The *Plastique* collection: A set of resin objects for material appearance research

[1]Jean-Baptiste THOMAS, [2]Aurore DENIEL, [1]Jon Y HARDEBERG
[1]The Norwegian Colour and Visual Computing Laboratory, NTNU, jean.b.thomas@ntnu.no, jon.hardeberg@ntnu.no
[2]Aden Keramikk, ad.ceramique@laposte.net

1. Introduction

We present a collection of resin objects dedicated to the study of material appearance. This collection is both an artwork and a scientific set of objects. The independent artist Aurore Deniel from Aden Keramikk [1] created the collection by commission from NTNU, funded by the MUVApp project (See acknowledgement). She accepted to help us with the analysis through a series of interviews. The artwork is named *Plastique*, which in French, relates to three definitions: the polymeric material, the silhouette of a person, and the class of arts in which the aesthetic is developed around the modification of shape or volume [2, 3]. We shall thus refer to the *Plastique* collection.

In addition to presenting the collection in terms of technical realization, this article contains the interpretation of an interview of the artist. We transcribed the interview on paper and performed an analysis based on the grounded theory analysis [4]. The *grounded theory analysis* is a qualitative research methodology derived from the *grounded theory approach*, which emerged within the Chicago School of Sociology [5]. Through the analysis, we can provide a structured description of the content of this interview and identify the difficulties of realization, but also any processes that may be helpful in the analysis of the future quantitative analysis that will use those samples.

Before going further in the description of this collection, we should recall that our scientific interest is in the visual appearance of materials [6]: this may be defined as total appearance, by the perceptual attributes color, gloss, translucency and texture. Here, we mostly exclude texture as an explicit attribute, but address the three others. The large majority of investigations on visual perception today use virtual reality facilities, from the basic stimulus presentation on a display or stereo-system to complex virtual set-up using VR glasses such as Oculus Rift (see e.g. [7, 8, 9, 10, 11, 12, 13]). Although there are still studies carried out on real materials (e.g. [14]), most of the research is performed through some types of electronic displays. This is for several good reasons. It is indeed difficult technically, and expensive in both time and funding, to realize real samples. The material availability of real samples is reduced, and only available materials can be used, which does not span the whole range of possible physical parameters, which could affect a scaling experiment. The measurement of optical parameters of real samples is very difficult and may be inaccurate, while the computer graphics facilities permit a direct access to the model. Conditions of stimuli presentation are harder to control and visual experiments may be harder or slower to perform. Despite those strong advantages, the computer graphics creation of scenes creates a layer of intermediate media between the light, the object and the observer, so the interaction is less natural. The appearance of an object or material on a display is also very different from a real version of this object, despite many technological efforts in particular in the computer graphics. In addition, the virtual objects usually do not show any imperfection that may play a role in their visual interpretation.

By realizing these objects, we propose, as future work, to study in depth this corpus and generate a work of theorization about their appearance through different actions. First, we intend to perform optical measurement [15] of each sample type by different means (ellipsometer, gonio-spectrophotometer, camera-based measurements, spectral transmittance and reflectance, etc.), in which we would focus on material definition. This would help to validate procedures of measurement and would be the foundation for further appearance studies. Secondly, we would perform an investigation into the way people interact physically with those samples. Third, we would investigate how people describe the samples. These data should lead to a better understanding of material appearance anchored to this collection and the generation of further research hypothesis.

The purpose of this article is to describe this collection of objects, first from a technical point of view, i.e. quantity of matter, manufacturing processes, that may impact the results of the steps mentioned above. This is developed in Section 2 and 3. Secondly, we would like to convert a part of the artist experience into useful technical knowledge. Because the collection is handcrafted, it is relevant to perform such a qualitative analysis independently. We develop that in Section 4, before we conclude.

2. Description of the objects

This section describes the objects and proposes an adequate labelling system. We wanted to develop a collection of objects that varies in color and in translucency. We identified that the surface of the object, referred to later as coarseness, will influence greatly on both the translucency and the gloss aspect of the object (referred to as *opacity of the surface* by Motoyoshi [16]) as well as the intrinsic material properties. We also understand from the literature that the shape influences greatly the cues generation of material appearance through orientation and thickness (e.g. [8]). Very important features were that there is an achromatic mix from transparent to opaque, but also chromatic components.

In order to have several objects, varying in shape, ratio of mixed components and surface texture, and in a reasonably controlled manner, discussion lead us to resin as material. The price, time and technical difficulties made us limit the number of objects to what is described below. At first, we selected principal hues and primaries but no specific mixes, this decision has been taken later on after some tests, and further discussion, as we wish is described well in the following.

The objects are made of resin *Gédéo* from the brand *Pébéo* [17]. We used the Crystal resin as the Transparent material (T), the Colour resins Lapis Blue (Blue, B) and Topaz (Yellow, Y) version for the chromaticity. The opacity was created by adding drops of white paint (W), *Pébéo ceramic nº 10,* to the crystal resin. The limitation to two hues came from practical reasons. They were chosen as roughly opponent colors. We considered 5 steps of discretization between those 4 primaries (Y, B, W, T) and three level of surface coarseness (C1, C2, C3; C1 being the smoothest surface). See Figures 1, 2, 3, and 4.

The objects are Rectangular, Spherical and Complex shapes. The rectangular shape was selected in order to have a benchmark shape to measure the optical material properties. This shape also varies in thickness, depending on the orientation; cubes have been used in translucency experiments [8]. The spherical shape is selected for isometric properties, and because it will be easy to recreate this shape in a virtual environment for potential comparisons. The complex shape is an original creation by the artist, a meaningful representation, named *Plastique,* and shows different thickness of materials.

Then, a labelling system may be created as Shape-Primaries-Coarseness-Number of the object. An example is S-T1W3B0Y0-C2-N68 for Sphere, Transparent to White level 4, coarseness level 2, object number 68. Ratio of primaries are described in Section 3. All objects are named from R-T4W0B0Y0-C1-N1 to C-T3W0B0Y1-C3-N171 and archived in an Excel file *plastique.xls*.

Figure 1: Image of the spheres from transparent to color to white and the three levels of coarseness.

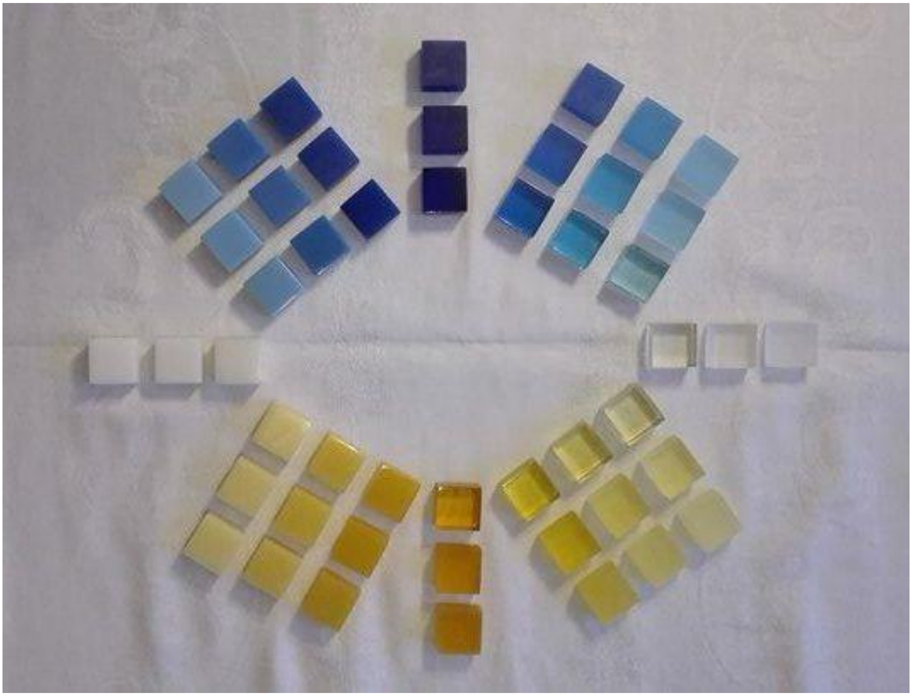

Figure 2: Image of the rectangles from transparent to color to white and the three levels of coarseness.

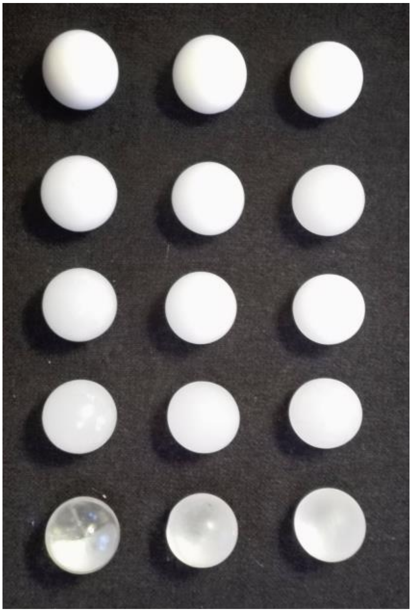

Figure 3: Image of the spheres from transparent to white.

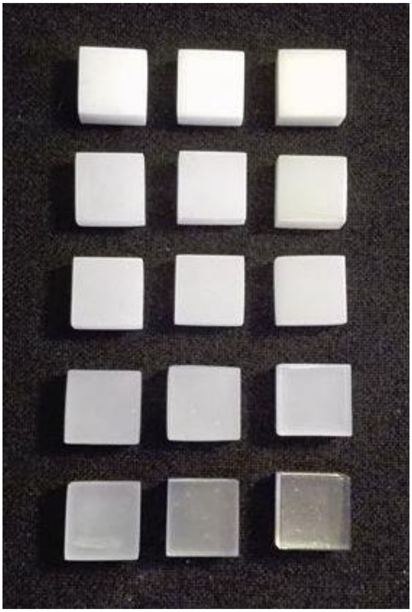

Figure 4: Image of the rectangles from Transparent to white.

3. Description of the manufacturing process

This section describes the manufacturing processes and difficulties of realization.

3.1. Surface coarseness and shape

The rectangle shape has been created with latex flexible molds, with dimensions 27x27x15mm. The mold was opened at one of the square faces. Due to this fact, and to a reduction of volume during the polymerization step, 5 faces were matte but the last face was not planar and very shiny/glossy. It should also be noted that latex is slightly coarse. After molding, each pieces was then reworked by hand.

C1 pieces have been sanded down with a P1200 sand paper (15.3 µm). Then a thin layer of Crystal resin has been applied to regenerate the glossy appearance. C2 pieces have been sanded-down by P120 (125 µm) sand paper, then P1200, then polished with a polishing paste and then by a soft-fabric sander and finally a jean-fabric polishing process. C3 have been sand-down by a P120 paper, followed by a polish-paste and a jean-fabric polishing process. Examples are provided in Figure 5.

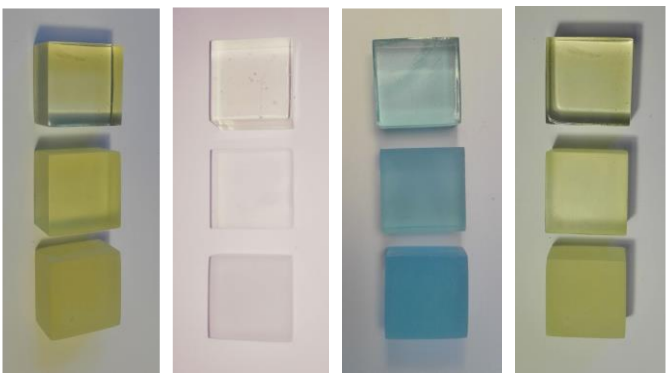

Figure 5: Close up of rectangles with different coarsness.

The sphere shape was achieved with a silicon mold of 40mm diameter, which contrarily to latex produces a very smooth surface. The diameter of the spheres is 40 mm. Essentially, the C1 spheres have not been reworked, except locally where the mold has the filling injection point. Light sand paper and Dremel work has been performed at this point (See next section). C2 spheres have been sand-down with P1200 paper then polished with a polishing paste then by a soft-fabric sander and finally a jean-fabric polishing process. C3 spheres have been sand-down by a P120 paper, followed by a polish-paste and a jean-fabric polishing process. Note that on C2 and C3, the injection point does not appear in the spheres. See Figure 6.

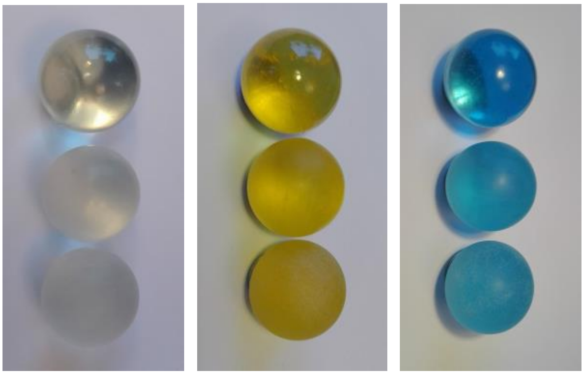

Figure 6: Close-up of spheres of different coarseness.

The complex shape *Plastique* was realized in clay first, then molded with liquid latex by using a paintbrush (many tries were performed before achieving the right mold). The mold was a sock mold, which can be used a single time. Coarseness levels have been generated similarly to the rectangle shape. See Figures 7 and 8. Two objects of the three coarseness levels were generated and served to create silicon molds. The objects were realized from those molds, which permitted to create objects of the adequate coarseness directly for C1 and C2 with the minimum of changes between realizations. Level C3 has been achieved by a similar process than rectangles.

Figure 7: Original clay version of the *Plastique* bust, the *complex object* of the collection.

Figure 8: From left to rigth; Original in clay, broken as per mold creation procedure; one of the liquid latex mold creation; Mold created with liquid latex and reinforced with fabric to avoid deformation; resin object after molding. Three of those objects were created and derived in three coarseness, then served as primaries for the silicon molds.

Figure 9: Image of the resulting collection.

3.2. Selection of resin ratios

In general, for all the different modalities, ratios have been chosen from a visual observation of rectangle shapes of 11 mixtures of two primaries viewed under ambient light. Three ratios were chosen in order to have an approximated perceptually homogeneous step. However, we can observed in the Figures above that this is not obvious on the pictures, and can vary with the illumination, viewing angle and shape. The color mix from transparent to color resins was technically relatively easy: We opted for already-colored resins, so the pigments are already uniformly mixed with an industrial quality. Ratio are in percent as B/T and Y/T: 100/0, 90/10, 80/20, 66.66/33.33, 0/100. This scale has been chosen to be relatively uniform in terms of appearance of color in the mix. The artist mentioned “Colored resins are transparent too, so there is no difference in transparency in those objects.” This is yet to be investigated as pigment presence clearly affect transmission of light.

White opaque resin is created by using 40 drops of white painting (Pebeo Céramic, semi-opaque, Laquée) for 60 mL of the Crystal resin. This painting is showing a lightfastness ***/I of the ASTM D5067 standard (pigments very robust to fading due to light). To create the colored to white objects, ratios are given in percent as B/W and Y/W 100/0, 83.33/16.66, 50/50, 16.66/83.33, 0/100. The gradient is referred to as more or less uniform. The artist stated that along this scale it would have been beneficial to create more samples, because the white resin makes the object opaque very fast, and there is a lot of possible appearance variations along this scale, more than the transparent scale above.

To create the samples from transparent to white, she used Crystal resin and drops of white painting. So that for T/W, the scale is created with 0 drops, 240mL/5d, 180mL/5d, 60mL/10d, 60mL/40d.

3.3. Difficulties of realization

In general, defaults are surface defaults and bubbles present in the resin. Bubbles does not escape from the resin because the injection point may be small and the quantity of matter is large. This is more visible for the sphere due to mold shape. In some of the spheres, some bubbles artifacts appear at the lower half surface.

The injection point of the sphere mold is almost invisible in some spheres, but appearing clearly in others. This area has been manually reworked. An alternative to correct for surface defaults of spheres could have been to attach the sphere to a hook and dip them into Crystal resin. However, this would have the drawbacks of creating a visible artifact in some transparent spheres, which would have served as cue to rate transparency in following experiments, so together with the artist, we decided to stay with more uncontrolled type of artifacts. Surface artifacts also include some brush marks for the coarsest objects.

We imposed some constraints on the complex object, as we wanted an object with complex light interactions and several thicknesses in the object. There were several tentatives and proposals. One of those was fishes in motion, with scales and volutes, which proved to be very difficult to mold with liquid latex, due to many fine details. A Viking warrior bust was proposed, but it was compact and there was not enough variability in material thickness, which is very important in perception of translucency. The choice of the woman body was a good compromise: It is a beautiful object, and it shows several variations of material thickness while still being technically acceptable to model without much variation from one instance to another. Quantities of material to mix, procedure and polymerization time were also part of the difficulties.

We still need to understand how the artist views her artwork. The artist appears to express different feelings about the result. Some dissatisfaction comes from the observation of irregularities in the manual realization of the surface texture and from defaults emphasized by the discovery of a new observation procedure (see next section). However, satisfaction comes for the distribution of colors in both sampling quality, which appears to be regular and beauty of the objects and optical effects generated. The artist mentioned that “This is handcraft; in fact, I could still spend 6 more months to realize better objects.”

4. Qualitative analysis of the interview

A series of interviews were conducted with the artist. The 14th of December 2017 was dedicated to the technical description of the object. The 24th and 30th of January and the 06th of February 2018 were dedicated to the description of the basic objects Rectangle and Spheres. We looked at all the collection and observed all pieces independently and in relation with the others. The transcript of these interviews has been separated into two groups. The technical information has been taken out, structured and reported above.

The rest of the transcript of these interviews have been studied according to the *grounded theory analysis*, following the recommendations of [4]. This methodology consists in six steps: Codification (convert transcript into code-words), Categorization (identify conceptual categories from the code-words), Co-linking (understand how the categories interact), Integration (redefine what this system describes, which can be different from what was originally intended), Modeling (reconstruct the dynamic of the phenomenon) and finally, Theorization. The result is a structured description of the content of the interviews. Note that once the categorization step is performed, there is a verification process, which aims at ensuring that the categories exist in the data. Typically, we go back to the transcript and verify that the data can fit into the categories.

The default analysis was still into this corpus, but was finally linked to the technical description, and reported above. Also, the feeling of the artist, that was one of the targets of the research, was dropped as a category and is presented together with the factual description of defaults.

The resulting theorization on the rest of the interviews is presented below, and put in relation two main phenomena: 1-The difficulty of communicating total appearance of materials, and 2-the instability of description depending on observation conditions. This is to be put in relation with the objects, but also to a methodology of evaluation that is created by the observer who is out of resources (An expert in the concept of total appearance had the semantic tools to describe the data very efficiently, but in a less rich way, see below).

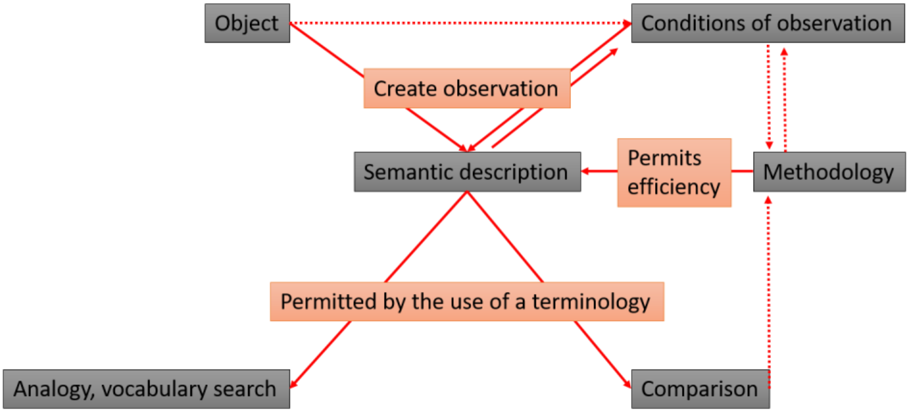

Figure 10: Semantic appearance description process. We observe that the semantic description depends strongly on the conditions of observation and is made stable by the creation of a methodology. The description is based on a vocabulary, that is not always obvious, and strongly based on comparison. We insist on the fact that this is not a model of perception, but a model of the data collected during the interviews.

Figure 10 is the resulting theorization rooted into the interviews content. In gray boxes, the categories that have been extracted from the research methodology, we verified their relevance and their empirical existence by performing the verification procedure. Their interaction is complex, but to us, a way to read this model is as follow: To provide a semantic description of the appearance of the objects, the object is put into a condition of observation according to a methodology, which permits analysis and comparison. The object is described according to these conditions and these methodologies in different ways. One way is the comparison to something else, the other way is to use descriptive vocabulary. The vocabulary is reduced, so there is a searching process involving analogy.

To give sense to this model, we must describe carefully those categories.

The Semantic description itself consists of tentatives to name, to describe. There are also semantic tentatives of general definition more or less successful, e.g. '*Matte: for paints or enamels that do not send back the light and hide suface defects and textures*'. One of the most interesting aspect is that there are many failures in the tentative '*I do not know how/what to say*'. We also observed that analogy was a major description strategy, and that defaults were often used as discriminative hints '*We can see the bubbles in this situation / for this object / for this transparency*'.

The Methodology is a convergence towards a stable, systematic, description process. Until convergence, there is often failure in the description. The convergence aims and permits faster interpretation, continuity in the description and generate a feeling of safety. It is interesting to note that the observer proposed methods for observation naturally, e.g. change light source, specify geometries, etc. but also to note that this convergence happens after a few tries only in both vocabulary and conditions. We also observed several tentatives of generalization, which is quite dangerous and usually only valid very locally in the object collection due to sample diversity.

The Conditions of observation are a predominant cause of instability and are probably the reasons for the need of a methodology. In this category, we include illumination source and optical effects, i.e. description depends on the light source. We include geometry of illumination, viewing angle, which determine strongly what is perceived. We also include the background on which the object is observed (e.g. dark or clear, but also scenes or objects). This situation have a very strong impact on all perceptual attributes!

The Object itself is a key information, yet it is very stable. What seems to influence is the shape, surface, size, but also specific light effect, such as halo projected on the floor for spheres.

Comparison permits to describe objects by reference to something else. We identify similarity and difference to an arbitrary chosen other object. We observe also a comparison based on changes, e.g. between sample N and N-1. There were creation of scales such as '*we see the opposite angle of the object*', '*we see a shape/shadow through the object*', '*we recognize an object that is behind*'. We observe also several instances of what we called a **naïve expression of a physical model**. Example of that is '*In this yellow object, we can see the structure through, but less clear than the blue variant'*, that express a practical understanding of absorption and scattering. We also observe a strong need for reference. Reference could take various form. It could be to see an arbitrary object through the object so description is based on its deformation. Reference could be the light, and how it is deformed within the object. Or it could be that the current is more or less [any adjective/name] than another object of reference, of the same shape or of different shape.

Analogy drove strongly the description due to absence of adequate vocabulary. We observe a need to invent or define a terminology that could be gradual. One observation is that color naming was very important, and include a lot of material related embedded aspects. Vocabulary was fairly rich, with more than 15 color names for objects that have basically two hues (e.g. *aquamarine*). Reference to color atlas also permitted to identify appropriate names, in particular color palette from the make-up industry, that contains a bit more relation to material and appearance than diffuse color atlas. Beside, analogical naming was a basic process, e.g. '*like water*', '*fog*', '*a veil*', etc. Complex appearance terminology was also used, e.g. *Matte, satin, glossy*; *Transparent, translucent, opaque*; *Opalescent and iridescent*.

This is **not** a general model, but only a structured observation of the content of the interviews of one artist performed in French and translated here during the analysis. A very easy example of the impossibility to generalize this model is that an expert in appearance described some objects very fast in terms of translucency, gloss, color and texture (e.g. *no texture, very translucent, blue, quite glossy*). This confirms that we surely do not want to pretend to a generalization of this model. Additionally, the corpus of objects is limited to simple theoretical objects made of a homogeneous material and of no specific use.

Nevertheless, this qualitative description model permits to formulate a few research observation. First, we need to investigate the relationship between observation conditions and constancy, as already identified in the literature, e.g. [10]. Semantic communication of appearance needs also to be studied further, so that the concept of appearance description becomes more familiar and easier to teach, but also that the semantic definition of appearance concepts are aligned with a scientific formulation if possible. The fact that there is a search for reference/comparison is a good hint that we surely can provide a measure eventually. We must put an effort in identifying the adequate references.

5. Conclusion

We introduced a collection of objects, which is intended for research on material appearance. We gathered technical data about the realization of these objects through interview of the artist and co-analysis with her. A model of the interview, which concerns the description of appearance, augments this factual description. Thanks to that, we formulated a few research direction for future research.

Acknowledgement

This work was supported by the MUVApp project N-250293, funded by the Research Council of Norway.

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