Available online at www.sciencedirect.com
SciVerse ScienceDirect
Int. J. Human-Computer Studies 71 (2013) 217–227
International Journal of Human-Computer Studies
www.elsevier.com/locate/ijhcs

How will the use of graphics affect visual aesthetics? A user-centered approach for web page design

Yang-Cheng Lin[a,*], Chung-Hsing Yeh[b], Chun-Chun Wei[c]

[a]Department of Arts and Design, National Dong Hwa University, Hualien 970, Taiwan
[b]Faculty of Information Technology, Monash University, Clayton, Victoria 3800, Australia
[c]Department of Industrial Design, National Cheng Kung University, Tainan 701, Taiwan

Received 12 May 2011; received in revised form 16 August 2012; accepted 17 October 2012
Communicated by M. Zanker
Available online 26 October 2012

Abstract

This paper addresses new and significant research issues in web page design in relation to the use of graphics. The original findings include that (a) graphics play an important role in enhancing the appearance and thus users' feelings (aesthetics) about web pages and that (b) the effective use of graphics is crucial in designing web pages. In addition, we have developed a web page design support database based on a user-centered experimental procedure and a neural network model. This design support database can be used to examine how a specific combination of design elements, particularly the ratio of graphics to text, will affect the users' feelings about a web page. As a general rule, the ratio of graphics to text between 3:1 and 1:1 will give the users the best feelings of ease-to-use and clear-to-follow. A web page with a ratio of 1:1 will have the most realistic look, while a ratio of over 3:1 will have the fanciest appearance. The result provides useful insights in using graphics on web pages that help web designers best meet users' specific expectations and aesthetic consistency.

Keywords: Graphics; Web page design; User perception; Visual aesthetics; Kansei Engineering; Neural network

1. Introduction

Information retrieval or visual searching (navigation) is one of the most frequent activities in using the Web (Ling and van Schaik, 2004). When users make a query to a web search engine, the web search engine usually shows a large number of web pages (websites) (Vegas et al., 2007). However, which one should be chosen for meeting the requirements of the users with special goals (Matrai et al., 2008)? In other words, how do the users know the web page chosen is just that one they are looking for? Very often the users do not know unless they browse or navigate the web page. Once the users feel frustrated or are not satisfied with the web page, they will abandon it immediately and then go to other web pages (Parush et al., 2005). Consequently, the first impression of the web page as perceived by the users is an important issue for web retailers and designers (Basso et al., 2001; Sanchez-Franco and Roldan, 2010).

The first impression and subjective experiences of users are strongly influenced by the appearance of the web page (Lindgaard et al., 2006; Tuch et al., 2010). Some researchers propose an aspect in web page design, called "visual aesthetics" or "visual ergonomics" (Lavie et al., 2011; Tuch et al., 2010). However, in contrast to the abundant amount of studies focusing on human–computer interaction (HCI) or usability of web pages (Goonetilleke et al., 2001; Grahame et al., 2004; Leuthold et al., 2008; Oetjen and Ziefle, 2009; Sears et al., 2000), only a few studies have focused on the visual aesthetics of web pages (Kim et al., 2003; Lavie and Tractinsky, 2004; Schenkman and Jonsson, 2000; Tuch et al., 2010). As a result, HCI researchers and users can hardly find any reference to aesthetic considerations in web page design (Lavie et al., 2011). In other words, most studies are paying

*Corresponding author. Tel.: +886 3 8227106x2285; fax: +886 3 8227106x2298.
E-mail address: lyc0914@cm1.hinet.net (Y.-C. Lin).

1071-5819/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ijhcs.2012.10.013

more attention to "operational ergonomics" than "visual ergonomics", even though aesthetics is found to play an important role in new web page design or new system (or product) development (Yamamoto and Lambert, 1994; Postrel, 2001; Walker et al., 2009). Based on the above discussions, this paper will focus on web aesthetics in relation to visual ergonomics, rather than operational ergonomics in relation to usability.

Visual layout has a strong impact on web aesthetics and is a critical factor in the design of HCI and web pages (Parush et al., 2005). Graphics play an essential role in enhancing the visual layout of web pages (Noiwan and Norcio, 2006). The primary purpose of using graphics on a web page is to get users' attention and give visual focus on the function of the web page (Shneiderman, 1997). Users usually look at graphics of a web page before reading its text in order to find out specific information. In addition to enhancing the function of a web page, effective use of graphics will enhance its appearance and make it visually appealing. However, overuse or misuse of graphics on a web page will confuse users (disorientation and cognitive overload), undermine its functionality, and increase the download time of the web page (Wang and Emurian, 2005). Consequently, the "visual density" which reflects the amount of text information, white space, and margins can be properly used to increase the overall aesthetics of a web page (George Saade and Alexandre Otrakji, 2007).

In order to meet users' feelings and expectations about a particular web page, a balanced combination of graphics and text is required (Hong et al., 2004; Koh and Sundar, 2010; Ou and Sia, 2010). However, few studies have examined how various ratios of graphics to text affect the users' feelings about a web page, and whether or not there is an adequate combination of graphics and text to match the users' preferences for a web page. In addition to the combination of graphics and text, there are other distinctive design elements of a web page that may also affect the users' feelings (or aesthetics) about the web page (Cheng and Patterson, 2007). As such, to use graphics effectively in web page design, we need to consider not only the ratio of graphics to text but also its interactions with other design elements that contribute to the users' feelings about a web page.

This paper aims to address these significant research issues in web page design by answering the following research questions. What are the key design elements of a web page that affect the users' feelings (aesthetics) about the web page? Is the ratio of graphics to text a significant design element in affecting the users' feelings about a web page? How do various ratios of graphics to text affect the users' feelings about a web page? Is there a combination of graphics and text that best matches the users' desirable feelings for given design elements of a web page? To answer these questions, we conduct an experimental study on university web pages using a number of modelling and analytical techniques including morphological analysis, Kansei Engineering, grey relational analysis, and neural networks.

In subsequent sections, we first present the experimental study for extracting representative web page samples and for identifying key design elements of web pages using morphological analysis. We then describe an evaluation process based on the concept of Kansei Engineering for assessing the web page samples with respect to the users' feelings about a web page. Next we conduct a grey relational analysis to identify the most influential design elements that affect the users' feelings about a web page. Finally we develop a web page design support database based on a neural network model for examining how each combination of design elements, particularly the ratio of graphics to text, will affect the users' feelings about a web page.

2. User-centered experimental procedure

This section presents an evaluation process based on the concept of Kansei Engineering.

2.1. Kansei Engineering

As an ergonomic user-centered methodology, Kansei Engineering has been applied successfully in the design field in order to explore the relationship between the psychological feelings of users and the design elements of the system or product (Ishihara et al., 1995; Lin et al., 2007; Schutte and Eklund, 2005; Zhai et al., 2009). Kansei Engineering has been developed as integrative design strategies to satisfy users' psychological feelings and preferences (Nagamachi, 1995; 2002). According to Nagamachi (1995 and 2002), Kansei Engineering aims to address the following four issues: (a) how to grasp the user's feeling (Kansei in Japanese) about a system or product in terms of ergonomic and psychological estimation, (b) how to identify the design characteristics of the system (or product) from the user's feeling, (c) how to build Kansei Engineering as an ergonomics technology, and (d) how to adjust system (or product) design to the current societal change or people's preference trend.

The user-centered Kansei Engineering is a process of linking the users' feelings about a system (or product), represented by feeling word pairs, to the product design elements, using a survey or an experiment (Nagamachi, 1995). There are several main steps in the survey (or experiment), including (a) extracting representative experimental samples, (b) conducting morphological analysis of product elements, (c) assessing users' preferences for a given set of product images, (d) utilizing the intelligent computing technology (such as neural networks, genetic algorithm, fuzzy logic, and so on) to explore the relationship between the users' preferences and the design elements, (e) building an inference model or expert system of Kansei Engineering for the new system (or product) design and development. In this paper, these main steps will be presented in the following sections.

2.2. Participants

There are 51 participants (including six design experts and 45 experienced web users) involved in the experimental study, divided into three groups. The first group consists of six design experts to perform the morphological analysis (to be discussed in Section 2.3). These experts have at least five years of web page design experience and the relevant analytical experiences of HCI. According to Nielsen (1993), the optimal number of evaluators or experts in a heuristic evaluation or experimental study is three to five, which can identify about 66–75% of the usability problems in the system interface. For the minimum number of the quantitative analysis required, the second group has 30 participants (with the average age being 20.5) for evaluating the visual aesthetics of experimental samples (to be discussed in Section 2.5), whose result is used as a basis for building a web page design support database. Each participant in the second group has more than six years' experience of using web pages. For the validity test, the third group has 15 participants (with the average age being 23.6 with more than 10 years' experience of using web pages) for assessing the visual aesthetics of the six test samples in order to evaluate the prediction performance of the NN model (to be discussed in Section 3.3).

2.3. Morphological analysis of web page design elements

The university homepages are selected as the experimental samples due to their functionalities and users being relatively straightforward and homogeneous, as compared to other kinds of commercial websites. We first collect more than 200 homepages of university websites, and then discard the similar ones and inappropriate ones after a preliminary assessment. In this study, two websites are regarded as similar if they use the same design template or framework, thus having the same first impression perceived by users. In addition, a website is inappropriate for use in this study if it uses an unusual or even extraordinary layout, which is unique and hard to discuss in the morphological analysis. Finally, 96 homepages of university websites are used as experimental samples, which are also used in our previous works (Lin and Yeh, 2008; Yeh and Lin, 2008). In Lin and Yeh (2008), we use these homepages to examine whether the NN model is an effective technique and what structure is better for the web page design among 16 NN models built. In Yeh and Lin (2008), we use these homepages to examine how the hyperlink styles (including text only, text and symbol, and text and icon) affect users' feelings about a web page. In this study, we use the same experimental data as a basis for developing a new user-centered approach in order to address new and significant research issues in web page design as discussed in the Introduction section.

The morphological analysis is conducted in two steps (Yeh et al., 2007). In the first step, the six design experts of the first group are asked to write down the key design elements of web pages that are likely to affect users' feelings about web pages, according to their knowledge and experience. In the second step, the six experts form a focus group (Bruseberg and McDonagh-Philp, 2002; Caplan, 1990) to discuss the results, combine similar opinions or components, and discard the minor design elements (e.g. the spacing between paragraphs, the size of the margins around the text, and so on). Table 1 shows the result of the morphological analysis, with seven influential design elements being "Ratio of Graphics to Text", "Whitespace Ratio", "Layout Style", "Frame Style", "Hyperlink Style", "Number of Colours", and "Background Colour".

Each design element has different types of its own, ranging from three to five, as indicated by the type number 1, 2, 3, 4 or 5 in Table 1. For example, "Ratio of Graphics to Text (X_1)" means that the ratio between the area used by graphics and the area used by text on a web page. This ratio takes five values, corresponding to five different types, i.e. "$>$3:1", "3:1$>X>$1:1", "1:1", "1:1$>X>$1:3", and "$<$1:3". For another example, the design element "Hyperlink Style (X_5)" has three types, i.e. "Text only", "Text and symbol", and "Text and icon", meaning that the hyperlink style is "only" text, or "adding" some symbols (e.g. small circles or square shapes without a specific meaning), or "adding" some icons (e.g. photographs or drawings with a specific meaning).

2.4. Extracting representative web page samples

As described in Section 2.3, 96 university web pages are extracted as experimental samples to perform the morphological analysis, with seven design elements and 23 ($=5+6\times3$) types of design elements. In order to avoid or reduce the cognitive demand from the experimental participants (to be discussed in Section 2.5) and to

Table 1
Extracted design elements of web pages.

Elements		Type 1	Type 2	Type 3	Type 4	Type 5
X_1	Ratio of Graphics to Text	$>$3:1 (Above 3)	3:1$>X>$1:1 (Between 3 and 1)	1:1 (1)	1:1$>X>$1:3 (Between 1 and 1/3)	$<$1:3 (Below 1/3)
X_2	Whitespace ratio	0–20%	20–40%	40–60%		
X_3	Layout style	2 columns	3 columns	Multiple columns		
X_4	Frame style	Up and down	Left and right	Compound style		
X_5	Hyperlink Style	Text only	Text and symbol	Text and icon		
X_6	Number of colours	Below 4 colours	4–7 colours	Above 7 colours		
X_7	Background colour	Cold colour	Warm colour	Neutral colour		

maintain the judgment consistency, it is necessary to reduce the experimental samples. To this end, the hierarchical cluster analysis is used to extract the representative samples of web pages, based on the result of morphological analysis. If the experimental sample has a particular type of a design element, the value of the corresponding input is 1; otherwise, the value is 0. The 33 web page samples are selected by the cluster tree diagram as the representative experimental samples (the red-solid line in Fig. 1), including 27 training samples and six test samples (the red-dotted line in Fig. 1) for training and testing the NN model to be developed. To collect

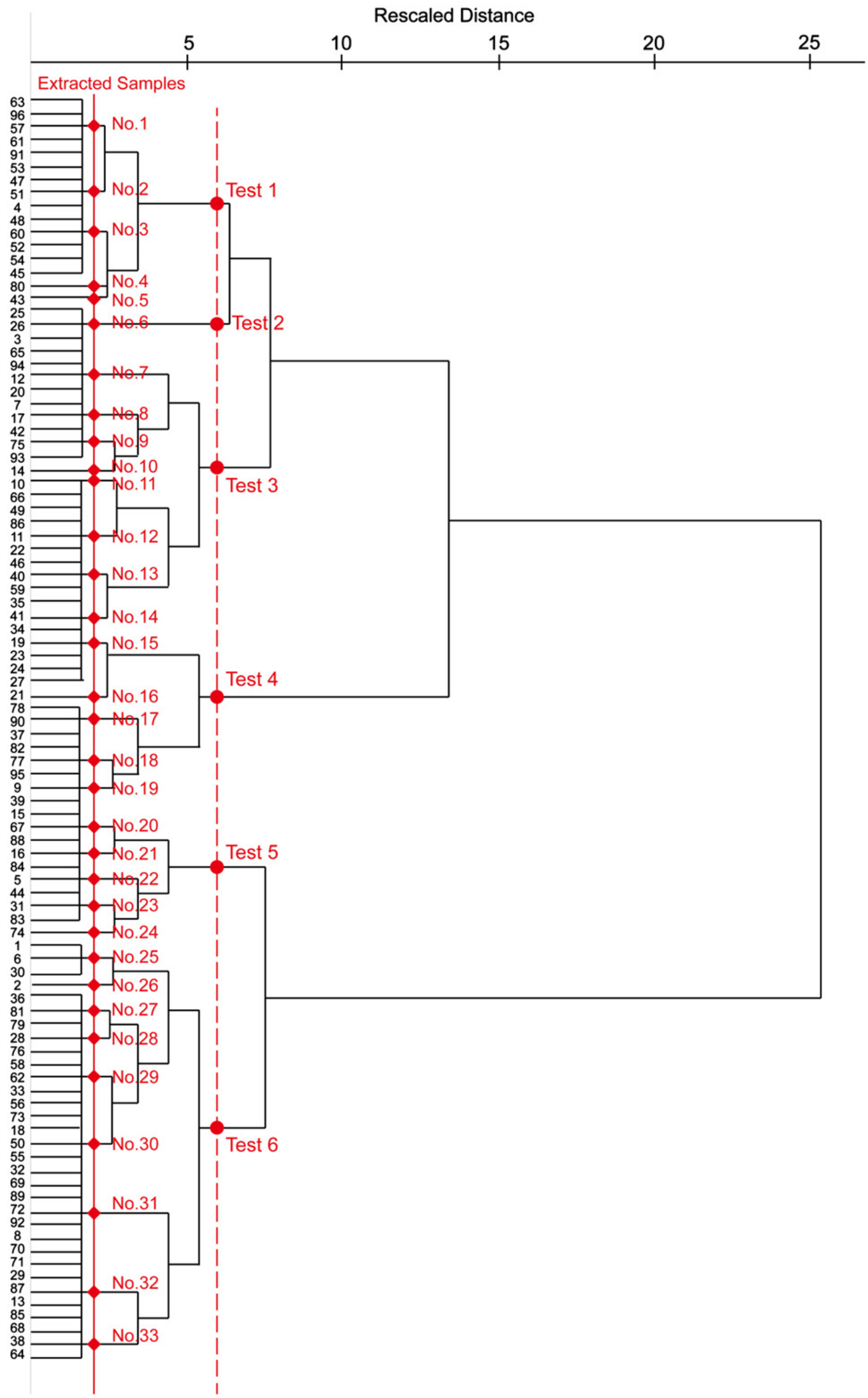


Fig. 1. Cluster tree diagram of 96 homepages of university websites. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

numerical data for performing numerical analysis, the degree to which each of the 33 representative web page samples matches a given set of users' feelings is to be assessed in the following section.

2.5. Evaluating users' feelings about experimental samples

In Kansei Engineering, emotion assessment experiments are usually performed to elicit users' psychological feelings about a system (or product) using the semantic differential method (Osgood and Suci, 1957). Image or feeling word pairs are often used to describe users' feelings about the system (or product) in terms of ergonomic and psychological estimation (Nagamachi, 1995, 2002). In order to describe users' feelings about web pages, we need to collect a large set of feeling word pairs with respect to visual aesthetics. The procedure of extracting feeling word pairs involves the following five steps:

Step 1: Collect a large set of feeling word pairs from magazines, product catalogues, websites, blogs, and web designers. In this study, we first collect more than 100 feeling word pairs which are used to describe the web pages, such as modern–traditional, local–international, realistic–fancy, etc.

Step 2: Combine the similar feeling word pairs and select the more suitable ones for describing the web pages by the focus group with two rounds of discussions. Then, 30 feeling word pairs are selected for the next step.

Step 3: Evaluate the 30 selected feeling word pairs using the semantic differential method (Osgood and Suci, 1957).

Step 4: Apply the factor analysis and cluster analysis according to the result of semantic differential obtained at Step 3. Table 2 shows the result of the factor analysis for 30 selected feeling word pairs. In Table 2, the first column shows the feeling word pair number and Columns 2–4 show the factor loadings on three factors (extracted from the factor analysis) for each feeling word pair respectively. The higher the factor loading value, the more influential the feeling word pair. The second last row of Table 2 shows the percentage of variance for each of three extracted factors. The higher the percentage of variance, the more influential the extracted factor.

Step 5: Determine the representative feeling word pairs based on the analyses performed at Step 4. In this study, we finally select three feeling word pairs for describing the feelings (aesthetics) about web pages, which respectively have the highest factor loading value in each factor extracted as shown in Table 2. These three pairs are Pair no. 3 (realistic–fancy R–F), Pair no. 20 (clear–confusing C–C), and Pair no. 5 (easy–difficult E–D).

The 30 participants of the second group are asked to assess the degree to which each of the 33 web page samples matches the E–D, C–C and R–F feelings respectively using the five scales (1–5) of the semantic differential method. For example, each participant assesses each web page sample for the E–D feeling on a scale of 1–5, where 1 is very easy to use and 5 is very difficult to use. For the C–C feeling, the value of 1 represents the web page is very clear to follow, and 5 represents the web page is very confusing. For the R–F feeling, the value of 1 represents the web page looks very realistic, and 5 represents the web page looks very fancy. As an illustration, Fig. 2 shows six web page samples out of the 33 representative experimental web page samples, which are assessed as the easiest, the most difficult, the clearest, the most confusing, the most realistic, and the fanciest respectively. In Fig. 2, the fist line under the sample number shows that the web page sample is assessed as the clearest, the easiest, etc. The second line or the third line indicates that the sample is perceived with two feelings or three feelings based on the evaluation result.

For each representative web page sample in Table 3, the first column shows the web page number and Columns 2–8 show the corresponding type number for each of its seven design elements, as given in Table 1. The last three columns of Table 3 show the assessment results for the 33 experimental samples, including six test samples (asterisked). The E–D, C–C, or R–F feeling value shown is the average of the values assessed by the 30 participants. For example, Web page no. 1 is the clearest to follow (with a C–C value of 1.70), while Web page no. 4 is the most confusing (with a C–C value of 3.48). Fig. 2 and Table 3 show that Web page no. 1 has a higher ratio of graphics to text (Between 3–1, Type 2 of X_1), as compared to Web page no. 4 (Below 1/3, Type 5 of X_1). Web page no. 2 is the easiest to use (with an E-D value of 2.11) with a higher ratio of graphics to text (1, Type 3 of X_1) than Web page no. 25 (with an E–D value of 4.11; Below 1/3, Type 5 of X_1). This result is in line with the general understanding that graphics play an important role in enhancing the appearance and thus users' feelings (aesthetics) about web pages (Noiwan and Norcio, 2006).

Table 3 provides a numerical data source for performing grey relational analysis, and training and testing neural network models to be presented in the following section.

3. Results and discussion

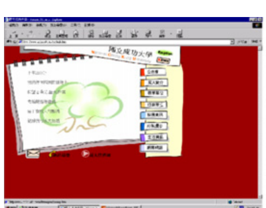
In this section, we present the results of applying the grey relational analysis (GRA) and building the neural network (NN) model in order to answer the research questions. The GRA is used to determine the most influential design elements of web pages for a given set of users' feelings. The NN model is used to examine the complex relationship between input variables (design elements of web pages) and output variables (users' feelings about web pages).

Table 2
Result of the factor analysis for 30 selected feeling word pairs.

Feeling word pairs	Factor loading		
	Factor 1	Factor 2	Factor 3
Pair no. 3	0.975	0.066	0.005
Pair no. 1	0.964	0.077	−0.090
Pair no. 23	0.960	−0.105	0.043
Pair no. 17	0.959	−0.123	0.161
Pair no. 4	0.955	0.000	0.032
Pair no. 9	0.937	0.143	−0.077
Pair no. 13	0.935	−0.140	−0.112
Pair no. 22	0.915	0.207	0.265
Pair no. 21	0.908	0.134	−0.150
Pair no. 15	0.891	−0.041	0.190
Pair no. 16	0.813	−0.405	0.226
Pair no. 19	0.745	−0.552	0.169
Pair no. 24	0.737	−0.588	0.289
Pair no. 25	−0.732	−0.507	0.179
Pair no. 18	0.692	0.617	−0.194
Pair no. 11	0.679	0.635	−0.080
Pair no. 27	0.659	0.517	0.260
Pair no. 8	−0.658	−0.252	0.559
Pair no. 28	−0.556	0.283	0.434
Pair no. 30	−0.508	−0.077	−0.374
Pair no. 20	0.060	0.933	0.224
Pair no. 12	−0.115	0.929	0.014
Pair no. 14	−0.058	0.873	0.310
Pair no. 2	0.339	−0.826	−0.152
Pair no. 10	0.023	0.676	0.637
Pair no. 7	0.399	−0.646	0.419
Pair no. 29	−0.540	0.596	−0.389
Pair no. 6	0.431	0.565	0.112
Pair no. 5	−0.370	−0.063	0.811
Pair no. 26	−0.355	−0.110	0.793
Percentage of variance	48.5%	23.8%	11.1%
Cumulative percentage of variance	48.5%	72.3%	83.4%

Table 3
Assessed users' feelings for 33 representative web page samples.

Web page no.	X_1	X_2	X_3	X_4	X_5	X_6	X_7	E–D value	C–C value	R–F value
1	2	2	2	3	2	2	2	2.28	1.70	2.90
2	3	3	3	3	1	1	2	2.11	2.16	2.27
3	3	3	2	1	2	3	1	2.63	2.59	2.42
4	5	3	2	3	2	1	3	3.26	3.48	2.73
5	3	2	3	1	3	2	1	2.84	2.57	2.75
6	1	1	2	1	3	3	3	2.44	2.48	2.95
7	3	3	1	2	1	1	1	2.47	2.42	2.26
8	5	2	2	3	2	1	3	2.78	3.16	2.42
9	1	1	1	1	3	3	3	3.27	3.11	4.06
10	1	2	1	2	1	2	3	2.60	2.28	2.94
11	3	3	2	1	2	1	1	2.77	2.33	2.53
12	4	1	2	2	1	2	2	2.64	2.63	2.46
13	2	2	3	1	1	3	3	2.27	2.33	2.58
14	2	1	3	2	1	2	3	2.73	2.31	2.21
15	4	1	2	1	3	3	2	2.89	2.63	2.61
16	4	2	3	3	3	3	1	2.67	2.78	2.52
17	2	3	2	3	2	1	3	2.26	2.00	2.85
18	4	1	2	3	2	3	2	2.68	2.59	2.47
19	5	2	3	2	1	2	1	2.96	2.90	2.42
20	5	3	1	2	1	1	3	2.34	2.28	2.59
21	4	2	2	3	3	3	2	2.37	2.26	2.55
22	1	1	2	3	3	2	3	2.70	2.49	3.26
23	3	2	3	1	1	2	3	2.73	3.00	2.70
24	4	3	3	1	1	2	2	3.15	2.89	2.77
25	5	3	3	3	3	1	2	4.11	3.36	3.06
26	2	2	3	3	2	1	1	3.02	3.07	2.79
27	1	1	3	3	2	3	1	3.06	3.26	2.75
28*	2	2	2	1	3	2	2	2.80	2.20	2.27
29*	2	3	1	2	2	1	3	2.27	2.27	2.60
30*	1	2	2	2	3	2	3	2.80	3.07	3.80
31*	3	3	1	1	1	3	1	2.53	2.47	2.40
32*	2	1	3	3	3	3	1	3.60	3.40	2.80
33*	2	1	3	3	2	3	2	2.80	2.87	2.73


No. 1
Clearest
Easiest and clearest


No. 2
Easiest
Easiest, clearest and most realistic


No. 4
Most confusing

No. 9
Fanciest


No. 14
Most realistic

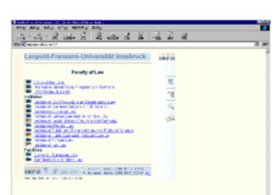

No. 25
Most difficult
Most difficult and most confusing
Most difficult, most confusing and fanciest

Fig. 2. Six web page samples out of 33 representative samples by users' feelings evaluation.

3.1. Grey relational analysis for measuring the relative importance of design elements

The grey system theory (Deng, 1982) has been developed to examine the relationship among factors in an observable system where the information available is grey, meaning uncertain and incomplete (i.e. only part of the information is known). It has been successfully used in a wide range of fields, including some recent application results (Chou and Hsiao, 2007; Lai et al., 2005; Lin and Wu, 2011; Yang, 2011) highlighting its effective handling of incomplete known information for exploring unknown information. The grey system that can be built for answering specific research questions in product design with respect to product form and product image is grey in essence, as there is no way to identify all the product form elements that affect a particular product image perceived by users.

The GRA is used to determine the relationship (similarity) between two series of stochastic data in a grey system. One is the reference series ($X_0 \in X$), and the other is the m comparison series ($X_i \in X$, $i=1, 2, \ldots, m$), where $X=\{X_\sigma|\sigma=0, 1, 2,\ldots, n\}$ is a given grey relational element set, given as

$$X = \begin{bmatrix} X_1(1) & X_1(2) & \cdots & X_1(m) \\ X_2(1) & X_2(2) & \cdots & x_2(m) \\ \vdots & \vdots & \cdots & \vdots \\ X_n(1) & X_n(2) & \cdots & x_n(m) \end{bmatrix} \tag{1}$$

The grey relational degree between the two series at a certain time point k is represented by the grey relational coefficient $r(X_0(k), X_i(k))$, defined as (Deng, 1982, 1989)

$$r(X_0(k), X_i(k)) = \frac{\min_i \min_j |X_0(k)-X_i(k)| + \xi \max_i \max_j |X_0(k)-X_i(k)|}{|X_0(k)-X_i(k)| + \xi \max_i \max_j |X_0(k)-X_i(k)|},$$

$$k = 1,2,\ldots,n\,; i = 1,2,\ldots,m. \tag{2}$$

where $\xi \in [0,1]$ is a distinguishing coefficient for controlling the resolution scale, usually being assigned the value of 0.5. The grey relational coefficient has the following properties:

(a) Space norm interval:
$0 < r(X_0, X_i) \leq 1, \forall i$,
$r(X_0, X_i)=1 \Leftrightarrow X_0 = X_i$,
$r(X_0, X_i)=0 \Leftrightarrow X_0 \cap X_i \in \phi$

(b) Space duality symmetric:
$r(X_0, X_i)=r(X_0, X_i) \Leftrightarrow X=\{X_0, X_i\}$

(c) Space wholeness:
$r(X_i, X_j) \neq r(X_j, X_i) \Leftrightarrow X_i, X_j \in X=\{X_\sigma|\sigma=0, 1, 2,\ldots, n\}$, $n \geqq 2$

(d) Space approachability:
$r(X_0(k), X_i(k))$ increases as the distance $|X_0(k)$-$X_i(k)|$ decreases at a time point k.

The grey relational degree of each comparison series X_i ($i=1, 2,\ldots, m$) to reference series X_0 at all time points can be calculated by

$$r(X_0, X_i) = \frac{1}{n}\sum_{k=1}^{n} r\,(X_0(k), X_i(k)), i = 1,2,\ldots,m. \tag{3}$$

Table 4
Result of GRA.

$r(X_0, X_i)$	E–D feeling	Ranking	C–C feeling	Ranking	R–F feeling	Ranking
X_1	0.63	2	0.70	1	0.56	5
X_2	0.60	4	0.60	5	0.57	4
X_3	0.60	4	0.67	2	0.56	5
X_4	0.57	6	0.61	3	0.53	7
X_5	0.66	1	0.60	5	0.66	1
X_6	0.61	3	0.61	3	0.63	2
X_7	0.54	7	0.59	7	0.61	3

We perform the GRA to determine the most influential design elements of web pages for the E–D, C–C, and R–F feelings. With the value ranging from 0 to 1, Table 4 shows the grey relational degree $r(X_0, X_i)$ between the web page feeling (X_0) and the design element (X_i). Each of the seven design elements (X_i, $i=1, 2,\ldots, 7$) is obtained by the GRA. If $r(X_0, X_i) > r(X_0, X_j)$, then the design element X_i is closer to the web page feeling X_0 than the design element X_j. The higher the $r(X_0, X_i)$ value, the more influential the design element X_i.

Table 4 shows that the "Hyperlink Style (X_5)" element, with the highest GRA value of 0.66, affects the E–D feeling the most, followed by the "Ratio of Graphics to Text (X_1)" element and the "Number of Colours (X_6)" element. This implies that the web designers should focus their attention more on these three most influential elements, when the design objective is to achieve a desirable E–D feeling. On the contrary, the designers may pay less attention to the less influential elements, as these elements contribute relatively little to users' E–D feeling. In addition, the "Ratio of Graphics to Text (X_1)" element has the highest GRA value of 0.70 for the C–C feeling of web pages, meaning that the "Ratio of Graphics to Text (X_1)" element primarily affects the C–C feeling. This result reflects the notion again that the effective use of graphics in web page design is crucial in affecting visual aesthetics.

3.2. The neural network model for examining the complex relationship between design elements and user feelings

With its effective learning ability, the neural network (NN) model has been widely used to examine the complex and non-linear relationship between input variables and output variables (Lin et al., 2004; Negnevitsky, 2002). In this paper, we use the multilayered feedforward NN trained with the backpropagation learning algorithm, as it is an effective supervised learning algorithm (Negnevitsky, 2002). In addition, the learning rule used is Delta-Rule and the transfer function used is Sigmoid (Nelson, 1991). To examine the relationship between the seven web page design elements and the three users' feelings about web pages, we build the NN model with a single hidden layer. The number of neurons in the single hidden layer is 26, which is determined by the number of input neurons (being 23) plus the number of output neurons (being 3). This is a commonly used rule for building NN models (Lai et al., 2005; 2006).

The 23 types of the seven design elements in Table 1 are used as the 23 input variables for the NN model. If the web page has a particular design element type, the value of the corresponding input neuron is 1; otherwise, the value is 0. The assessed average values of the E–D, C–C, and R–F feelings are used as the output neurons. The 27 web page samples in the training set, given in Table 3, are used to train the NN model. Each model is trained 5,000 epochs at each run. When the cumulative training epochs are over 100,000, the training process is completed. The lowest root of mean square error (RMSE) in the training process is 0.0274.

3.3. Performance evaluation of the NN model

To evaluate the performance of the NN model in terms of its ability to predict the users' feelings for a new web page with given design elements, the six web page samples in the test set are used. Rows 3–5 of Table 5 show the average assessed values of the three feelings on the six test samples given by the 15 participants of the third group, and Rows 6–8 show the predicted values for the three feelings by using the NN model.

To evaluate the performance of a model, the RMSE is commonly used, given as

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - x_{0(i)}\right)^2}{n}} \tag{4}$$

where x_i is the i-th output value predicted by the model and $x_{0(i)}$ is the expected values assessed by the participants in the experiment. If there is no difference or error between the output value and the expected value, the RMSE is 0.

The RMSE of the NN model given in the last column of Table 5 is normalized, with the values (the assessed values and the predicted values) being transformed into a value between 0 and 1. As indicated in Table 5, the normalized RMSE value is 0.1354. This result indicates that the NN model has an accuracy rate of 86.46% (100 − 13.54%) for predicting the value of the E–D, C–C, and R–F feelings about web pages. This suggests that the NN model is a promising approach for modelling the users' feelings about web pages.

4. Web page design support database

In design settings where the designers have to design the easiest and the clearest web page, what should they do? What if the designers wish to design a web page with a lot of graphics (i.e. the ratio of graphics to text being above 3, Type 1 of X_1) and with the "Text only" hyperlink style (Type 1 of X_5)? What if the designers want the web page to be the easiest to use, and to look the clearest and very fancy? These questions can be answered by using the NN model built.

To help determine the best web page design for meeting specific web page feelings (aesthetics), all possible combinations of design elements can be input to the NN model for generating their associated feeling values. As a result, a web page design support database can be generated, consisting of 3,645 ($=5\times3\times3\times3\times3\times3\times3$) different combinations of design elements, together with their associated E–D, C–C, and R–F feeling values. As an illustration for the ratio of graphics to text element, Table 6 shows the best combination of design elements for the E–D and C–C feelings under various ratios of graphics to text. That is, the combinations of design elements shown in Table 6 will produce the easiest and clearest web pages as perceived by users for the five different ratios of graphics to text respectively.

It is commonly agreed that web pages should be easy to use and clear to follow, by implementing an easy-to-use navigation with simplicity and consistency (Ozok and Salvendy, 2000; Wang and Emurian, 2005). Consistency can be defined as a combination of an object's properties, based on colour, shape, size, orientation and other properties of the appearance (Ling and van Schaik, 2004). As the structure and design of web pages throughout a website are consistent, "users feel more confident using the website because they can transfer their learning from one sub-site

Table 5
Predicted feeling values and RMSE of the NN model for the test set.

	Web page aesthetics	Web page sample number						RMSE
		28	29	30	31	32	33	
Average assessed value by 15 participants	E–D value	2.80	2.27	2.80	2.53	3.60	2.80	
	C–C value	2.20	2.27	3.07	2.47	3.40	2.87	
	R–F value	2.27	2.60	3.80	2.40	2.80	2.73	
Predicted value by the NN model	E–D value	2.6579	2.5851	2.2252	2.7589	2.8669	2.9531	
	C–C value	1.9702	1.9800	2.0120	2.7138	2.7261	2.4980	0.1354
	R–F value	3.1434	3.3157	2.8624	2.7196	2.6170	2.8622	

Table 6
Best combination of design elements for the E–D and C–C feelings under various ratios of graphics to text.

Ratio of graphics and text (X_1)	Whitespace Ratio (X_2)	Layout Style (X_3)	Frame Style (X_4)	Hyperlink Style (X_5)	Number of Colours (X_6)	Background Colour (X_7)	Total value of E–D and C–C feelings
>3:1 (Above 3)	40–60%	3 columns	Compound style	Text only	Above 7 colours	Warm colour	3.64
(1)	(3)	(2)	(3)	(1)	(3)	(2)	(1.86, 1.78)
3:1 $> X >$ 1:1 (Between 3 and 1)	20–40%	3 columns	Compound style	Text only	Above 7 colours	Warm colour	3.24
(2)	(2)	(2)	(3)	(1)	(3)	(2)	(1.68, 1.56)
1:1 (1)	40–60%	3 columns	Compound style	Text only	Above 7 colours	Warm colour	3.52
(3)	(3)	(2)	(3)	(1)	(3)	(2)	(1.79, 1.73)
1:1 $> X >$ 1:3 (Between 1 and 1/3)	40–60%	3 columns	Compound style	Text only	Above 7 colours	Warm colour	3.91
(4)	(3)	(2)	(3)	(1)	(3)	(2)	(1.90, 2.01)
<1:3 (Below 1/3)	20–40%	3 columns	Left and right	Text only	Below 4 colours	Neutral colour	4.43
(5)	(2)	(2)	(2)	(1)	(1)	(3)	(2.11, 2.32)

to the next rather than having to learn everything over again for each new page" (Nielsen, 1998,1999). Consequently, in some design settings, the designers have to use the same ratio of graphics to text in order to maintain the overall design style (aesthetic consistency) of web pages throughout the website. In other words, if the designers wish to design an easier and clearer web page with a very realistic look, is there any combination of design elements for a given ratio of graphics to text? On the contrary, if the designers want to get a very fancy web page, is there any restriction?

To find out the best ratio of graphics to text to use for designing a web page which is the easiest to use and the clearest to follow, as perceived by users, we conduct another analysis of the NN model. Table 7 shows the result for each ratio type, which gives the minimum value, the maximum value, the average value and the standard deviation of a feeling (E–D, C–C or R–F) for all the combinations of other design elements. The result suggests that a web page with the ratio of graphics to text between 3:1 and 1:1 has the best possibility of being easiest and clearest. A web page with a ratio of 1:1 will have the most realistic look, while a ratio of over 3:1 will have the fanciest appearance.

5. Limitations and further research

The experimental study presented in this paper has two limitations. First, the university homepages are selected as the experimental samples with their functionalities and users being relatively straightforward and homogeneous, as compared to other kinds of commercial websites. Users may also have a very specific attitude towards university web pages. Second, the experimental samples selected are all static. In the further experiments and studies, the animated (dynamic) web pages, such as those made by Flash, can be considered.

Although the university homepages are chosen as an illustration, the user-centered approach presented in this paper is applicable to other kinds of websites with various design elements (e.g. multimedia or animated displays) and other users' feelings (e.g. classic or modern). In particular, as the World Wide Web infrastructure is getting better and better (e.g. the high-bandwidth with a higher visual resolution), the web search engine will show a number of relevant websites with not only a short text summary but also a visual appearance while an user issues a query to a web search engine. The user can select directly the website to browse. By then, the approach presented will provide an effective mechanism for facilitating the user-centered web design process in addressing visual aesthetics.

6. Conclusion

The first impression and subjective experience are strongly influenced by the appearance of a web page. Graphics play a significant role in enhancing the appearance of the web page and particularly in affecting the users' feelings (aesthetics) about the web page. This paper has focused on the web aesthetics (visual ergonomics) rather than usability (operational ergonomics). In this paper, we have presented an experimental study on university homepages to address the issue of how to use graphics effectively in web page design, using morphological analysis, Kansei Engineering, grey relational analysis, and neural network techniques. To this end, we have considered not only the ratio of graphics to the text but also its interactions with other design elements that contribute to the users' feelings about a web page.

The result of this study has demonstrated the advantages of using these techniques to examine how the ratio of graphics to text of a web page will affect the users' feelings about the web page. In particular, a web page design support database based on the neural network model has

Table 7
The E–D, C–C, and R–F feeling values for a given ratio of graphics to text.

Ratio type	E–D				C–C				R–F			
	Min.	Max.	Ave.	Std. dev.	Min.	Max.	Ave.	Std. dev.	Min.	Max.	Ave.	Std. dev.
$>3{:}1$ (Above 3)	1.72	4.01	2.92	0.54	1.57	3.54	2.60	0.39	2.01	4.19	2.99	0.55
$3{:}1>X>1{:}1$ (Between 3-1)	1.64	3.77	2.68	0.52	1.39	3.33	2.21	0.39	1.98	4.18	2.97	0.56
1:1 (1)	1.66	3.79	2.69	0.49	1.53	3.37	2.46	0.38	1.84	3.82	2.56	0.49
$1{:}1>X>1{:}3$ (Between 1 and 1/3)	1.75	4.07	2.99	0.53	1.75	3.66	2.86	0.38	1.89	3.99	2.72	0.53
$<1{:}3$ (Below 1/3)	1.94	4.33	3.32	0.59	2.20	3.87	3.19	0.37	1.93	4.20	2.96	0.56

been developed to help web designers find out the best ratio of graphics to text for a given set of design elements and the users' feelings in web page design. As a guideline, web designers should consider using the ratio of graphics to text between 3:1 and 1:1 on web pages in order to best match the users' feelings of easy-to-use and clear-to-follow. In specific design settings, the design support database can be used to help web designers work out the optimal combination of design elements of web pages for enhancing users' particular expectations and meeting the desirable aesthetic consistency.

Acknowledgements

This research is supported in part by the National Science Council of Taiwan, ROC under Grant no. NSC 97–2918-I-026-001. We are grateful to the six design experts and 45 experienced web users in Taiwan for their participation and assistance in the experimental study. We also thank the editor and anonymous reviewers for their valuable comments and advice.

References

Basso, A., Goldberg, D., Greenspan, S., Weimer, D., 2001. First impressions: emotional and cognitive factors underlying judgments of trust e-commerce. In: Proceedings of the 3rd ACM Conference on Electronic Commerce, Tampa, FL, USA, pp. 137–143.

Bruseberg, A., McDonagh-Philp, D., 2002. Focus groups to support the industrial/product designer: a review based on current literature and designers' feedback. Applied Ergonomics 33, 27–38.

Caplan, S., 1990. Using focus groups methodology for ergonomic design. Ergonomic 33, 527–533.

Cheng, H.-I., Patterson, P.E., 2007. Iconic hyperlinks on e-commerce websites. Applied Ergonomics 38, 65–69.

Chou, J.-R., Hsiao, S.-W., 2007. A usability study on human–computer interface for middle-aged learners. Computers in Human Behavior 23, 2040–2063.

Deng, J.L., 1982. Control problems of grey system. System and Control Letters 1, 288–294.

Deng, J.L., 1989. Introduction to grey system theory. The Journal of Grey System 1, 1–7.

George Saade, R., Alexandre Otrakji, C., 2007. First impressions last a lifetime: effect of interface type on disorientation and cognitive load. Computers in Human Behavior 23, 525–535.

Goonetilleke, R.S., Shih, H.M., On, H.K., Fritsch, J., 2001. Effects of training and representational characteristics in icon design. International Journal of Human-Computer Studies 55, 741–760.

Grahame, M., Laberge, J., Scialfa, C.T., 2004. Age differences in search of Web pages: the effects of link size, link number, and clutter. Human Factors 46, 385–398.

Hong, W., Thong, J.Y.L., Tam, K.Y., 2004. Designing product listing pages on e-commerce websites: an examination of presentation mode and information format. International Journal of Human-Computer Studies 61, 481–503.

Ishihara, S., Ishihara, K., Nagamachi, M., 1995. An automatic builder for a kansei engineering expert system using self-organizing neural networks. International Journal of Industrial Ergonomics 15, 25–37.

Kim, J., Lee, J., Choi, D., 2003. Designing emotionally evocative homepages: an empirical study of the quantitative relations between design factors and emotional dimensions. International Journal of Human-Computer Studies 59, 899–940.

Koh, Y.J., Sundar, S.S., 2010. Effects of specialization in computers, web sites, and web agents on e-commerce trust. International Journal of Human-Computer Studies 68, 899–912.

Lai, H.-H., Lin, Y.-C., Yeh, C.-H., 2005. Form design of product image using grey relational analysis and neural network models. Computers and Operations Research 32, 2689–2711.

Lai, H.-H., Lin, Y.-C., Yeh, C.-H., Wei, C.-H., 2006. User oriented design for the optimal combination on product design. International Journal of Production Economics 100, 253–267.

Lavie, T., Tractinsky, N., 2004. Assessing dimensions of perceived visual aesthetics of web sites. International Journal of Human-Computer Studies 60, 269–298.

Lavie, T., Oron-Gilad, T., Meyer, J., 2011. Aesthetics and usability of in-vehicle navigation displays. International Journal of Human-Computer Studies 69, 80–99.

Leuthold, S., Bargas-Avila, J.A., Opwis, K., 2008. Beyond web content accessibility guidelines: design of enhanced text user interfaces for blind internet users. International Journal of Human-Computer Studies 66, 257–270.

Lin, S.-L., Wu, S.-J., 2011. Is grey relational analysis superior to the conventional techniques in predicting financial crisis? Expert Systems with Applications 38, 5119–5124.

Lin, Y.-C., Lai, H.-H., Yeh, C.-H., 2004. Neural network models for product image design. Lecture Notes in Computer Science 3215, 618–624.

Lin, Y.-C., Lai, H.-H., Yeh, C.-H., 2007. Consumer-oriented product form design based on fuzzy logic: a case study of mobile phones. International Journal of Industrial Ergonomics 37, 531–543.

Lin, Y.-C., Yeh, C.-H., 2008. User-centered interface design of social websites. Lecture Notes in Computer Science 5075, 366–376.

Lindgaard, G., Fernandes, G., Dudek, C., Brown, J., 2006. Attention web designers: you have 50 milliseconds to make a good first impression!. Behaviour and Information Technology 25, 115–126.

Ling, J., van Schaik, P., 2004. The effects of link format and screen location on visual search of web pages. Ergonomics 47, 907–921.

Matrai, R., Kosztyan, Z.T., Sik-Lanyi, C., 2008. Navigation methods of special needs users in multimedia systems. Computers in Human Behavior 24, 1418–1433.

Nagamachi, M., 1995. Kansei Engineering: a new ergonomics consumer-oriented technology for product development. International Journal of Industrial Ergonomics 15, 3–10.

Nagamachi, M., 2002. Kansei Engineering as a powerful consumer-oriented technology for product development. Applied Ergonomics 33, 289–294.

Negnevitsky, M., 2002. Artificial Intelligence. Addison-Wesley, New York.

Nelson, M., 1991. A Practical Guide to Neural Nets. Addison-Wesley, New York.

Nielsen, J., 1993. Usability Engineering. Academic Press, United Kingdom.

Nielsen, J., 1998. Introduction to web design. In: Proceedings of the CHI 98 Conference, Los Angeles, CA, USA, pp. 107.

Nielsen, J., 1999. Designing Web Usability: The Practice of Simplicity. New Riders, USA.

Noiwan, J., Norcio, A.F., 2006. Cultural differences on attention and perceived usability: investigating colour combinations of animated graphics. International Journal of Human-Computer Studies 64, 103–122.

Oetjen, S., Ziefle, M., 2009. A visual ergonomic evaluation of different screen types and screen technologies with respect to discrimination performance. Applied Ergonomics 40, 69–81.

Osgood, C.E., Suci, C.J., 1957. The Measurement of Meaning. University of Illinois Press, Urbana.

Ou, C.X., Sia, C.L., 2010. Consumer trust and distrust: an issue of website design. International Journal of Human-Computer Studies 68, 913–934.

Ozok, A.A., Salvendy, G., 2000. Measuring consistency of web page design and its effects on performance and satisfaction. Ergonomics 43, 443–460.

Parush, A., Shwarts, Y., Shtub, A., Chandra, M.J., 2005. The impact of visual layout factors on performance in web pages: a cross-language study. Human Factors 47, 141–157.

Postrel, V., 2001. Can good looks guarantee a product's success? The New York Times, July 12.

Sanchez-Franco, M.J., Roldan, J.L., 2010. Expressive aesthetics to ease perceived community support: exploring personal innovativeness and routinised behaviour as moderators in Tuenti. Computers in Human Behavior 26, 1445–1457.

Schenkman, B.N., Jonsson, F.U., 2000. Aesthetics and preferences of web pages. Behavior and Information Technology 19, 367–377.

Schutte, S., Eklund, J., 2005. Design of rocker switches for work-vehicles-an application of Kansei Engineering. Applied Ergonomics 36, 557–567.

Sears, A., Jacko, J.A., Dubach, E.M., 2000. International aspects of World Wide Web usability and the role of high-end graphical enhancements. International Journal of Human-Computer Interaction 12, 241–261.

Shneiderman, B., 1997. Designing information-abundant web sites: issues and recommendations. International Journal of Human-Computer Studies 47, 5–29.

Tuch, A.N., Bargas-Avila, J.A., Opwis, K., 2010. Symmetry and aesthetics in website design: it's a man's business. Computers in Human Behavior 26, 1831–1837.

Vegas, J., Crestani, F., De La Fuente, P., 2007. Context representation for web search results. Journal of Information Science 33, 77–94.

Walker, G.H., Stanton, N.A., Jenkins, D.P., Salmon, P.M., 2009. From telephones to iPhones: applying systems thinking to networked, interoperable products. Applied Ergonomics 40, 206–215.

Wang, Y.D., Emurian, H.H., 2005. An overview of online trust: concepts, elements, and implications. Computers in Human Behavior 21, 105–125.

Yamamoto, M., Lambert, D.R., 1994. The impact of product aesthetics on the evaluation of industrial products. Journal of Product Innovation Management 11, 309–324.

Yang, C.-C., 2011. Constructing a hybrid Kansei Engineering system based on multiple affective responses: application to product form design. Computers and Industrial Engineering 60, 760–768.

Yeh, C.-H., Lin, Y.-C., Chang, Y.-H., 2007. A neural network approach to website design. Dynamics of Continuous, Discrete and Impulsive Systems: Series B, Applications and Algorithms (DCDIS Series B) 14 (S2), 1598–1601.

Yeh, C.-H., Lin, Y.-C., 2008. User-centered design of web pages. Lecture Notes in Computer Science 5073, 129–142.

Zhai, L.-Y., Khoo, L.-P., Zhong, Z.-W., 2009. A rough set based decision support approach to improving consumer affective satisfaction in product design. International Journal of Industrial Ergonomics 39, 295–302.