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Quispel, Annemarie; Maes, Alfons; Schilperoord, Joost

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Graph and chart aesthetics for experts and laymen in design: The role of familiarity and perceived ease of use

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Annemarie Quispel¹, Alfons Maes² and Joost Schilperoord²

Abstract

We investigated the relationship between familiarity, perceived ease of use, and attractiveness of graph designs in two target groups: experts and laymen in design. In the first study, we presented them with a variety of more or less common graph designs and asked them without any additional task to evaluate their familiarity, attractiveness, and perceived ease of use. They judged the familiarity and ease of use of the graphs similarly, but they differed in their attractiveness judgments. Familiarity and perceived ease of use appeared to predict attractiveness, but stronger for laymen than for designers. Laymen are attracted to designs they perceive as familiar and easy to use. Designers are attracted to designs between familiar and novel. In the second study, we asked designers and laymen to first perform an information retrieval task with the same graphs and then rate their attractiveness. Laymen's appreciations remained the same, but the designers' judgments of attractiveness were different from those in study 1. Correlational analyses suggest that their attractiveness judgments after use were affected not by actual usability but by perceived ease of use of the graphs.

Keywords

Graphic design, data visualization, graphs, aesthetics, familiarity, ease of use

Graph aesthetics

Historically, data visualizations were primarily meant for use by statisticians and scientists. Their designs were aimed at an efficient and accurate reading of the data in analytical tasks. But data visualizations are growing popular. Bringing quantitative information to the attention of larger audiences may call for other qualities than accuracy and efficiency alone, such as attractiveness. This study addresses the aesthetic appeal of data visualizations, or graphs, which are not only becoming increasingly popular but also show a growing variation in designs in everyday mass media. We investigated the aesthetic judgment of graphs within two target groups: graphic designers, as producers of data visualizations, and laymen in design, as their audience. Graphic designers are trained to tailor their designs to the needs of their audiences. Therefore, the

main question we address in this article is the extent to which the two groups share opinions with regard to the aesthetics of graphs.

The term aesthetics has had several connotations through the centuries. Originally, it referred to the study of sensory perceptions, but since the 18th century it is commonly conceived as the study of beauty and fine art. Researchers studying displays like graphs

¹Academy of Fine Art and Design AKV St. Joost, Avans University of Applied Sciences, Breda, The Netherlands

²Tilburg Center for Cognition and Communication (TiCC), Tilburg University, Tilburg, The Netherlands

Corresponding author:

Annemarie Quispel, Academy of Fine Art and Design AKV St. Joost, Avans University of Applied Sciences, Beukenlaan 1, 4834 CR Breda, The Netherlands.
Email: a.quispel@avans.nl

use many terms to refer to the aesthetic value of these displays: sensory pleasantness,¹ beauty,² and attractiveness.³ All of these terms refer to a similar aspect of displays. But whereas the term “beauty” seems more appropriate for visual “displays” that are not directly intended for use (like works of art or natural sceneries), the terms “visual pleasantness” and “attractiveness” seem more appropriate for evaluating functional visualizations as the ones we focus on in our studies. Therefore, we prefer to use “attractiveness” to refer to the main topic of this article.

With the growing interest in data visualization and its aesthetics in design and artistic practices, researchers in the information visualization community (specialized in visualization of large, complex data sets) also have come to recognize and propose aesthetics and the interplay between aesthetics and usability as an important research subject.⁴ Several theoretical models have been proposed to bridge the gap between usability and aesthetics.^{5–8} These models share the viewpoint that the visualization community and the artistic community could benefit from each other’s knowledge on functional and visual qualities, but they shed little light on which variables actually contribute to aesthetic experience, and how. On the other hand, several empirical studies attempting to reveal such aesthetic factors have been conducted and show divergent approaches toward the notion of aesthetics.

Some studies attempt to reveal objective perceptual variables affecting aesthetic experiences. For example, the difference in preferences has been studied between “embellished,” pictorial graphs, and plain abstract graphs.⁹ It appeared that participants’ descriptions of the information in the two graph types were equally accurate, but that pictorial, embellished types were recalled better. Preferences for two-dimensional (2D) versus three-dimensional (3D) bar graphs have been studied,¹⁰ showing that people prefer 2D versions for immediate, analytical use, but chose to use 3D versions when they have to show quantitative data to others and want them to be remembered. Some studies have also investigated the influence of modern painting like color palettes on appreciation of topographic maps.¹¹ Rating and ranking tasks and skin responses showed that participants’ emotional responses can be systematically measured and analyzed to study the effect of aesthetic criteria. In another line of research, studies are conducted that aim to develop ways to attract viewers’ attention and to engage them in visualizations by applying aesthetically pleasing non-photorealistic rendering styles to data visualizations.^{12,13}

Other studies are based on the assumption that people are attracted to clearness. In these studies, aesthetics is treated as a characteristic contributing to

clarity and through clarity to visual appeal. In models within computer sciences, for example, aesthetic quality is defined as a set of quantifiable metrics. These models use algorithms to measure features such as order, balance, symmetry, or complexity.^{14,15} In information visualization, the term “graph aesthetics” commonly refers to heuristics for enhancing the readability of node-link diagrams, for example, by minimizing the number of bends.

The influence of such graphical variables on aesthetic perceptions is measured in several ways. Some studies capture aesthetic experiences objectively, measuring skin reactions associated with pleasant feelings¹¹ or activity in brain areas associated with rewarding feelings using magnetic resonance imaging (MRI).¹⁶ Most studies in the fields of data visualization, product design, and human–computer interaction (HCI) use subjective measures of preference or liking. In these studies, aesthetic perceptions are measured by asking participants to rate the beauty or attractiveness of visualizations,^{14,17–19} to rank visualizations from least to most preferred,¹⁷ or to choose one of several designs for use in a specific situation.^{10,19}

These studies conjecture that aesthetics is to be found first and foremost in properties of the object itself. At the same time, there is growing awareness that the way people’s aesthetic evaluation of graphs may be influenced by the way in which they interact with graphs. In this study, we define aesthetics as the subjective evaluation of a graph’s attractiveness. We do not attempt to reveal properties of graphs affecting their attractiveness. Instead, we investigate how people’s experience with graphs may affect their attractiveness. In the remainder of this article, we will discuss the role of three variables potentially affecting the aesthetic evaluation of graph designs: familiarity, perceived ease of use, and actual use. In particular, we will focus on how these variables differently affect judgments of experts and laymen in design. After that, we present two empirical evaluation studies. In the first study, we asked experts and laymen in design to evaluate the familiarity, perceived ease of use, and attractiveness of a set of more and less conventional graph designs. In the second study, we investigated the effect of actual usage of the graphs in an information retrieval task on evaluations of attractiveness by both groups. We conclude with a discussion of the results.

Familiarity and aesthetics

Ancient and modern theories about the nature of beauty make different predictions about the relationship between prior exposure or familiarity and aesthetics or attractiveness.

Classical theories about the nature of beauty advocate a balance between extremes in order to achieve appreciation and attention, for example, between chaos and order, expectation and surprise.²⁰ In ancient Greece, Plato (in the *Statesman*) defined beauty as “a standard removed from the extremes,” and according to Aristotle “a master of any art seeks the intermediate.”²⁰ Also during the Renaissance, beauty was believed to be found in an equilibrium between mutually counterbalancing factors.^{21,22} Novelty, originality, and variety were supposed to be necessary to make things lively, whereas familiarity, coherence, and economy would be necessary to prevent chaos. The idea of balance between extremes can also be found in more recent models where aesthetic preferences are described in terms of a balance between novelty and familiarity. For example, evolutionary aesthetics²³ propose that human beings derive aesthetic pleasure from phenomena that help them survive. On the one hand, they are attracted to familiar things because familiarity, as a result of repeated exposure, facilitates perceptual organization and helps them to bring order in a complex world.^{23,24} On the other hand, people are also attracted to new, unusual things, presumably because novelty facilitates learning, which is also a vital capacity for survival.²³ There is some experimental evidence for the assumption that aesthetic pleasure can be found in a balance between familiarity and novelty. Within experimental psychology, Berlyne²⁰ carried out several empirical studies to test the balance-between-extremes theories, including the balance between familiarity and novelty. Although his studies showed some evidence of the influence of both familiarity and novelty on aesthetic pleasure, several studies remained inconclusive and some results also have been contradicted by other studies.^{25,26} Studies in product design have shown that people indeed prefer product designs that balance typicality (a notion related to familiarity) and novelty.¹⁸ Participants were asked to evaluate a series of designs in terms of good (typical for the product category, for example, “teapots”) or poor examples of the category in question and in terms of aesthetic appeal. These studies showed that people prefer novel designs as long as the novelty does not affect typicality. In other words, a teapot that is unlike other teapots is nice, but only if it still resembles a teapot.

Other theories, however, predict that attractiveness linearly increases with increasing familiarity. For example, according to Zajonc,^{25,26} it is merely repeated exposure to a stimulus that increases its aesthetic appreciation. According to Reber et al.,²⁴ beauty is grounded in processing experiences. They propose that repeated exposure to a stimulus (which leads to familiarity) makes perceptual and cognitive processes easier and more fluent and that this fluency is

perceived as pleasing. Familiarity could also be aesthetically pleasing because it signals that a stimulus is probably not harmful.^{25,26} Dislike of novel stimuli could be a precognitive biological mechanism that makes people cautious in the case of potentially harmful stimuli. Several empirical studies have also supported this proposition that the more fluently someone can process an object, the more positive his or her aesthetic judgment is (for a review of such studies, see Reber et al.²⁴). This would suggest that people generally prefer familiar visualizations.

How can we apply these theories to the difference between experts and laymen in design, the two target groups we asked to rate the familiarity and attractiveness of a series of more or less conventional and novel graph designs? Familiarity is supposed to be the result of previous exposure. Design experts are accustomed to looking at and working with a variety of visual displays on a daily basis. Therefore, we expected that overall, they will perceive all graph designs as more familiar than non-designers. However, as the relative frequency of each graph should be the same for both groups, we expected that the rank ordering of the various graphs on the familiarity scale will be similar.

As for the relationship between familiarity and attractiveness, classical theories predict that both groups find designs in between familiar and novel the most attractive, whereas processing fluency theories predict a linear positive relation between familiarity and attractiveness. But there are reasons to expect differences in the evaluations of attractiveness between the two groups. Studies into aesthetic experiences of art works have shown differences between experts (with art training) and novices (laymen) in aesthetic preferences, with novices preferring simple and prototypical stimuli and experts preferring complex and novel stimuli.²⁷ This is also suggested by Reber et al.: they propose that aesthetic pleasure increases with increasing processing fluency, but acknowledge that in some cases people appear to be attracted to more complex and novel stimuli. It has been suggested that these differences may be caused by the fact that experts tend to consider not only the aesthetic experience itself (the pleasing of the senses) but also the aesthetic value of stimuli, in terms of what they consider good or bad taste.^{28,29} As a result, they may evaluate familiar stimuli more negatively than novel ones, despite the high processing fluency.²⁴ Although these studies focused specifically on the appreciation of works of art, we assume that similar mechanisms apply in design. Designers are well trained in processing visual information and tend to attach more value to visual appeal than to functionality.³⁰ They may therefore consider familiar designs less appealing because of a lack of originality and visual challenge. For this reason, it may be

expected that designers are more attracted to novel data visualizations than laymen and that the latter appreciate familiar designs.

Familiarity, attractiveness, and perceived ease of use

Several studies have shown relationships between aesthetics and perceived ease of use. In these studies, a distinction is made between perceived ease of use of displays based on visual impressions only, and perceived ease of use after displays has actually been used to carry out a certain task. Most of the studies describing relationships between aesthetics and (perceived) usability are situated in the field of HCI. In HCI, usability not only involves understanding and interpretation but also interaction with the design through a computer interface. In our study, we evaluated the perceived ease of use of static graphs without use, based on visual impressions, and after use in an information retrieval task. Because carrying out a task with a static graph does not imply interaction, but only interpretation of its informational content, we measured ease of use by assessing ease of interpretation.

The first study in which a relationship was shown between aesthetics and usability is Kurosu and Kashimura's.³¹ They asked participants to rate the perceived ease of use and the beauty of several user interfaces (without having to use them in functional tasks) and found that perceived ease of use was positively correlated with perceived beauty. The authors then calculated the "inherent usability" of the interfaces, based on design characteristics believed by interface designers to enhance usability, such as certain arrangements and groupings of keys. They only found a significant correlation between perceived ease of use and the usability measure of familiarity.

Tractinsky et al.³² tested the relationship between aesthetics and perceived ease of use before and after actual use of Automatic Teller Machine (ATM) layouts. They asked participants to rate the layouts' aesthetics and perceived usability before use and found high correlations between aesthetics and perceived usability. Then, participants performed tasks with the layouts, while usability—task completion times—was manipulated with dysfunctional buttons that caused delays. Results showed that perceptions of aesthetics and usability were not affected by these usability manipulations if participants worked with layouts that they already found highly aesthetic before use. They perceived the interfaces as equally aesthetic and equally usable as before use.

An explanation for the relationship between these perceptions of aesthetics and usability may be found

Figure 1. Proposed relationships between familiarity, perceived ease of use, and attractiveness.

in the concept of familiarity. As we described in the previous section, processing fluency theories submit that familiar things are found attractive because familiar things are perceived as easy to use (Figure 1). Tractinsky et al.³² did not measure the familiarity of the displays they evaluated. Perhaps participants in their study considered designs more attractive that were also more familiar to them and, as a result of this, were perceived as easy to use. This explanation is supported by the high correlation found between perceived ease of use and familiarity in Kurosu and Kashimura's study.³¹

In our studies, we started from the strong link between familiarity and ease of use as found in the literature and studies described above. The more familiar devices are, the more they are perceived as easy to use. Therefore, we expected strong correlations between familiarity and perceived ease of use, both for designers and for laymen. However, the focus in our studies concerns the way familiarity and perceived ease of use are associated with evaluations of attractiveness. Here, we expect to find differences between laymen and designers. Based on processing fluency theories and Tractinsky et al.'s³² study, we expected familiarity and perceived ease of use to predict a large amount of attractiveness values for the laymen. Based on studies showing differences between novices and experts,²⁷ and a previous study into preferences of designers and laymen,³⁰ we expected familiarity and ease of use to be stronger predictors of attractiveness for laymen than for designers. Also based on studies showing differences in preferences between experts and novices, we expected designers to prefer more novel designs than laymen. Therefore, we expected the relationship between familiarity and attractiveness to show an inverted U-shape for the designers (designs between familiar and novel being found the most attractive). For laymen, classical theories give reason to expect an inverted U-shaped relationship, whereas processing fluency theories predict a linear relationship.

Finally, we wondered whether actual use would affect perceptions of attractiveness and whether differences would occur here between designers and laymen.

The results in Tractinsky et al.'s study showed that perceptions of aesthetics and usability were not affected by use, even if using the devices was frustrated (by adding dysfunctional buttons). Therefore, we expected that fairly simple, common tasks with the graphs (as we asked the respondents to perform in study 2) would not change laymen's and designers' judgments.

Research goals

Our main goal in this study was to investigate, for design experts and laymen in design, the relationships between attractiveness, familiarity, and perceived ease of use. On the basis of the considerations given above, we had the following expectations.

1. We expected designers to be more familiar with all design types than laymen in design.
2. We expected rankings of familiarity ratings to be similar for both groups.
3. Correlations between familiarity and perceived ease of use were expected to be significant for both groups.
4. (a) We expected familiarity and perceived ease of use to be predictors of attractiveness for both groups. The two factors were expected to be stronger predictors for laymen than for experts.
(b) For laymen, we expected either a linear or an inverted U-shape relation between familiarity and attractiveness. For designers, we expected an inverted U-shape relation.
5. We expected actual use of the graphs not to affect judgments of attractiveness.

We address the first four hypotheses in study 1, where we asked participants to rate the familiarity, perceived ease of use, and attractiveness of a set of graph designs. The last hypothesis is addressed in study 2, an explorative study in which we asked participants to perform an information retrieval task with the graphs and then to rate their attractiveness.

Evaluation study 1

We asked designers and laymen to rate the familiarity, attractiveness, and perceived ease of interpretation of 12 more and less conventional graphs in an online survey. These variables were measured using a 7-point Likert scale.

Method

Participants. Overall, 272 laymen in design (79 women) and 44 design experts (28 women) participated in the survey. Laymen data were collected using

the crowdsourcing service CrowdFlower (www.crowdflower.com), a platform of which an evaluation study has shown that it is suitable to obtain high-quality data,³³ especially for relatively easy tasks such as a rating task. CrowdFlower uses a built-in quality control system banning respondents who have shown to yield unreliable results. The survey was taken by participants in 15 Western countries (for US\$0.30 compensation). The results of 23 respondents were removed because they had filled in exactly the same ratings for each question or because they indicated to have design experience or education. Design expert data were collected by sending an email with an invitation to take part in the survey to students at the departments of graphic and visual communication design in Cambridge (UK) and New York (USA). Participation was voluntary. The majority of the laymen (62%) and the designers (80%) were between the ages of 18 and 34 years. Of the laymen, 58.7% followed vocational (19.7%) or university/polytechnic (39%) education and the others high school (41.3%) as their highest educational level. All of the designers followed university/polytechnic studies. In the analyses, we only included the results from laymen with educational levels similar to those of the designers (university/polytechnic, $n = 97$; 30 women).

Materials. We designed a set of 12 static graphs (Figure 2). The graphs represented a combination of quantitative and nominal data, thus mirroring the majority of graphs in newspapers and magazines (think of election results or budget cuts). The 12 graph designs were chosen to reflect the diversity of visualization techniques with which a combination of quantitative and nominal data can be represented. The construction of a graph is determined by the dimensions of the plane ("surface") used to represent quantity (e.g. length or area) and by the particular way in which these dimensions are portrayed (e.g. rectangular or circular). The test materials contained both graphs using length and graphs using area to represent quantity, and both circular and rectangular forms. We decided not to use line graph designs since these encode different types of data (ordinal or interval data) and do not offer much variation in design.

In a pilot study, we checked the distribution of conventional and new designs by counting the frequency of the graph types in everyday mass media. These counts mirror the level of exposure of people to each of the graphs and thus guarantee a broad distribution of the familiarity ratings in our data. Over a period of 6 weeks (April–May 2014), we counted 136 graphs representing nominal $\times$ quantitative data in three Dutch national newspapers (*Volkskrant*, *NRC*,

Figure 2. Tested graphs and their proportions in the pilot study count.

Telegraaf) and three opinion magazines (*Time*, *Elsevier*, and *Groene Amsterdammer*). As shown in Figure 2, six of the graph designs were used in the media, some frequently and some rarely (57% bar graphs, 16% pie graphs, 10% divided bars, 8% donut charts, 7% bubble charts, and 2% semi-circles); the other six were not found in the pilot study at all.

The 12 graphs were all designed using an identical color palette, and each graph represented the same six proportions. So, they all represented the same data set, but the graphs were not related to a specific functional context enabling participants to interpret the data. No numbers or scales were included, to make sure that judgments were based only on the visual structure of the graphs. The pictures of the graphs measured 500 pixels (width) $\times$ 510 pixels (height). As we used an online survey, we had no control over the sizes of the screens on which the survey was taken.

To measure attractiveness, familiarity, and perceived ease of use, 7-point Likert scales were used. The attribute familiarity was chosen to capture the degree of exposure of respondents to the graphs. We opted for attractive as an adequate generic option to elicit an aesthetic judgment about functional visualizations as the ones we presented to them. Finally, as explained above, we opted to inquire about ease of interpretation to gauge their judgment about the perceived ease of use of the graphs. We realize that single-item measures may be less valid than multi-item construct measures. Still, we considered possible disadvantages less important than the danger that repeated exposure to too many questions could result in overloading respondents.

Procedure. The survey started with written instructions. The instruction explained that participants were about to look at graphs as they could appear in a journal or magazine or on a website and that each graph could be used to represent the same kind of data, for example, election results per political party or budget

cuts per public sector. The instructions were followed by a practice example, after which the respondents went through 12 screens with the graphs (presented in a random order) at their own pace (by pressing the forward button). Each screen presented a graph centered at the top without any legends or text labels. At the bottom of the screen, the same three 7-point Likert scales were presented in the same order (Figure 3).

The scales ranged from “strongly disagree” to “strongly agree.” Participants were asked to indicate to what extent they thought each graph was familiar, attractive, and easy to interpret. The survey could only be completed when each question was answered. After the rating task, participants’ personal information was collected with questions about age, gender, nationality, and education. It took participants about 5 min to complete the survey.

Results

Table 1 shows the ratings for each of the three variables for laymen and designers, ranked from the highest to the lowest ratings. The results confirmed our hypotheses.

Familiarity and perceived ease of use ratings. As it becomes apparent from Table 1, the graph types that were used most frequently in our mass media survey are highest in the familiarity rankings, followed by the less frequently encountered types.

1. The designers’ familiarity ratings were overall higher than the laymen’s ratings (designers: $M = 4.99$, standard deviation (SD) = 0.80; laymen: $M = 4.61$, SD = 1.04; $t(139) = 2.13$, $p = .021$).
2. Designers and laymen judged the familiarity of the graphs similarly, as evidenced by strong correlations between the ranking orders according to their familiarity ratings: $r = .95$, $p < .001$.

Figure 3. Screen example from survey.

Table 1. Mean attractiveness, familiarity, and ease of interpretation ratings per graph for laymen and designers (SD) on a scale of 1–7.

Familiarity		Ease of interpretation		Attractiveness	
Laymen	Designers	Laymen	Designers	Laymen	Designers
6.52 (.82)	6.86 (.35)	6.53 (.69)	6.57 (.85)	5.71 (1.22)	5.39 (1.57)
6.44 (1.02)	6.84 (.43)	6.34 (1.03)	6.09 (1.18)	5.66 (1.27)	5.09 (1.25)
5.27 (1.52)	5.80 (1.49)	5.62 (1.29)	5.45 (1.37)	5.12 (1.38)	5.02 (1.47)
5.09 (1.58)	5.66 (1.48)	5.37 (1.21)	5.32 (1.54)	5.08 (1.28)	4.86 (1.96)
4.85 (1.64)	5.25 (1.56)	5.13 (1.51)	5.11 (1.62)	4.81 (1.48)	4.75 (1.79)
4.35 (1.67)	5.00 (1.64)	5.01 (1.55)	5.09 (1.46)	4.81 (1.51)	4.70 (1.81)
4.12 (1.85)	4.68 (2.00)	4.85 (1.69)	4.48 (1.84)	4.78 (1.47)	4.68 (1.46)
4.09 (1.90)	4.55 (1.70)	4.75 (1.75)	4.39 (1.65)	4.63 (1.62)	4.64 (1.94)
3.84 (2.00)	4.41 (1.88)	4.43 (1.72)	4.30 (1.84)	4.56 (1.78)	4.48 (1.80)
3.79 (1.93)	4.20 (1.65)	4.27 (1.67)	3.86 (1.86)	4.38 (1.85)	4.48 (1.53)
3.71 (1.78)	3.34 (1.60)	3.62 (1.79)	3.20 (1.86)	3.97 (1.83)	4.45 (1.80)
3.28 (1.84)	3.30 (1.88)	3.55 (2.05)	3.09 (1.80)	3.93 (1.73)	3.91 (1.70)

SD: standard deviation.

Table 2. Summary of multiple regression analyses for variables predicting attractiveness for laymen (N = 97) and designers (N = 44).

	Laymen			Designers		
	B	SE B	Beta	B	SE B	Beta
Constant	1.58	0.11		2.84	0.21	
Familiarity	0.24	0.03	.28*	0.24	0.04	.05
Perceived ease of use	0.43	0.03	.47*	0.34	0.04	.38*

$R^2 = .46$, $*p < .001$; $R^2 = .17$, $*p < .001$.

Designers and laymen judged the ease of use of the graphs similarly as well, as the correlation between their ranking orders shows: $r = .95$, $p < .001$.

3. Familiarity and perceived ease of use appeared to be positively correlated, both for designers and for laymen (designers: $r = .55$, $p < .001$; laymen: $r = .65$, $p < .001$).

(4a) *Influence of familiarity and ease of use on attractiveness.* The ranking orders in Table 1 suggest that designers and laymen differ in their preferences for certain graph types. In order to investigate the relationships between familiarity, perceived ease of use, and attractiveness, we performed correlational and regression analyses.

For both the laymen and the designers, the mean familiarity and attractiveness ratings were positively correlated (laymen: $r = .58$, $p < .001$; designers: $r = .26$, $p < .001$), as were the mean ease of use and attractiveness ratings (laymen: $r = .47$, $p < .001$; designers: $r = .56$, $p < .001$). Because of the correlation between familiarity and perceived ease of use, we also analyzed partial correlations to see how both factors contributed to attractiveness separately. For the laymen, we found positive correlations again, both between familiarity and attractiveness ratings ($r = .28$, $p < .001$) and between ease of use and attractiveness ratings ($r = .44$, $p < .001$). For the designers, we found positive correlations between ease of use and attractiveness ratings ($r = .33$, $p < .001$), but no statistically significant correlations between familiarity and attractiveness ($r = .05$, $p = .263$).

In order to assess for both groups how much variance in the ratings of attractiveness can be explained by each of the predictor variables, we performed a regression analysis, separately for laymen and designers. Results are shown in Table 2.

Familiarity and ease of use explain a significant amount of the variance in the attractiveness values for both groups, but stronger for laymen than for designers. The analyses show that for laymen both

familiarity and ease of use significantly explain attractiveness. For the designers, perceived ease of use explains attractiveness, but familiarity did not reach statistical significance.

(4b) *Relationship between familiarity and attractiveness.* In order to test whether the relationship between familiarity and attractiveness is linear or curved, we first analyzed the scatterplots of the relationships for both groups (Figure 4). Whereas laymen's ratings are best fitted with a linear model, the designers' ratings are most adequately described by a quadratic model.

Curve estimation confirmed that the relationship between familiarity and attractiveness is linear for the laymen: adding a quadratic term did not cause a significant change in the model fit for them ($t(1161) = .72$, $p = .471$). For the designers, however, adding a quadratic term did cause a significant change in the model fit ($t(525) = -2.63$, $p = .009$). A negative beta weight of $-.63$ also suggested an inverted U-shape in the relationship curve. Therefore, we performed a hierarchical regression analysis with familiarity ratings as first predictor and quadratic familiarity ratings as second predictor variable of attractiveness. Adding the quadratic function caused a significant R^2 change ($.01$, $p = .009$), as Table 3 shows. With the linear model alone, familiarity predicts 6.8% of the attractiveness values ($R^2 = .068$), whereas with the combination of the linear and quadratic model familiarity predicts 8% of the attractiveness values ($R^2 = .081$). This result suggests that designers prefer designs situated between the most familiar and the most novel, as we expected.

Discussion

The results of study 1 show that designers and laymen share ideas about the familiarity and ease of use of the different graph designs, but differ in their appreciations. Familiarity and ease of use are predictors of attractiveness, but different for laymen and designers (Figure 5).

Figure 4. Scatterplots of the relationship between familiarity and attractiveness ratings for (a) laymen and (b) designers.

Table 3. Comparison of linear and quadratic regression models for familiarity predicting attractiveness for designers (N = 44).

		B	SE B	Beta
Model 1: linear	Constant	3.53	0.20	
	Familiarity	0.24	0.04	.26**
Model 2: linear and quadratic	Constant	2.56	0.42	
	Familiarity	0.79	0.21	.88**
	Quadratic familiarity	−0.06	0.02	−.63*

$R^2 = .07$ for model 1; R^2 change = .01 for model 2 ($p = .009$).
* $p < .05$, ** $p < .001$.

Figure 5. Relative weights of familiarity and perceived ease of use in the prediction of attractiveness for laymen and designers.

Laymen are attracted to designs that they find familiar and easy to use. Familiarity and ease of use together account for nearly half of the variance in attractiveness ratings. For designers, familiarity plays only a minor role in judgments of attractiveness. Perceived ease of use plays a more important role, but still familiarity and ease of interpretation together only account for 17% of the variance in the designers' attractiveness ratings. Obviously, we should look for other factors to explain designers' preferences.

Furthermore, the results show that the relationship between familiarity and attractiveness is linear for the laymen, supporting processing fluency theories that predict that people are attracted to familiar things, and contradicting classical aesthetic theories that predict that people are attracted to an equilibrium between familiarity and novelty. In the case of the designers, the relationship between familiarity and attractiveness is quadratic, which suggests that they are attracted to moderately familiar designs. It could be argued that this supports the balance-between-extremes theories. However, these theories do not assume differences between experts and novices and predict that novices (laymen) are attracted to moderately familiar designs as well. Therefore, we think it is more plausible that expertise is a moderating factor in the processing fluency theory, as Reber et al.²⁴ also suggest. As also shown in other studies²⁷, experts are apparently attracted to more novel stimuli, despite the pleasure of processing fluency that familiar stimuli seem to offer.

From study 1, on the whole, the results show positive relationships between perceived ease of use and attractiveness, although much stronger for the laymen than for the designers. We wondered how both groups would judge the graph designs after having used them, which we tested in study 2.

Evaluation study 2

The goal of study 2 was to find out whether attractiveness ratings would be influenced by actual use of the

graphs in an information retrieval task. We designed a task that reflects the way people commonly use this type of graphs in mass media, namely, comparing magnitudes. We asked participants to carry out comparison tasks with the graphs and then to rate each graph's attractiveness. We did not ask participants to judge the attractiveness before as well as after using the graphs, since asking this twice could have given them too much information about the goal of the study and could therefore have biased their responses.

Method

Participants. Participants in study 2 had similar educational backgrounds and ages as in study 1. Participants were 30 laymen in design (bachelor and premaster students of communication and information sciences at Tilburg University, receiving credits for participation; 17 females, 13 males, mean age: 22 years) and 31 volunteering design specialists (26 graduating bachelor students majoring in graphic design at the art academy of Avans University of Applied Sciences and 4 professional graphic designers; 17 females, 13 males, mean age: 24 years). None of the participants had taken part in the first survey.

Task. The information retrieval task involved comparing magnitudes of components. This task was chosen to reflect the way people normally use these kinds of graphs in mass media (think again of graphs showing election results). The task consisted of a series of statements with quantitative information paired with graphs. Participants were asked to assess whether a graph correctly represented the statement (yes or no). We designed statements requiring two types of tasks. The first required a direct comparison between one component of the graph and two others (e.g. "Fewer sheep have been exported than goats, and more sheep than cows"). The other type required an indirect comparison: mentally combining two components and

comparing the sum with another component (e.g. “More goats have been exported than sheep and cows together”).

Materials. The same 12 graphs were used as in study 1. In the information retrieval task, each graph was accompanied with a legend in the top right corner with the names of the components and the corresponding colors of the components in left-right or clockwise order. For each graph, the same color palette was used. No axes or numbers were included, to make sure that differences in performance and appreciation would only be attributed to differences in visual structure and not to differences in the way axes and numbers were integrated in the graphs. Each graph contained six segments (categories), each representing a different magnitude. The magnitudes were 5, 10, 15, 20, 25, and 30. Both the order of the categories (i.e. the magnitudes) and the colors of the segments were varied to prevent predictability and learning effects. Four different orders were used, evenly spread over graph types and task types.

Graphs including legends measured 810 (width) $\times$ 500 (height) pixels and were displayed on a 16-in 1366 $\times$ 768 resolution liquid crystal display (LCD) screen together with the statement and yes/no buttons below them (see Figure 6). Like in study 1, attractiveness was measured by a rating task, using again a 7-point Likert scale.

Procedure. Each participant received 24 statements, one direct and one indirect comparison statement for each graph type, with true and false statements evenly distributed among graph and statement type. Graph and statement pairs were presented in random order. The information retrieval task started with a written instruction explaining that the participant was about to see a series of statements paired with graphs, one pair at a time, and that it was his or her job to decide whether the graph correctly represented the information in the statement or not. Participants were instructed to answer as accurately and quickly as possible. The instruction was followed by two trials. Each statement was presented together with the representing graph until the subject pressed the yes or no button, without time constraints. Statements and graphs were presented in random order. After the information retrieval task, respondents were asked to rate the attractiveness of each graph. This second task also started with a written instruction, explaining that the participant would be presented with the graphs again, one at a time, and that they had to indicate how attractive they found it. Graphs were presented in random order again, one by one until the participant had rated

Figure 6. Example of graph with legend.

it and pressed the forward button. It took participants about 10–15 min to complete the test. Usability was measured by logging correct response rates, response times, and response times for incorrect answers. The response times for erroneous responses were used as an indication of the amount of time it takes for a participant to complete a seemingly difficult task.

Results

Average correct response rates per graph ranged from 100% to 77% for direct and 93% to 52% for indirect comparisons. Average response times per graph ranged from 12 to 27.4 s for direct and 11.4 to 24.8 s for indirect comparisons. As we were interested in the question of how the experience of using the graphs would affect attractiveness ratings, in the remainder, we only focus on the attractiveness ratings.

We found no correlations between performance measures (correct response rates, response times, and erroneous response times) and attractiveness ratings, for either of the two groups, neither for the direct comparison task nor for the indirect one.

Table 4 shows the attractiveness ratings for laymen and designers, including the rankings of the graphs according to attractiveness, both in study 1 (without use) and in study 2 (after use).

T-tests revealed that the attractiveness ratings of the participants from study 2 were significantly lower than those obtained from the participants in study 1 (laymen: $t(359) = -6.75$, $p < .001$; designers: $t(371) = -8.77$, $p < .001$), suggesting a moderating effect of actual use on attractiveness.

To further analyze effects of actual use on attractiveness, we calculated the ranking orders of the graphs according to attractiveness ratings and analyzed, for designers and laymen separately, the correlation

Table 4. Attractiveness rankings and ratings without and after use, for laymen and designers (SD).

Laymen		Designers	
Without use	After use	Without use	After use
5.71 (1.22)	6.30 (1.95)	5.39 (1.57)	5.10 (1.64)
5.66 (1.27)	5.87 (1.20)	5.09 (1.25)	4.42 (1.69)
5.12 (1.38)	4.93 (1.48)	5.02 (1.47)	4.26 (1.44)
5.08 (1.28)	4.37 (1.38)	4.86 (1.96)	4.19 (1.38)
4.81 (1.48)	4.33 (1.21)	4.75 (1.79)	4.16 (1.73)
4.81 (1.51)	4.33 (1.35)	4.70 (1.81)	4.16 (1.86)
4.78 (1.47)	4.33 (1.27)	4.68 (1.46)	3.94 (1.32)
4.63 (1.62)	3.73 (1.70)	4.64 (1.94)	3.94 (1.69)
4.56 (1.78)	3.60 (1.48)	4.48 (1.80)	3.77 (1.52)
4.38 (1.85)	3.43 (1.61)	4.48 (1.53)	3.74 (1.57)
3.97 (1.83)	2.57 (1.48)	4.45 (1.80)	3.06 (1.57)
3.93 (1.73)	2.03 (1.27)	3.91 (1.70)	2.39 (1.63)

SD: standard deviation.

between the rankings in study 1 (no use) and study 2 (use). A strong positive correlation between the attractiveness ranking orders would indicate that use had no effect, whereas a weak or negative correlation would indicate that use did have an effect on attractiveness. The laymen's rankings with and without use appeared to be significantly correlated ($r = .825$, $p = .001$), suggesting no effect of actual use. Furthermore, the laymen's attractiveness ranking order in study 2 appeared to be significantly correlated with the familiarity and ease of interpretation ranking orders in study 1 (ease: $r = .782$, $p = .003$; familiarity: $r = .754$, $p = .005$). For the designers, we found no correlation between attractiveness rankings in study 1 and study 2 ($r = .225$, $p = .482$), which suggests that the attractiveness ranking order in study 2 differed substantially from study 1. Furthermore, the designers' attractiveness ranking order in study 2 showed no correlation with the familiarity ranking orders found in study 1, but it did with the perceived ease of use ranking order in study 1 ($r = .593$, $p = .042$).

Discussion

No relationships were found between attractiveness ratings and performance measures. Participants did not receive feedback about correctness of their responses, so we did not expect relationships between correct response rates and attractiveness. But they could have experienced that with some graphs it took

longer to carry out the tasks than with others. Apparently, efficiency, in terms of response times or erroneous response times, did not influence judgments of attractiveness of either of the two groups. The finding that attractiveness ratings in study 2 were lower than in study 1 may indicate a moderating effect of actual use on attractiveness. Furthermore, after having experienced using the graphs, the designers find other graph types attractive than without user experience. The correlation between the attractiveness and perceived ease of use ranking orders suggests that after having used the graphs, not actual but perceived ease of use influences their judgments of attractiveness.

General discussion and conclusion

We were interested in the influence of familiarity and perceived ease of use on attractiveness of graphs for designers and laymen in design. Familiarity and perceived ease of use appeared to be correlated for both groups. Both variables also appeared to be predictors of attractiveness for both groups, but differently for laymen than for designers. Both variables accounted for almost half of the variance in the attractiveness ratings of the laymen and for less than 20% of the variance in the attractiveness ratings of the designers. Therefore, other factors must be of influence on attractiveness judgments as well. In the field of HCI, interesting studies have been done attempting to reveal such factors.^{34–36} Certainly, some of the factors as

defined by them will also apply in graph design such as being clear, original, or creative, but others, such as service quality factors (e.g. “feel joyful,” “can count on site”) may not be very relevant. An interesting direction for future research is to investigate criteria for graph design for a broader public.

Our finding that the relationship between familiarity and attractiveness is linear in the case of laymen contradicts the classic theories that predict that people prefer moderately familiar stimuli,^{1,20} and supports processing fluency theories that predict that people prefer familiar and thus “perceived as easy to process” stimuli.²⁴ This result is not in line with findings of, for example, Hekkert et al.,¹⁸ who found that people prefer moderately typical designs (novel, but still typical). An explanation for this may perhaps be found in the type of stimuli. Empirical studies within experimental psychology attempting to find evidence for the equilibrium between extremes theory have shown inconclusive results, whereas studies in product design showed that people prefer unusual yet typical products. In the first type of study, simple artificial stimuli were used. In the latter, daily products such as telephones and teapots were used. Just as in the product design studies, we used realistic stimuli, made for use in everyday life. The difference between the results of Hekkert et al.¹⁸ and ours may perhaps be caused by differences in the types of stimuli. Consumer products like teapots are quite ordinary and using them does not require much cognitive effort. Graphs, on the other hand, are less ordinary to most people and may be perceived as more difficult to process. Even highly familiar graphs might still offer enough arousal to be aesthetically pleasing. A study investigating how novices construct graphs also showed that novices prefer familiar graph types because, as participants explained, they understood them well.³⁷ Some studies have indeed shown that the mere exposure effect is more easily found for complex stimuli than for simple ones.³⁸ This would mean that repeated exposure and thus increasing processing fluency are appreciated for complex stimuli, whereas a balance between familiarity and novelty is appreciated for simple stimuli, that otherwise might become boring after repeated exposure.

The finding that designers prefer more novel designs than laymen is as expected and may be explained by their tendency to consider aesthetic value, besides perceived ease of use. In a previous study, we asked laymen why they preferred standard designs and designers why they preferred non-standard designs.³⁰ It appeared that laymen appreciate clarity the most, whereas the designers mentioned attractiveness and being different from the standard as the main reason for their preference. A more elaborate, qualitative study, in which participants are interviewed in

more depth about their evaluations of particular types of designs, could shed more light on their reasons for aesthetic preferences.

Study 2 revealed that there were no correlations between attractiveness ratings and performance measures for either of the two groups. Actual ease of use apparently did not affect attractiveness in the task we used. Studies in HCI have shown that poor usability may affect evaluations of aesthetics.³⁵ Perhaps stronger usability manipulations would also affect attractiveness in data visualization.

Of course, there are limitations to this study. We found strong correlations between familiarity and perceived ease of use, but judgments of ease of use and attractiveness may also be based on other factors. The tested graphs differ not only in terms of familiarity but also in terms of the features they use to represent quantity, such as length or area, and in the way the segments are arranged, as separate parts or as parts of a whole.^{39,40} This may also affect perceived and actual ease of use. Besides design characteristics, also reader characteristics and type of task may influence evaluations. All participants had received higher education, but people’s understanding is also influenced by culture and experience.⁴¹ As for the type of task, we deliberately chose a type of task reflecting daily life kind of graph use, but perceived and actual ease of use could be different with another type of task. Furthermore, both aesthetics and usability are complex constructs, while we only measured correlations between single items. It would be worthwhile to further investigate the relationship between aesthetics and usability using multi-level scales. As mentioned above, this would require the development of measurement scales that are appropriate for graph design and that measure criteria considered relevant by both designers and laymen in design.

Still, our findings show clear differences in appreciations between designers and laymen, the designers’ audience. This means that designers should be well aware of possible differences between their and their audiences’ ideas about attractiveness and understandability, or clarity. Furthermore, the fact that the two groups share opinions about perceived ease of use, but differ in their judgments of attractiveness, may also indicate that attractiveness does not affect perceived ease of use, as is suggested in several studies,^{31,32} but that perceived ease of use may affect attractiveness. After all, if attractiveness would predict perceived ease of use, laymen and designers should not only differ in their attractiveness judgments but also in their judgments of ease of use, which was not the case. Moreover, the shift in the designers’ appreciations after use suggested an influence of perceived rather than actual usability on attractiveness. A future study

should shed more light on the precise relationships between aesthetics and usability in graph design.

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