FORM-GIVING: EXPRESSING THE NONOBVIOUS

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ABSTRACT

The design of richly informative interfaces would benefit from an account of how visual forms convey information. In this paper we suggest that the study of *form-giving* in Industrial Engineering might provide a foundation for such an account. We present three studies of designed synesthesia, in which objects' forms indicate non-visible attributes such as taste or smell. These studies illustrate the rich possibilities for conveying information with form, possibilities which are routinely exploited in industrial design. We suggest that similar opportunities exist for interface design, and that further studies of form-giving may help in taking advantage of them.

KEYWORDS: Interface design, visualization, form-giving, affordances, ecological approaches

INTRODUCTION

Graphical interfaces allow information to be perceived visually rather than interpreted verbally. The graphics used in current interfaces, however, are relatively simple, having advanced little beyond those used in the original Xerox Star or Apple Macintosh. In part this reflects limitations of display technologies: Richer representations are beginning to appear with the advent of high-performance graphics workstations [2] and virtual reality systems [13]. More fundamentally, however, simple graphics seem to reflect the lack of an account describing how higher-level attributes of (potentially physical) forms can convey information about the attributes and affordances of computer interfaces.

In this paper, we describe ongoing research in the domain of *form-giving* for Industrial Design, and suggest that it may provide a basis for understanding the design of intuitively accessible computer interfaces. In particular, we describe a series of exploratory studies which demonstrate the ability of designers to convey surprisingly complex information through the forms they create [11, 12]. The results suggest that this ability does not depend solely on social conventions or literal physical similarities, but also on higher-level attributes of physical structure. Finally, we point to ways that interface design may benefit from an examination of form-giving.

Understanding Graphical Interfaces

There are few guides to the design of richly informative graphics for user interfaces. Excellent work has been done on the design of graphical displays of quantitative information and on visualization techniques for multidimensional data [e.g., 1, 9, 14], but such research is largely concerned with mapping data to the appropriate kinds of graphical dimensions (e.g., additive data should be represented by additive graphical dimensions) and with understanding the perceptual interactions among graphical elements. Neither domain is concerned with making the mapping between graphical elements and data self-revealing, instead it is assumed that prior learning or text labels will usually be necessary.

Other work has focused on the types of mappings that exist between graphical elements and their referents [e.g., 4, 5, 8]. This work is useful in helping to understand, broadly, how icons are interpreted by users and in pointing towards qualitative differences in the ways they work. Some of these schemes [e.g., 4] even offer relatively quantitative accounts for the effectiveness of metaphors in terms of the number of shared features between icons and their referents. Nonetheless, these theories do not explain, for instance, why one example of a trashcan icon may be more appealing and attractive than another. Nor are they generative: they only hint at strategies for creating new graphical representations. Most fundamentally, they assume that graphical elements map to their referents by way of some real-world referent. As graphical interfaces become environments in their own right, however, it often seems more fruitful to think of graphical elements *expressing* their referents more directly.

Graphic artists are often concerned precisely with how to express large amounts of information in intuitively-accessible ways. A well-designed logo, for instance, provides far more information than that conveyed by its textual elements alone (if there are any). Clearly such skills are valuable for successful interface design. It is worth noting, however, that designing interfaces presents significant new challenges to graphic design. Graphic design has traditionally involved static marks on a twodimensional medium. With the trend for interfaces to model inherently dynamic, three-dimensional worlds, the contributions of graphic designers may increasingly be complemented by those of industrial designers.

Form-Giving in Industrial Design

Industrial designers produce the specifications for manufacturing the myriad of mundane physical artifacts that surround us – doorknobs, coffeepots, flashlights and automobiles. In performing their jobs, they require good technical and technological knowledge to work with specialized electrical and mechanical engineers. But they also must concern themselves with the physical forms artifacts will take, with shaping them so that they are understandable and usable. This is the domain of form-giving.

Form-giving is concerned with the interfaces to industrial design products. Like human-computer interface design, the primary concern is with the surface appearance of products, the ways they present themselves to users. However, just as interface design may have ramifications that extend far beneath appearances to the basic functionality of the system itself, so does form-giving merge with concerns about functionality and construction. It is not enough to design a coffee maker that heats water to the correct temperature and pours it though the grounds at the correct rate, for instance. It must also be designed so that it is ergonomically correct for users, and so that its controls fit with users' desires. These concerns may have profound implications for the technologies used and how they are put together.

Beyond a consideration of ergonomics and controls, form-giving is concerned with designing the appearances of objects so that they convey information about themselves. Ideally, artifacts will make a wide range of information available to potential users, enabling them to answer questions that range from the concrete to the general:

- What is the artifact for? What functions does it perform?
- How much does it weigh? Is it fragile? Complex? Powerful? How do I pick it up, or take it apart?
- Is it meant to be fun, or serious? Is it a toy, is it for children, amateurs, or professionals?
- What socioeconomic community is it meant for? Is it meant to appeal to youth fashion, to impress the rich and powerful, to seem comfortably home-spun? What will this artifact say about me?

It should be clear that these are sorts of questions are also relevant for computer interfaces, and that the ability to shape objects that convey the information necessary for their answers is relevant to designers of graphical user interfaces. It should also be clear that, insofar as form-giving is successful, traditional psychological, sociological, and anthropological accounts would focus on social conventions, experience, and memory in accounting for this success. We argue that these accounts are incomplete, and support our claim by showing that designers can create mappings between forms and information that are implausible from social or cognitive perspectives.

Designing Synesthesia

In the following, we describe a series of studies that explore industrial designers' ability to create forms to convey non-obvious information. In each of these studies, designers were asked to design the visible form of an artifact to suggest its non-visible attributes. In the first study, the task was to design portable tape players to express the music they would play. In the second, dessert packages were designed to indicate the flavours and textures of the desserts they would hold. Finally, the third study explored designers' abilities to express unfamiliar scents using forms.

Each of these tasks can be seen as an exercise in designed synesthesia , in which artifacts are created that allow people to see music, tastes, or scents. For the purposes of this paper, however, the focus is not on matching information from different senses [though see 10, 11, 12], but more broadly on the ability to express complex information.

We used basically the same methodology for each of the three studies. Third-year undergraduate industrial design students are given the design tasks as an assignment in a 6-week practical design course. From the forms that they produce, we choose, with the help of several professional designers, a subset that are judged to most effectively express the relevant information. This is tested by asking a different group of students to match the forms to the original stimuli. This allows us to empirically test the success of their designs.

In what follows, then, we describe each of these three studies in turn. We present all three, despite their basic similarities, both in order to indicate the generality of the results and because they vary in the degree to which they are open to charges that cultural conventions are the basis for their success.

STUDY 1: CASSETTE PLAYERS THAT EXPRESS MUSIC

For this study, each of the 101 students attending our practical design course was assigned one of nine musical pieces representing artists of various styles (see Table 1) and had to design a portable cassette player expressing this music. A group of established artists picked the five most effective designs for each of the nine styles, making a total of 45 stimuli to be used in the subsequent test (see Figure 1).

In the test phase, students were instructed to listen to music on a cassette player and choose a model that they felt best expressed the stimulus music. For each choice, they were presented with one of the five models designed to express that style, and two distracters chosen randomly from models meant to express different styles. Each subject was tested on each of the 45 stimuli.

In order to test the degree to which judgements might reflect an artists' "image," as represented in videos, *Figures unavailable for PDF – sorry!*

Philip Glass Dolly Parton Prince

Figure 1: Examples of the model cassette players used in Study 1.

advertisements, album covers and the like, we added a second condition in which students were presented with stylistically similar music by different artists. So, for example, where the original artist for a particular group of designs was originally Philip Glass, we tested the second group of students using music by Steve Reich. Ten subjects were tested for each condition, for a total of 20 students in all.

Results

Table 1 shows the number of times the models designed to represent a particular style of music were actually chosen for that style. Overall, subjects who heard the original music to which the designers had listened chose the correct model 50 out of 90 times (56%); subjects who heard stylistically similar music made 55 out of 90 (61%) correct choices. Both groups' performances were above the chance level of 33% correct.

Subjects judging music which was similar to that listened to by the designers did as well as those listening to the original music. This indicates that the designs did not rely on the visual symbols employed by particular artists (e.g., logos). They may, however, have relied on the visual style of communities associated with particular types of bands. We tried to reduce the possibility of these wider effects of convention in our next task.

Table 1: Correct Matches of Music to Models*

Original Artists	# Correct	Similar Artists	# Correct
Motörhead	10	Riot	10
Mozart	8	Rachmaninov	5
Beatles	4	The Kinks	8
Dolly Parton	7	Tammy Wynette	4
Philip Glass	6	Steve Reich	5
Prince	5	Jill Jones	6
Bill Haley	4	Chubby Checker	5
Andre Hazes	4	Heikrekels	5
U2	2	The Sound	7

STUDY 2: THE TASTE OF DESSERT PACKAGES

For this study, we obtained samples of ten different desserts from Campina, a food company in the Netherlands. The task we gave the 150 students in our practical design course was to design packaging that expressed the various tastes through its form and colour.

Students were divided into groups of ten such that each student in a group had a different taste for which to design packaging. The desserts were presented to students in identical white plastic containers without any graphics, and students were encouraged to taste all the deserts to aid in differentiating their tastes from the others.

The design exercise was divided into three parts to encourage students to rely on their senses, rather than on language or social conventions. In Part 1, they were asked to make colour sketches or models to express the impressions and associations that the taste and consistency of the dessert elicited. In this stage, they were encouraged not to think of the packaging, but of the form and colour which best expressed the taste and consistency of the dessert. In Part 2, they had to visualize the method of eating the dessert as well as the atmosphere or ambience in which it would be eaten. For example, they had to think about whether it would be served in a dish or a bowl, whether it could be served with a spoon or poured, whether it would be a quick meal or a part of an elaborate dinner ritual, etc. Again, this exercise had to result in sketches or models. Part 3 involved integration of the findings of Part rice milk raspberry pudding strawberry-banana yoghurt drink

Figure 2. Examples of the model dessert packages used in Study 2.

1 and Part 2 into a design of the final packaging. Limitations enforced by the choice of material and the manufacturing process had to be taken into consideration in the final design.

Out of the 150 model packages that were thus produced, a group of experienced designers chose a subset of 30 designs, three for each dessert, which they thought best expressed their tastes (see Figure 2). This subset was used in the subsequent test in which different students tried to match the packaging to the desserts.

The methodology we used to test the designs was similar to that of the previous study. Subjects were asked to taste a dessert and choose one model from three alternatives: the target designed to express that taste, and two randomly selected models (the distracters) designed for other tastes. In all, each subject had to choose 30 models, 3 each for the 10 tastes. Ninety designs were therefore required for this study (30 targets chosen by designers and 60 distracters chosen randomly out of the non-target designs). Sixteen students from the Faculty of Architecture participated in the study for a small fee. These students had experience with form and colour exercises, and thus were prepared to deal with the novelty of the packaging and the exercise.

Table 2: Correct Matches of Tastes to Models*

Desserts	Target Designs			Total
rice milk	15	12	10	37
strawberry-banana yoghurt drink	13	13	11	37
vanilla pudding	14	12	10	36
cappuccino bavarois	15	14	7	36
raspberry pudding	15	13	8	36
semolina porridge	15	10	9	34
yoghurt drink	13	10	9	32
yoghurt	15	12	4	31
vanilla cottage cheese	13	9	9	31
macaroon custard	11	7	3	21

*maximum 16 per cell, 48 total; chance 5.33 and 16

Results

The results of the matching are shown in Table 2. The percentage correct choices is 61%, again above chance performance of 33%.

This study demonstrates that designers were able to use color and form to convey information about the taste and consistency of desserts. Color and form both seem to play important roles in conveying this information. In a subsequent study, we assessed subjects' abilities to match models to taste in two new conditions. In the first, subjects wore spectacles smeared with petroleum jelly so that shapes were indistinguishable while color information remained; in the second, they viewed the models under sodium lighting, which makes colors indistinguishable while preserving shape information. Only the 10 designs which scored the best (87% correct overall) in the original study were used. Removing either shape or color information degraded performance, though remained significantly above chance. When judgements relied on color alone, an average 75% correct choices were made; when they relied on shape alone, performance fell to 66% correct. Both color and shape contributed to the ability of these forms to convey information.

The mappings between tastes and designs in this study seem less susceptible to influences of social conventions or stereotypes than those between musical styles and cassette players used in the last. Instead, many of the designs rely on a fairly literal mapping of shape and color. For instance, several of the forms meant to express the vanilla and raspberry puddings and the semolina porridge seem to reflect the semi-fluid consistency of these desserts; while the colours used for many of the models seem those of the ingredients themselves. These mappings may indicate some reliance on social conventions, as many food products contain artificial colors and thickeners to meet peoples' expectations. In any case, insofar as these results are due to the container models mimicking their intended contents in a straight-forward way, they are less interesting than if they depend on more abstract visual features. For this reason, we designed a third study in which mappings that relied either on physical similarity or social conventions seem implausible.

STUDY 3: SEEING SCENTS

In this study, each of the 70 students of our practical design course received one of nine synthetic scents and had to design a small coloured sculpture expressing this scent. None of the scents are in common usage, and thus we expected them to be unfamiliar to students. In addition, none of the scents were so unpleasant to elicit feelings of repulsion. The students in this exercise knew that different scents were used but not how many, nor were they allowed to smell other scents.

As with the previous studies, a team of expert designers chose a subset of the sculptures which seemed to best express their target scents. In this case, nine sculptures were chosen, three for each of the scents shown in Figure 3. Fifteen subjects, tested individually, were shown all nine sculptures placed randomly on a table. For each scent, subjects were given a test tube containing a scent strip to smell and then asked to choose from the nine sculptures one which best expressed this scent. The order of scents was counterbalanced across subjects.

Results

The results of the matching are shown in Table 3. The percentage correct choices is 78%, again above chance.

Again, designers were able to convey information using color and shape about aspects of an object that are usually thought to be non-visible. In this case, however, influences of cultural conventions (as might have occurred in Study 1) or direct physical resemblance (as might have accounted for the results of Study 2) seem unlikely. The scents used were synthesized and not widely encountered in concerning their visual portrayal could explain the results. Similarly, while physical attributes of the desserts design of model packaging, such a literal mapping would appear impossible between scent and form. Instead, it seems that designers were able to directly employ high-level features of form and color to convey information about similarly

Table 3: Correct Matches of Scents to Models*

Scents	# Correct
Amylacetate	12
Bornylacetate	12
Lacton c9gamma	11

* maximum 15 per cell; chance ~ 5

Figure 3. Sculptures expressing scents used in Study 3. (top-bottom: amylacetate; bornylacetate; lacton c9gamma)

high-level, semantic features of the scents.

DESIGNING HIGH-LEVEL INFORMATION

In sum, these studies demonstrate that designers have powerful abilities to convey complex, non-obvious information using shape and color. In addition, they appear able to do so without relying solely on cultural conventions or on literal similarity. Although it is difficult to rule out the effects of convention entirely, they seem minimal, at least in the case of the sculptures designed to express scent. Instead, designers seem to use high-level features of their sculptures to indicate high-level attributes of the target stimuli – for instance, by using angular surfaces to indicate piercing odours.

Clearly it would be desirable to characterize explicitly the visual characteristics used to convey information about target stimuli. Unfortunately, the design of these tasks makes it difficult to do so. One of the strategies we used to discourage students from relying on cultural clichés in their designs was to bypass verbal descriptions of relevant attributes or features of the target items. Instead, they were explicitly told to rely on their experience of the music, tastes, or scents, and to try to express this experience in their designs. While this tactic appears successful, it makes identifying the relevant visual information difficult, simply because we do not know explicitly what the relevant dimensions might be.

We plan to address this issue through a set of experiments in which forms are designed to express identifiable dimensions. For instance, students might be told to design two artifacts, each conveying a different extreme value along dimensions such as weight, size, complexity, speed, etc. By targeting their designs on explicit dimensions, and by comparing the results of their designs, we hope to be able to characterize strategies for conveying these attributes.

The ability to identify high-level form attributes that convey information about such dimensions would potentially be of great value for interface design. Such dimensions would allow the creation of parameterized icons [3, 7] in which icons are created which vary around a central exemplar along dimensions relevant for their underlying referents. For instance, text files might all be represented by a stack of paper, but these could be varied to indicate size, complexity, speed of processing, etc. The possibility of creating parameterized visual icons would contribute substantially towards the creation of interfaces that provide rich information about their attributes and the possibilities for action they offer [6].

In the meantime, these experiments illustrate the potential role that form-giving might play in interface design. Until the visual dimensions that convey high-level information can be explicated, form-giving is essentially a craft skill. But it is one that could already be employed more widely in computer design, not only of the physical housings of today's machines, but in giving shape to the virtual worlds they contain.

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