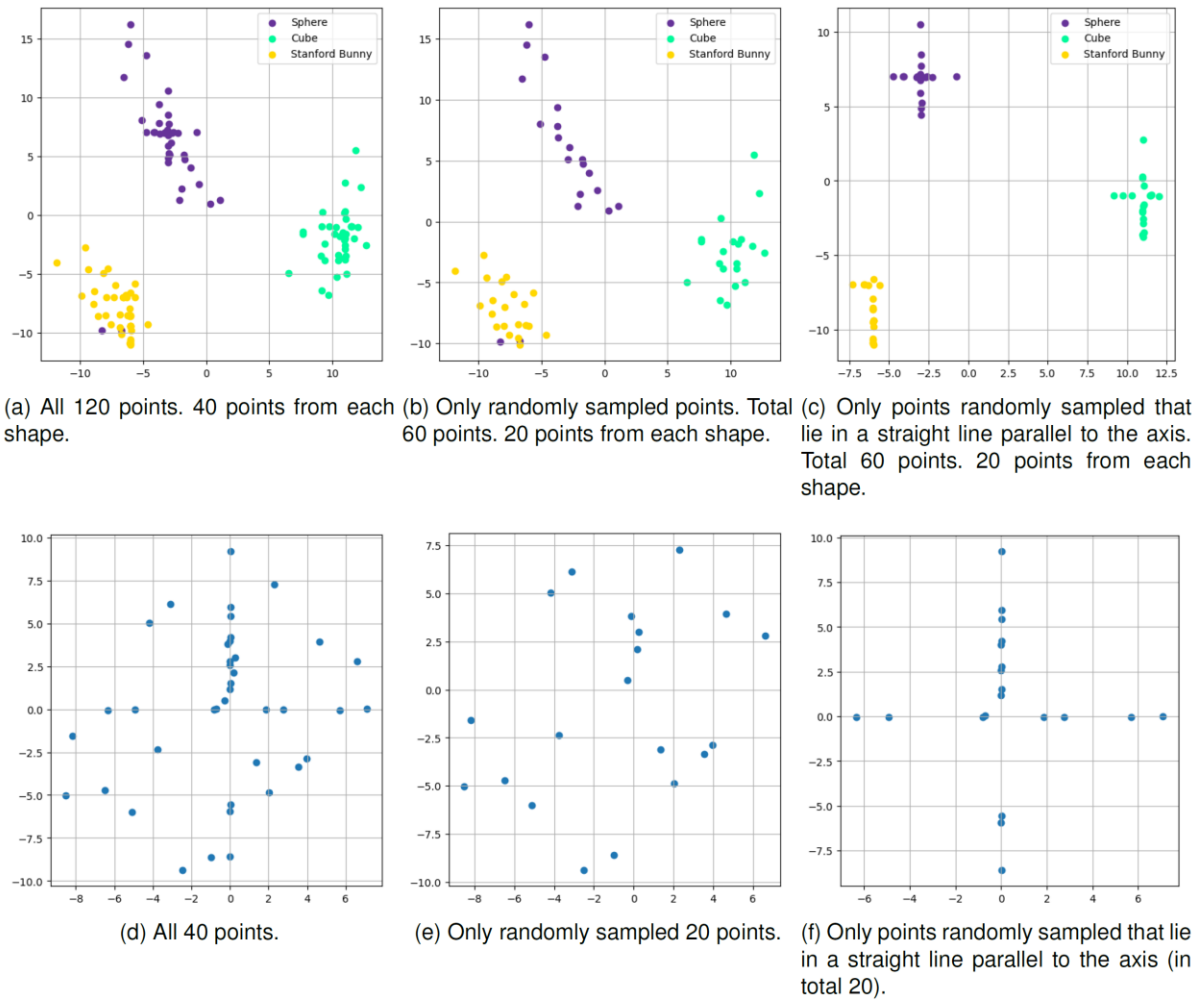
(c)



(d)

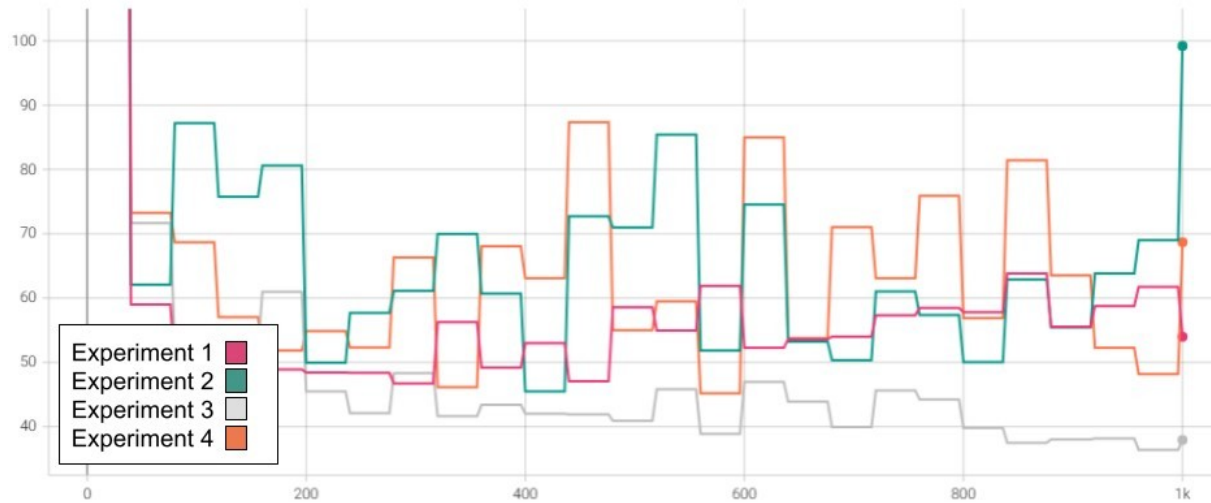
**Figure S.2.1. The experiment interface for translucency (a), gloss (b), lightness (c), and illumination direction (d) rating experiments. The image to be rated is shown on the left, and the reference images are shown on the right.**

### S3. Sampling the Latent Space for Psychophysical Evaluation

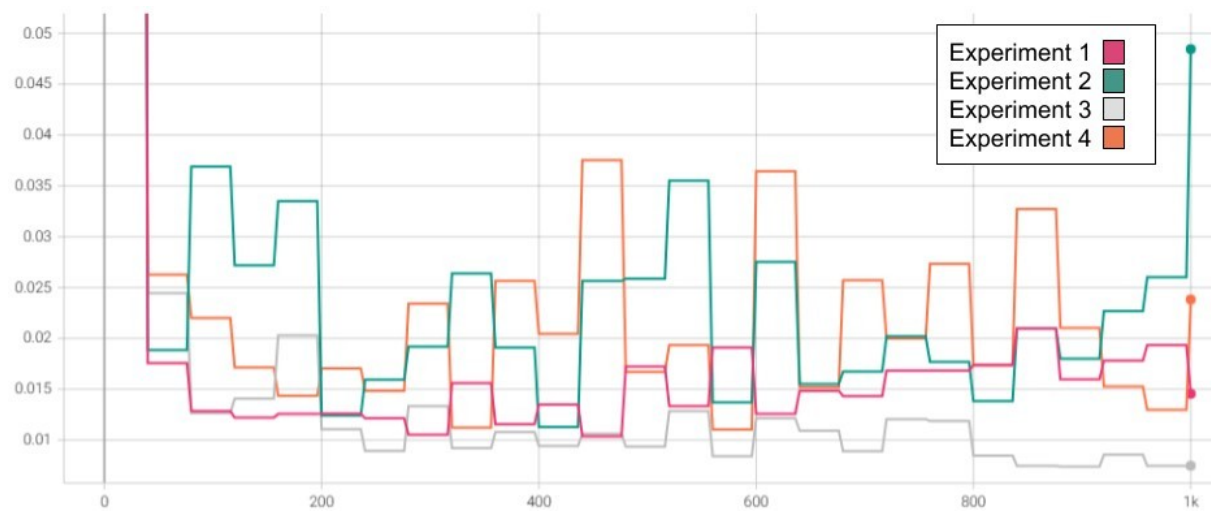


**Figure S.3.1. The latent space of Model 1 that was trained on fixed lighting dataset was sampled in two different ways for each shape. First, a uniform random sampling was applied to each cluster to select points that represent the distribution of that cluster; shown in (b). Second, the mid points of each cluster were identified via visual inspection. Then the points that lie on the locations parallel to the principal axes were randomly sampled; shown in (c). (a) shows all of the sampled points. (d-f) show the sampling for Model 2. The axes correspond to the two orthogonal bases that have the highest explained variance of the 512 dimensional latent space obtained using PCA.**

## S4. FID and KID Scores



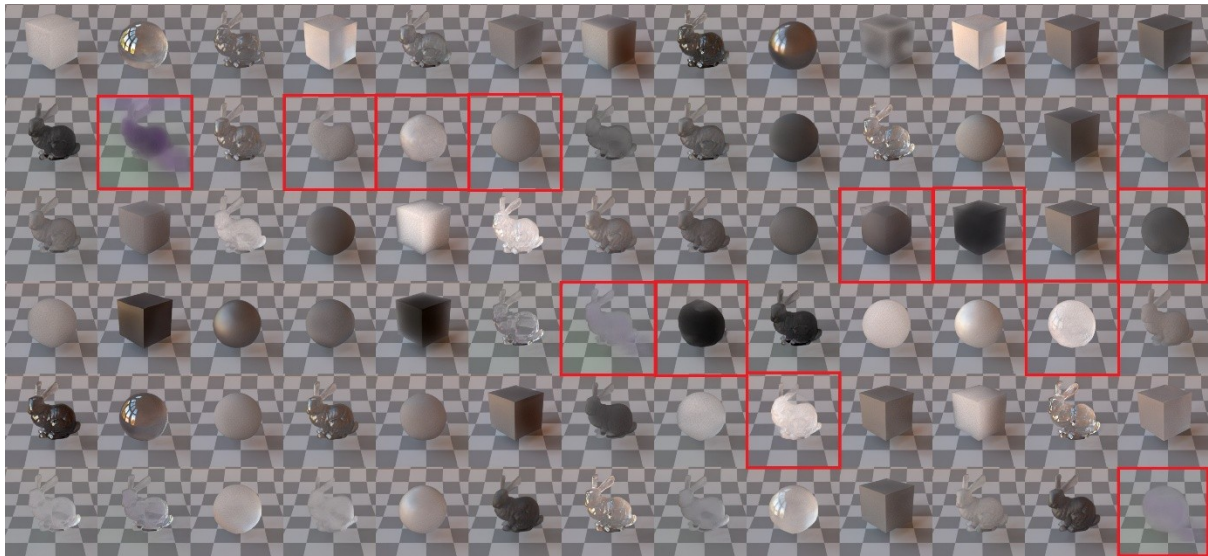
(a) KID



(b) FID

**Figure S.4.1. Comparison of FID (a) and KID (b) scores of training StyleGAN2-ADA with four different hyper-parameters on the uniform lighting set. The scores are calculated at intervals of 10 steps hence the appearance of the curve where the value in between the intervals are uniform.**

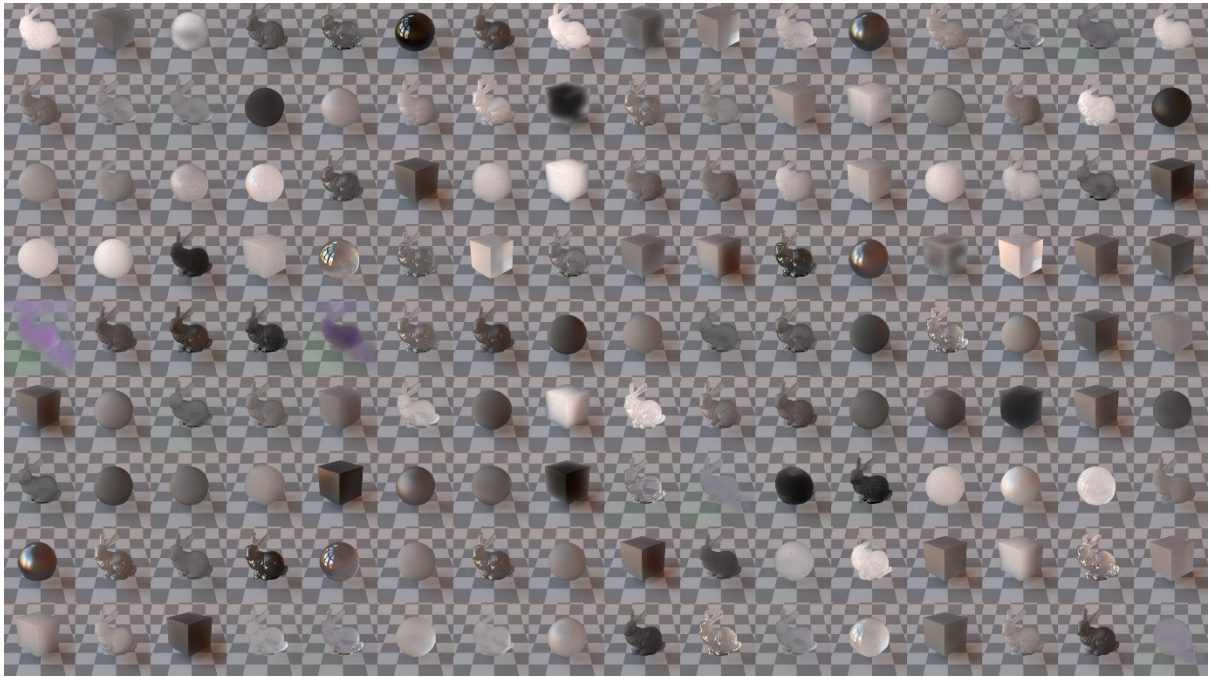
## S5. Examples of Synthesized Images



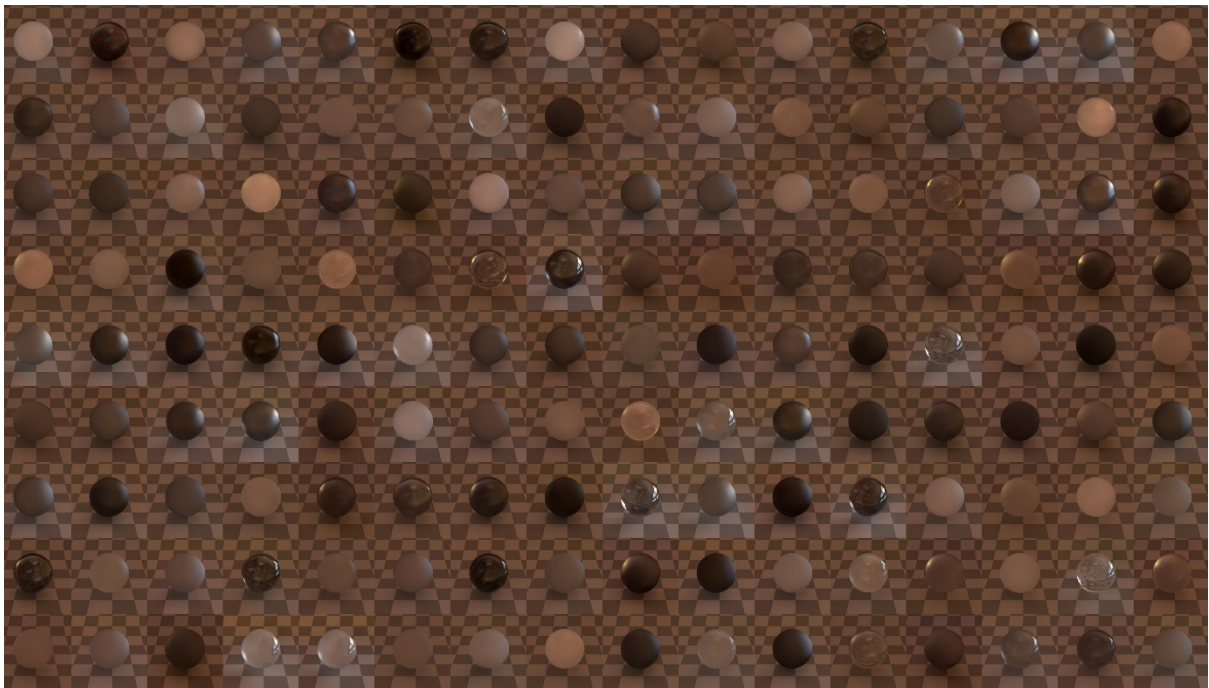
**Figure S.5.1.** Outputs from performing random synthesis using the model trained on fixed lighting set. The shape morphing artifacts are visible for examples marked with a red frame.



## S6. Morphing Artifacts



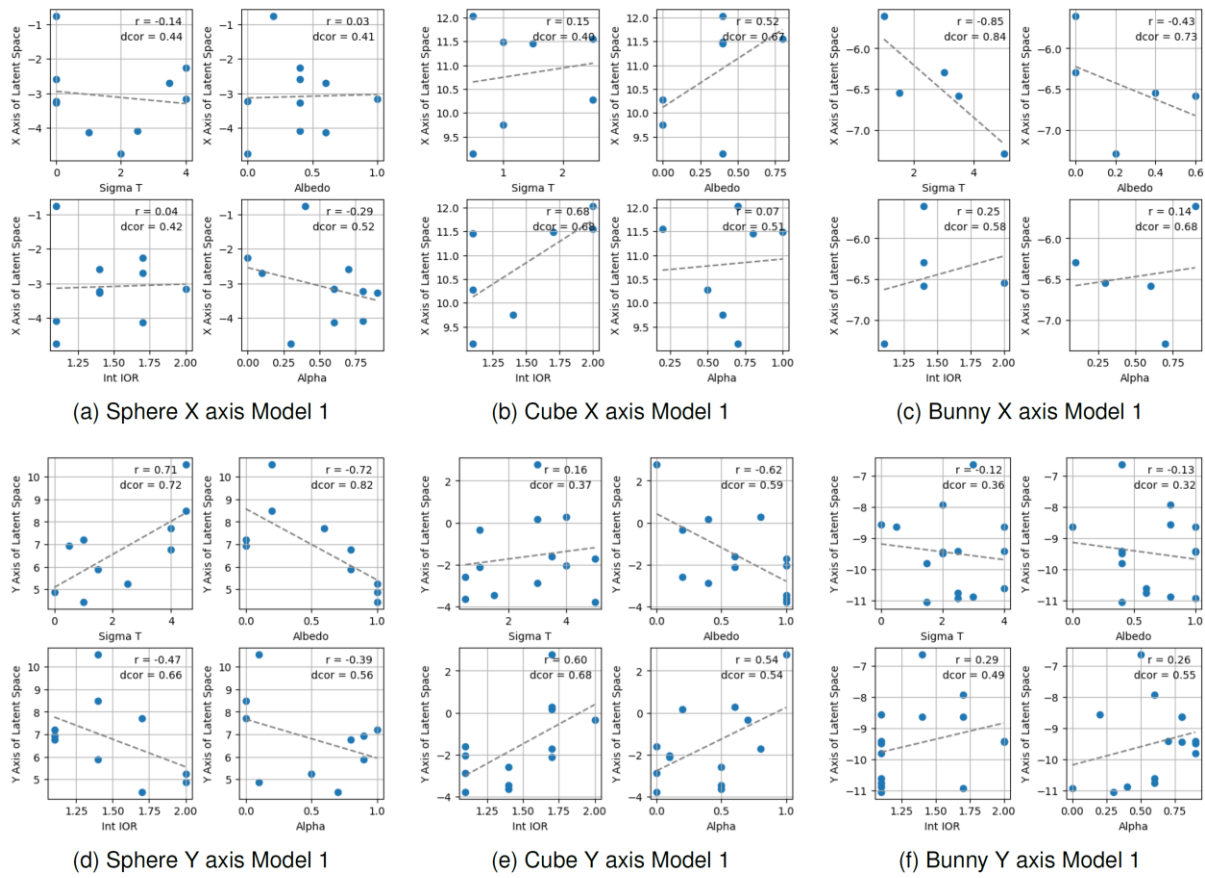
(a) Fixed Lighting Set



(b) Varying Lighting Direction Set

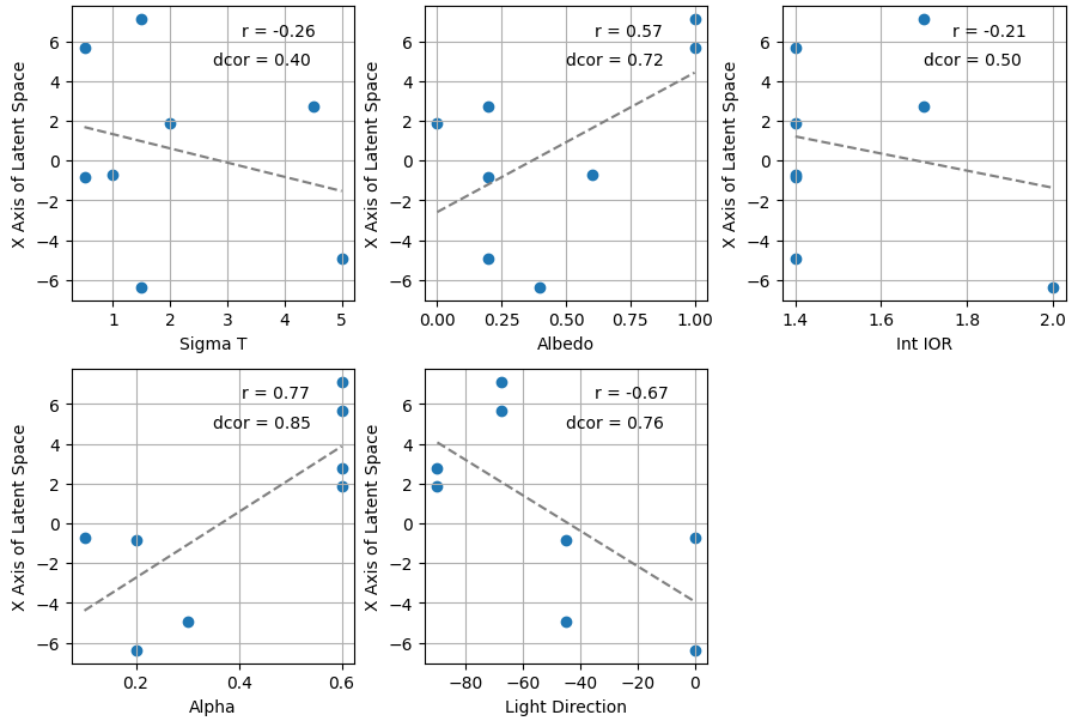
**Figure S.6.1. Outputs from performing random synthesis using the trained models. Shape morphing artifacts can be seen for fixed lighting set, which has 3 shapes (a), and illumination morphing artifacts can be see for varying illumination set (b).**

## S7. Relationship between Optical Properties and Latent Space Coordinates

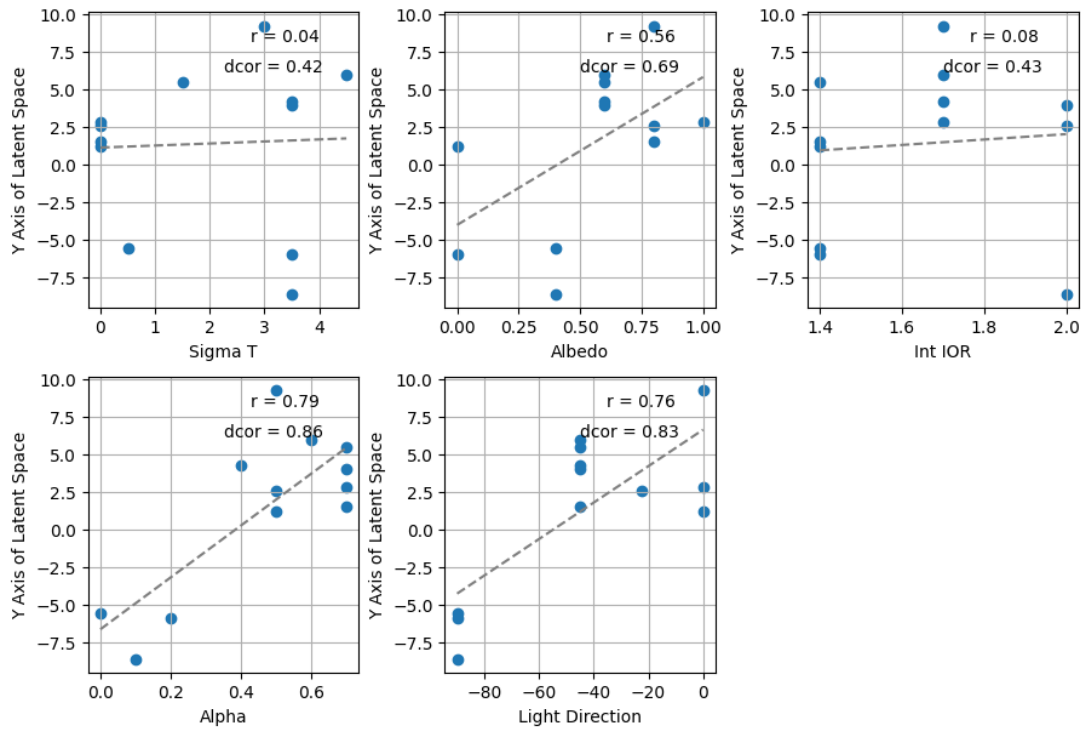


**Figure S.7.1. Scatter plots considering only the points that vary along the X axis (a) and Y axis (b) of the latent space of Model 1. The Pearson coefficient and the distance correlation are calculated and shown inside the plots.**





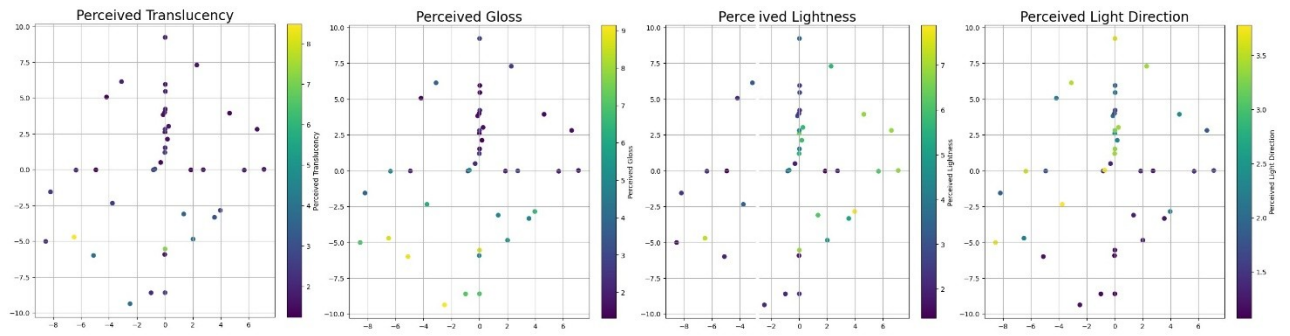
(a) X axis Model 2



(a) Y axis Model 2

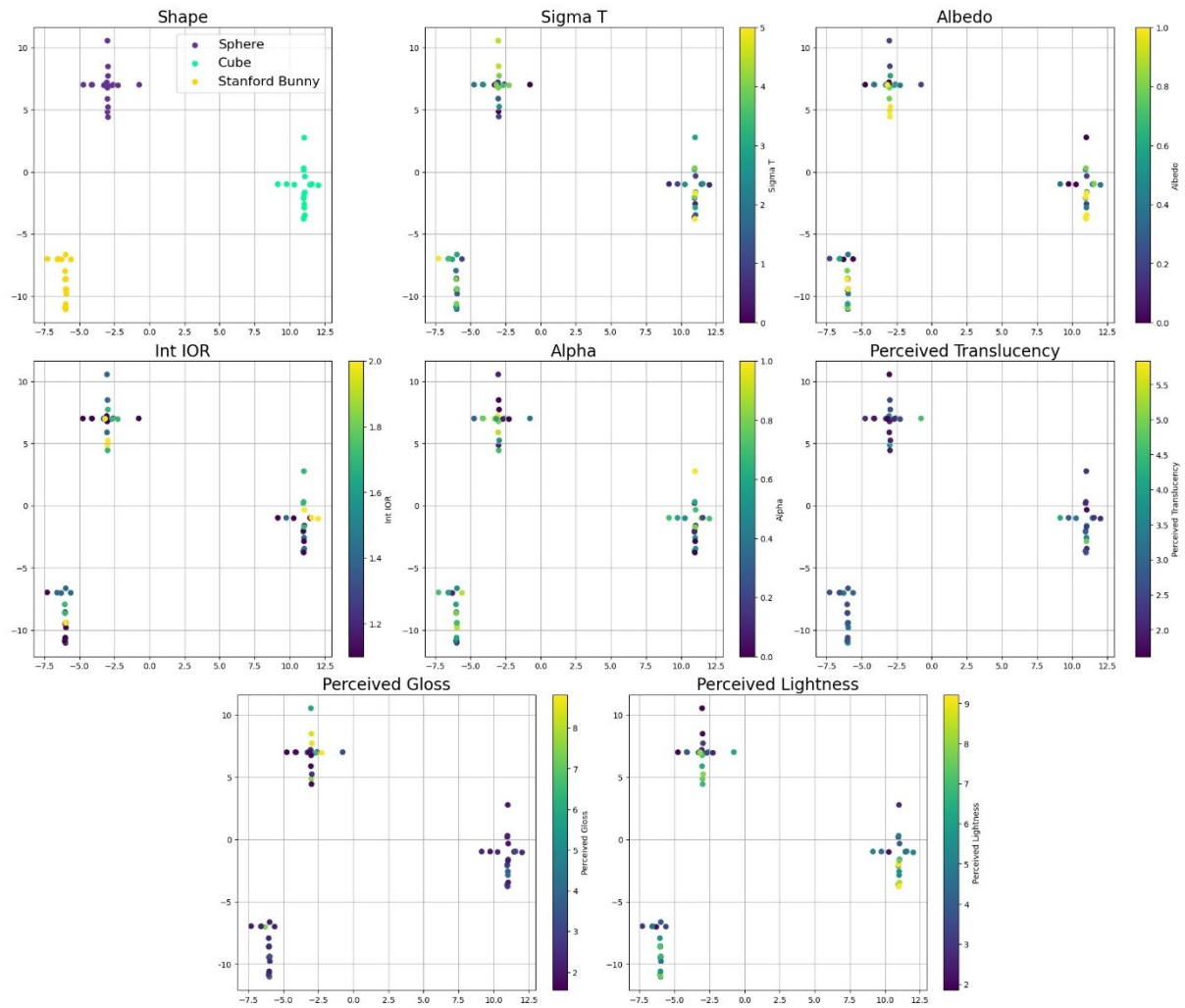
**Figure S.7.2. Scatter plots considering only the points that vary along the X axis (a) and Y axis (b) of the latent space of Model 2. The Pearson coefficient and the distance correlation are calculated and shown inside the plots.**

## S8. Magnitudes for Perceptual Attributes for Model 2

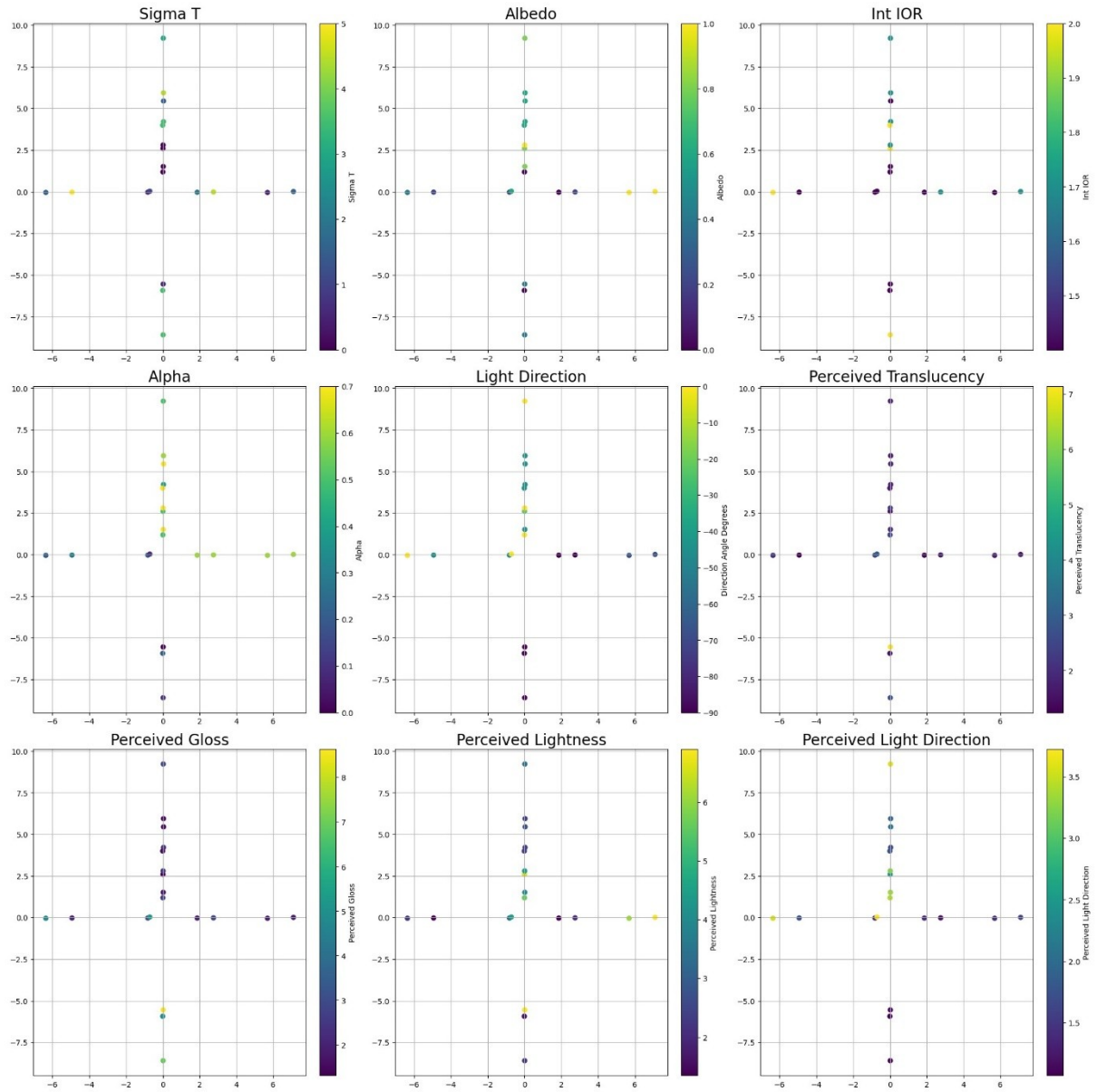


**Figure S.8.1.** The data points are labeled with the respective perceived attribute magnitudes. The axes correspond to two of the orthogonal bases which have the highest explained variance of the 512D latent vectors using PCA.

## S9. Magnitudes for Data Points in Straight Lines

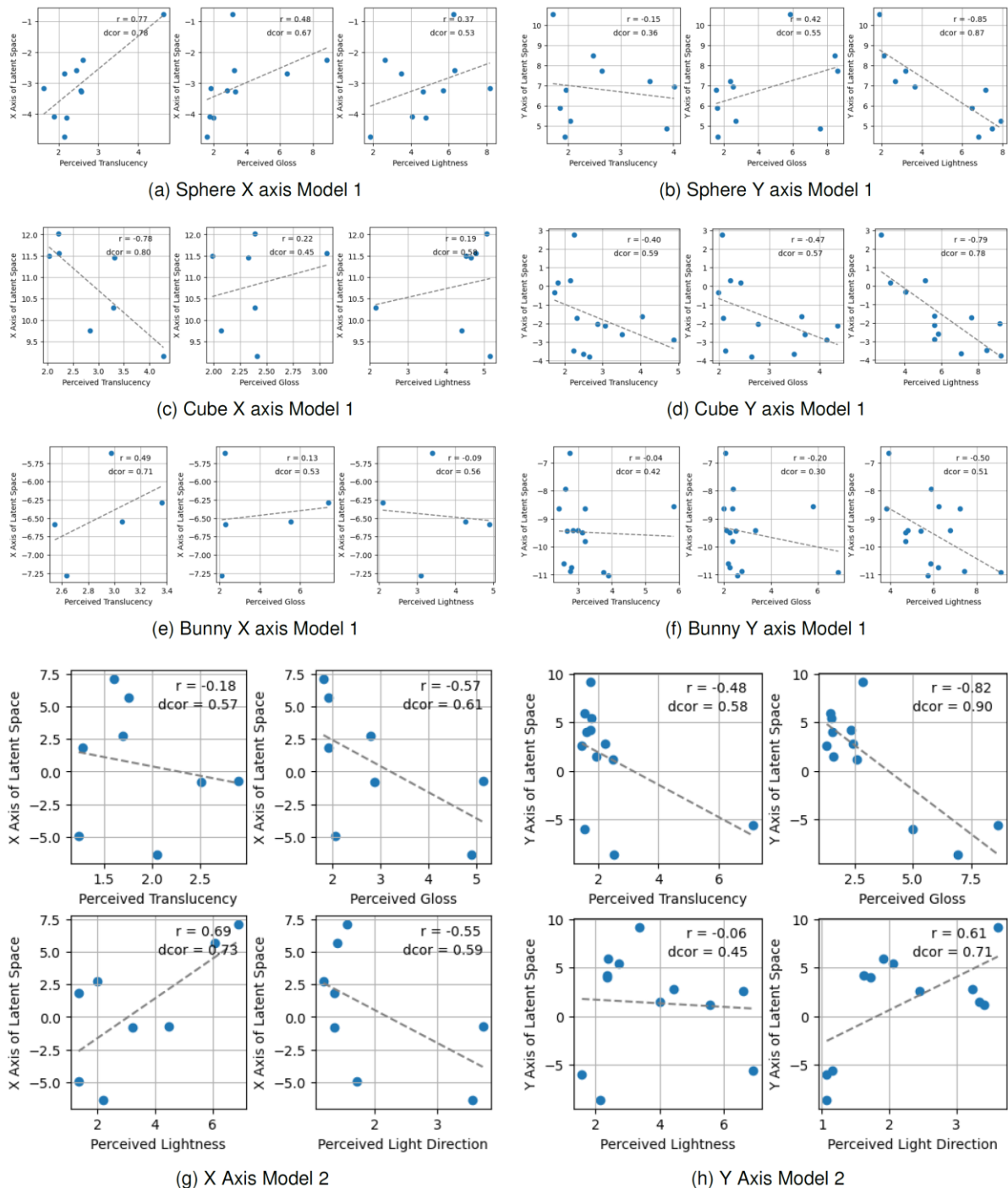


**Figure S.9.1.** Latent space of the Model 1 filtered to show only the data points that lie in a straight line along the principal axis. The data points are labeled with the optical parameters and estimated magnitudes of the perceived attributes. The axes correspond to the two of the orthogonal bases which have the highest explained variance of the 512D latent vectors using PCA.}



**Figure S.9.2.** Latent space of the Model 2 filtered to show only the data points that lie in a straight line along the principal axis. The data points are labeled with the optical parameters and estimated magnitudes of the perceived attributes and the illumination direction. The axes correspond to the two of the orthogonal bases which have the highest explained variance of the 512D latent vectors using PCA.

## S10. Relationship between Perceptual Properties and Latent Space Coordinates



**Figure S.10.1. Scatter plots considering only the points that vary along the X (a, c, e) and Y axis (b, d, f) of Model 1. (g) and (h) show the results for Model 2. Relationships are shown between the estimates of the perceived attributes and the respective coordinate in the latent space. The Pearson's coefficient and the distance correlation are calculated and shown inside the plots.**



## S11. Optical vs Perceptual Properties

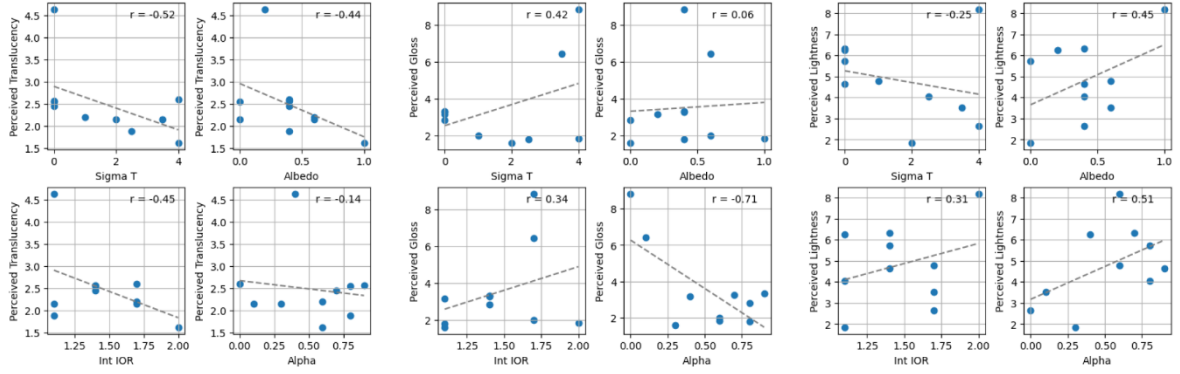
The relationships between perceived attributes and optical parameters was analyzed. The correlation coefficient was calculated for all combinations of magnitude estimations of the attributes and optical parameters. For this, data points that lie in a straight line parallel to an axis are considered. Correlations are calculated separately for each shape because the model has arranged the parameters and attributes uniquely for each shape.

**Figure S.11.1.** shows the correlation plots for the data points that lie in a straight line parallel to the X axis in Model 1. Correlations are calculated for each shape separately and for each perceived attribute. On observing the figures, there are some strong correlations present. The perceived gloss is highly negatively correlated with alpha. This makes sense as alpha is the surface roughness of the material. As it increases, the surface becomes more rough and hence less specular or glossy. The perceived lightness has a high positive correlation with the albedo. The albedo defines the amount of scattering in the object. High albedo means more scattering and lighter objects. Perceived translucency is negatively correlated with sigma T and albedo. Sigma T corresponds to the amount of absorption. A higher sigma T value will result in an object that absorbs more light, leading to an opaque appearance. For the other figures, the R coefficients do not indicate that there is a relationship. **Figure S.11.2.** shows the correlation plots for the data points that lie in a straight line parallel to the Y axis in Model 1. As in the case with the X axis data points, the perceived lightness has a strong positive correlation with albedo. Perceived translucency and sigma T are negatively correlated in the sphere and the bunny but not in the cube. Perceived gloss and alpha have a strong negative correlation. Overall, the relationships that are correlated have higher R coefficient values in the Y axis than in the X axis.

**Figure S.11.3.** shows the correlation plots for the data points that lie in a straight line parallel to the X axis in Model 2. Observing the relationships, the light direction has a strong positive correlation with perceived translucency, gloss, and light direction. Images with a light direction angle from -40 degree to 0 degree were rated as having higher gloss and closer to being transparent. This pattern could also be due to outliers. In the figures there are only two to three points that are in the upper right corner, while the rest of the points are in the bottom left corner and do not have a clear correlation. Alpha is negatively correlated with perceived translucency, gloss, and light direction. As surface roughness increases, the object becomes perceptually less transparent and glossy. Images with high alpha values were estimated to have a light direction of 0 degree. This could be related to the appearance of the objects with the four angles of light direction. At the extreme angles, the light usually casts a specular reflection spot on the object. This is more prominent to see when object is glossy, hence having low values of alpha. In the alpha vs light direction plot, four points have low alpha and are located at extreme ends of the Y axis indicating they were rated to have either extreme right direction of illumination or extreme left.

**Figure S.11.4.** shows the correlation plots for the data points that lie in a straight line parallel to the Y axis in Model 2. On the Y axis, the light direction correlates with the perceived light direction and gloss. For translucency, it can be concluded that the correlation observed on the X axis was due to outliers. However, for perceived gloss, there is a positive correlation here. One explanation can be that, because the specular reflections are more visible when the light direction is at the left side or right side of the object. In the figure, the high gloss values occur at an illumination angle of -90 degree. At the other end of the plot, although the gloss values are not high, they start to increase indicating specular reflection. The points in the middle are low, indicating that the gloss is rated low because there are no specular reflections. Similar behavior is present here with respect to alpha versus perceived translucency, gloss, and light direction as in the X axis. However, here the correlation with the perceived light direction is positive. Observing the perceived light direction versus the alpha plot, two groups can be seen at the right end of the plot. Some points have been rated as having a light direction from the left side, while others have a light direction from the right side. As opposed to on the X axis, here the higher values of alpha have polarizing light direction estimates. More detailed analysis will be required to understand this. Moving on, similarly to that

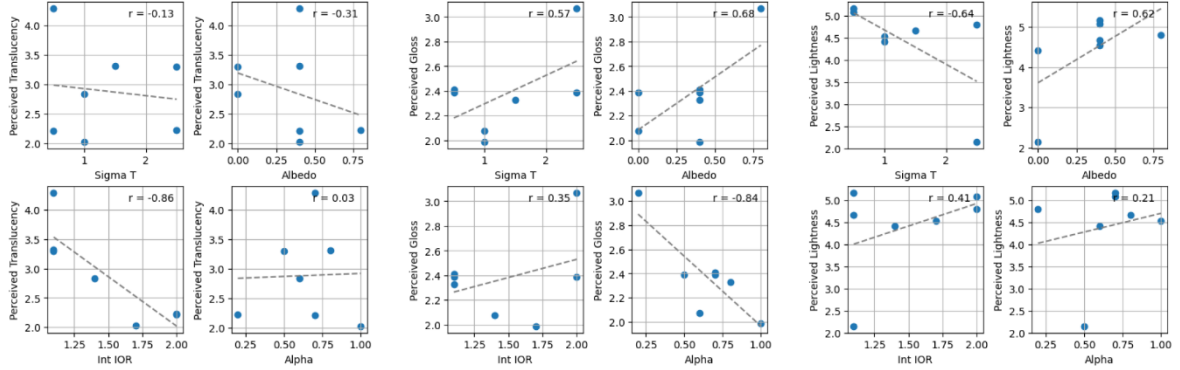
on the X axis, sigma T has a negative correlation with lightness. The rest of the scatter plots do not show any correlation.



(a) (X axis Sphere) perceived trans-lucency vs optical parameters.

(b) (X axis Sphere) perceived gloss vs optical parameters.

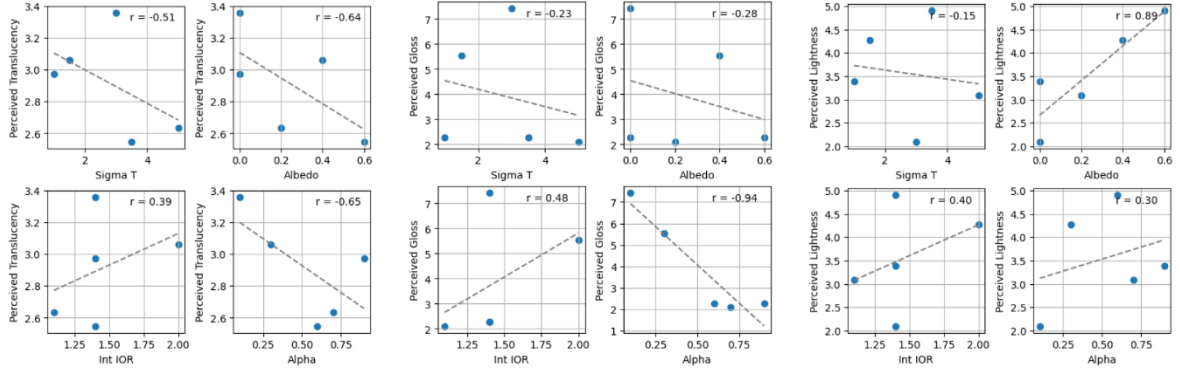
(c) (X axis Sphere) perceived lightness vs optical parameters.



(d) (X axis Cube) perceived trans-lucency vs optical parameters.

(e) (X axis Cube) perceived gloss vs optical parameters.

(f) (X axis Cube) perceived lightness vs optical parameters.

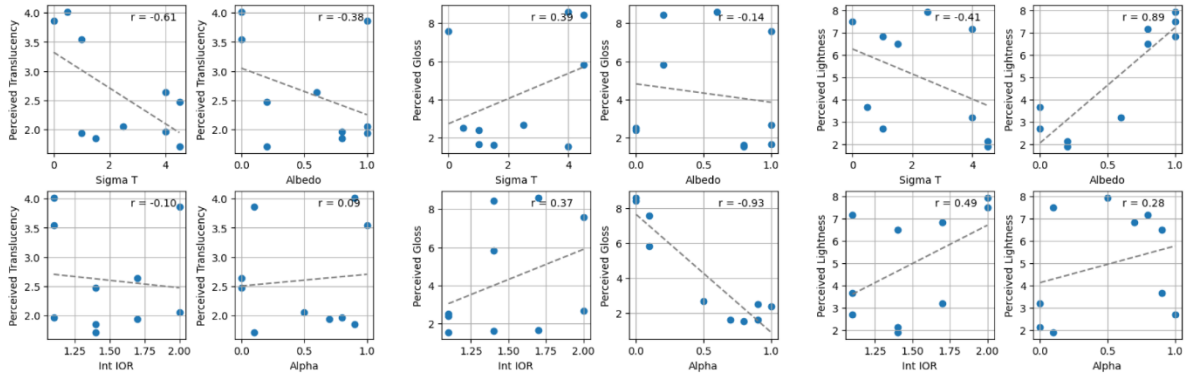


(g) (X axis Bunny) perceived trans-lucency vs optical parameters.

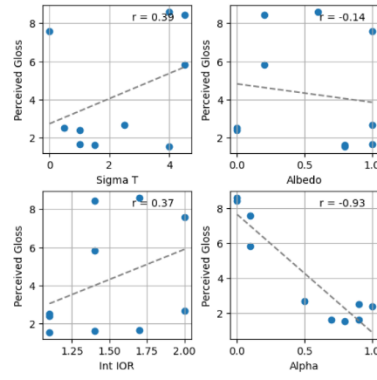
(h) (X axis Bunny) perceived gloss vs optical parameters.

(i) (X axis Bunny) perceived lightness vs optical parameters.

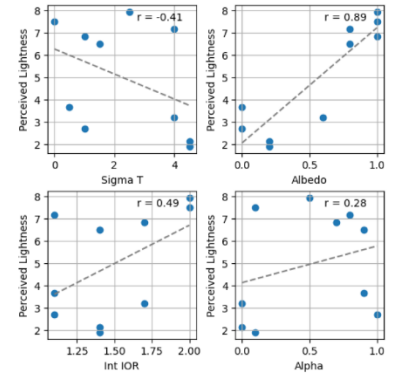
**Figure S.11.1. Correlations plots between the perceived attributes and optical parameters.** These plots are constructed using the data points that are located parallel to the X axis in the latent space of Model 1. The first row of figures corresponds to the sphere cluster. The second row to the cube cluster and the third to the bunny cluster. The Pearson correlation coefficient is also calculated and shown inside the figures.



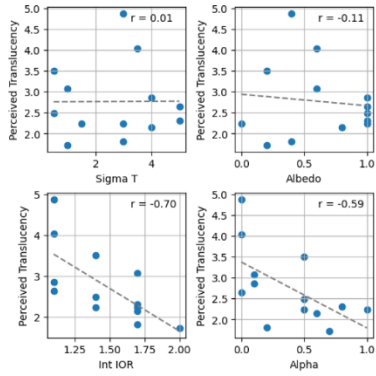
(a) (Y axis Sphere) perceived translucency vs optical parameters.



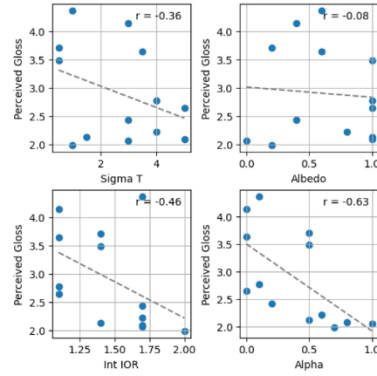
(b) (Y axis Sphere) perceived gloss vs optical parameters.



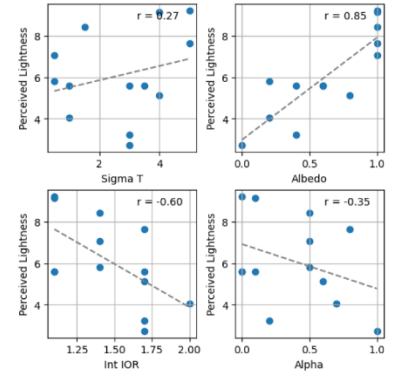
(c) (Y axis Sphere) perceived lightness vs optical parameters.



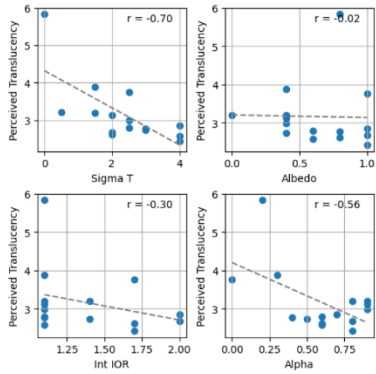
(d) (Y axis Cube) perceived translucency vs optical parameters.



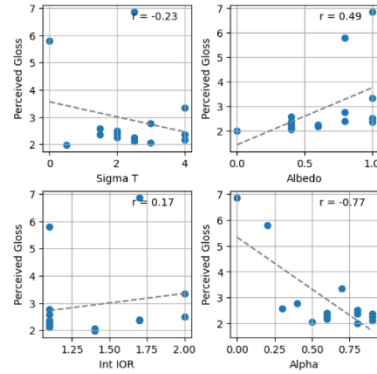
(e) (Y axis Cube) perceived gloss vs optical parameters.



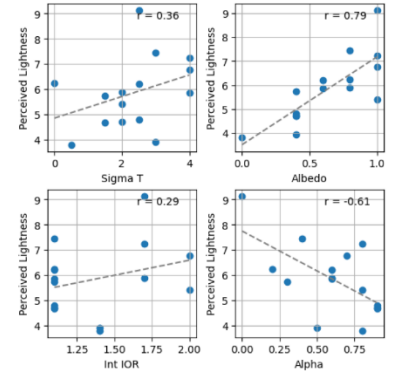
(f) (Y axis Cube) perceived lightness vs optical parameters.



(g) (Y axis Bunny) perceived translucency vs optical parameters.

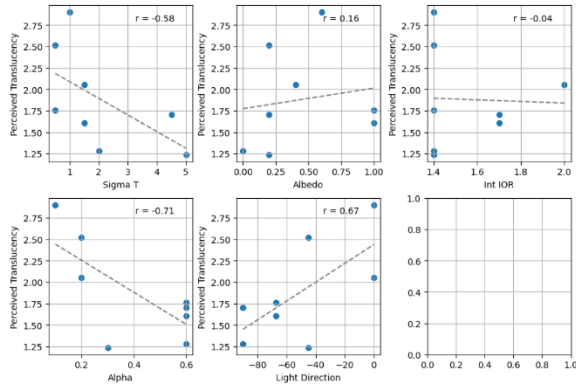


(h) (Y axis Bunny) perceived gloss vs optical parameters.

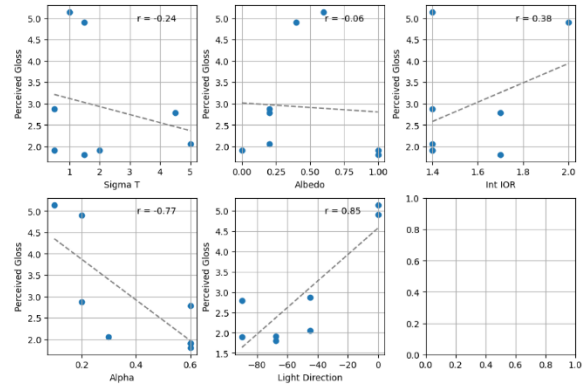


(i) (Y axis Bunny) perceived lightness vs optical parameters.

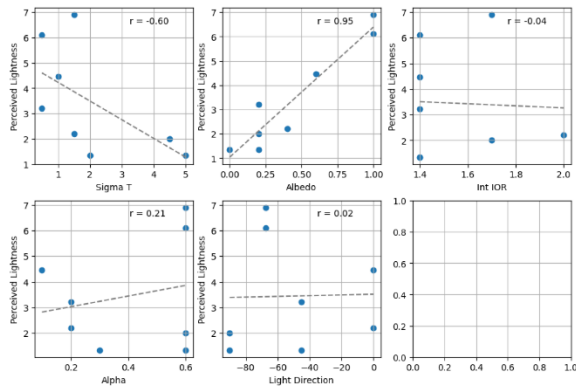
**Figure S.11.2. Correlations plots between the perceived attributes and optical parameters.** These plots are constructed using the data points that are located parallel to the Y axis in the latent space of Model 1. The first row of figures corresponds to the sphere cluster. The second row to the cube cluster and the third to the bunny cluster. The Pearson correlation coefficient is also calculated and shown inside the figures.



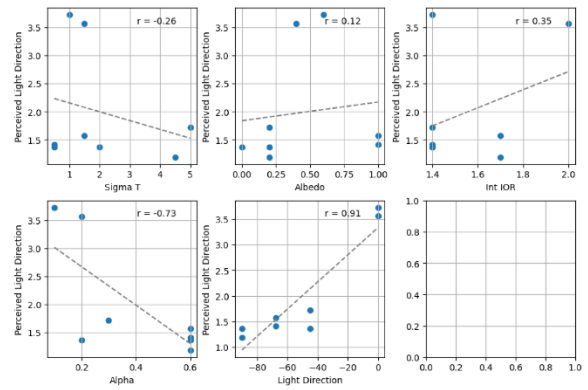
(a) (X axis) perceived translucency vs optical parameters.



(b) (X axis) perceived gloss vs optical parameters.

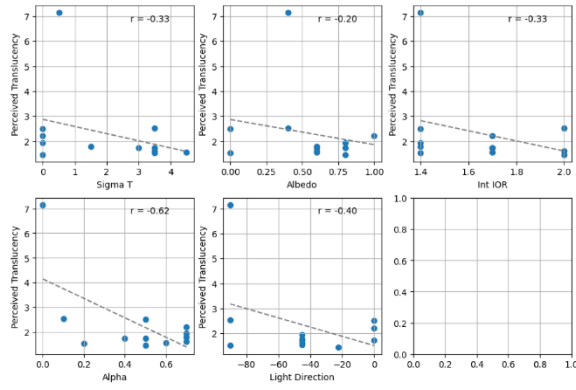


(c) (X axis) perceived lightness vs optical parameters.

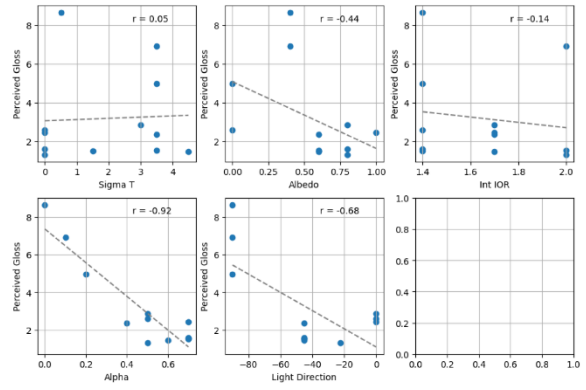


(d) (X axis) perceived light direction vs optical parameters.

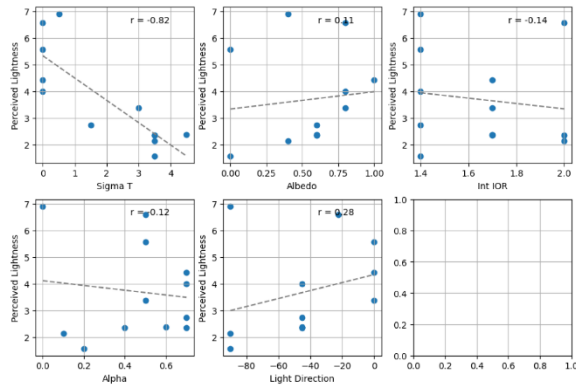
**Figure S.11.3. Correlations plots between the perceived attributes and optical parameters. These plots are constructed using the data points that are located parallel to the X axis in the latent space of Model 2. The Pearson correlation coefficient is also calculated and shown inside the figures.**



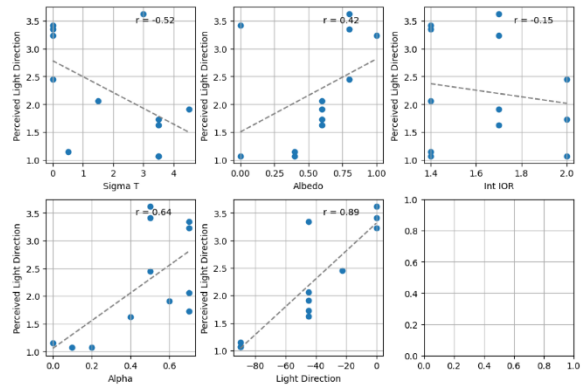
(a) (Y axis) perceived translucency vs optical parameters.



(b) (Y axis) perceived gloss vs optical parameters.



(c) (Y axis) perceived lightness vs optical parameters.



(d) (Y axis) perceived light direction vs optical parameters.

**Figure S.11.4. Correlations plots between the perceived attributes and optical parameters. These plots are constructed using the data points that are located parallel to the Y axis in the latent space of Model 2. The Pearson correlation coefficient is also calculated and shown inside the figures.**