

Optimising product colour

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Introduction

The final colour of a product on sale to the consumer is the end result of a complex interaction of knowledge, guesswork, practical constraint, and marketing skill [1]. Once the final colour is chosen, most of the problems associated with delivering the colour selected, under precise colour definition and control, at a reasonable cost, have been solved. Technical colour management is well served by accurate measurement and colour manipulation tools, and is founded on tried and tested science. By contrast, those managers whose responsibility it is to deliver successful colour selection, cannot appeal to much more than general principles, the dictates of fashion and intuition: they have very few tools and measurement techniques to assist them. Colour influences all aspects of our lives, from the clothes we wear and the food we eat to the environment in which we work [2]. The colour of an item of apparel worn by someone has an impact on how they are perceived by others and how they perceive themselves. This means that consumers are extremely sensitive to colour when choosing apparel goods.

The rapid development of computers and information processing technology offers the prospect of bringing together hitherto fragmentary knowledge and precision colour technology in a concerted effort to improve the process of optimising product colour. The following sections represent an overview of the research effort in this field, highlighting advances in consumer research, colour definition and communication.

Colour and consumer behaviour

Colour has an important effect on consumer behaviour. It is well known that certain colours elicit feelings of excitement while other colours are considered restful and can make people feel tired. In fact, there is some evidence that colours actually cause physiological reactions [3]. These effects can be used to companies' benefit in displays, advertising, signage and even décor. Psychologists have discovered that merely by looking at different colours, blood pressure can be altered along with heart rate and rate of respiration [4].

Marketers can use colours in many different ways to influence the consumer. The effects of colours on

the psychological state of the individual have been explored within the field of consumer behaviour [5–7]. This article draws upon recent research to uncover the way in which colour affects consumer perceptions and its propensity to enhance products.

For clothing and textile manufacturers, achieving the right colour for the product and the retail environment is critical. If this is not done successfully, a company can lose market share and profit. Current research is examining consumer colour preferences, including personality characteristics, age and gender. The aim of this research is to produce a strategic framework for colour decision making for specific market segments.

Common perceptions

The effects of various colours on consumer perceptions have been widely studied [8–10]. Table 1 lists a number of colours and the way in which they are commonly perceived, as well as examples of marketing stimuli that have utilised these colours. At one end of the light spectrum, colours with long wavelengths (reds, oranges and yellows) tend to elicit warm feelings in consumers. An example of a marketing application is the bright red seats that are found in many fast-food restaurants. These establishments want to move customers quickly through the eating process. The bright colours

Table 1 Common perceptions of colours [11]

Colour	Perceptions	Marketing examples
Red	Powerful Dangerous Exciting Passionate	First Alert Fire Extinguisher Coca-Cola
Green	Cool Calm Natural	Gillette 'sensitive skin' shaving gel Healthy Choice food products Nytol Herbal
Blue	Cool/cold	Phillips' Milk of Magnesia laxative and antacid Brut Aqua Tonic aftershave
Black	Sad Respectful Cold Prestigious Sophisticated	Mont Blanc pen Johnnie Walker Black Label whisky
Clear	Clean Pure	Palmolive Sensitive Skin dishwashing liquid Seltzers beverages

encourage fast movements; consumers perceive the seats to be warm and tend not to linger. At the other end of the light spectrum, short wavelength colours (blues and greens) are associated with coolness and encourage slower movements [5]. The seats in an expensive restaurant are more likely to be blue or green to promote a more leisurely dining experience.

Cultural differences

Colours have different connotations and traditional uses across cultures. Table 2 shows the connotations of certain colours in different cultures.

In south-east Asia, light blue symbolises death and mourning and Pepsi-Cola lost its dominant market share there to Coca-Cola when the manufacturer changed the colour of its coolers and vending equipment from deep ‘regal’ blue to light ‘ice’ blue [7]. In China white is associated with death. Most business travellers were shocked during the inauguration of United’s concierge services for first-class passengers on its Pacific Rim routes when, to mark the occasion, each concierge was proudly wearing a white carnation [13]. When designing advertisements and packages, marketers must be careful to avoid using colours that will send the wrong messages to the consumers of another culture.

Table 2 Colour connotations [12]

Colour	Connotation
White	Symbol for mourning or death in the Far East Associated with happiness and purity in the United States
Purple	Associated with death in many Latin American countries
Blue	Connotations of femininity in Holland Associated with masculinity in Sweden and the United States
Green	Used to designate jungle areas where there is danger and disease in Malaysia
Red	Unlucky or negative in Chad, Nigeria and Germany Positive in Denmark, Romania and Argentina. Brides wear red in China, but it is a masculine colour in the United Kingdom and France
Yellow	Yellow flowers are a sign of death in Mexico and are associated with infidelity in France
White	White lilies are linked to death in the UK

Colour trends

The importance of colour has given rise to what is in effect a specialised colour consultancy industry. In a given year, certain colours appear to be fashionable and to show up again and again in clothing, home furnishings, cars and many other items. These favoured colours tend to disappear as fast as they

appeared as they are replaced by another set of fashionable colours for the next year or season [8].

The colour choices of consumers are affected by these trends. One simple reason is that the colours available in the stores that consumers patronise will largely limit their choices. Few people, however, realise the extent to which these fashionable colours result from deliberate choices made by industry experts, in a process known as colour forecasting. Colour experts in groups meet periodically to predict which colours will best reflect a particular season, a year, five years and sometimes even ten years in advance [8]. Members make colour predictions based on cultural and social trends, and these recommendations are then used by manufacturers to plan production.

Marketers need to be aware of the influence that colour has on the consumer in order to deliver suitably coloured products to their customers. Even a slight difference of shade from the requirements of the consumer can be catastrophic to the manufacturer. Is there a range of colours on a colour palette that a clothing company can use each season, by simply adjusting the shades? This has worked for designers such as Armani, who uses a palette of basic colour such as grey, blue, black, beige and white. Could this simplistic range of colours ever work for high street retailers?

Colour psychology

Psychologists have done a great deal of research into the power of colour. It is accepted that colour is a powerful tool [5]; it can generate good feelings, positive emotions and a favourable disposition towards a brand [6,14]. However, the body of empirical research reported is fairly small. It has been observed that consumers make great use of colour as a cue to identify brands, infer weight, indicate temperature and even associate gender with a product [15].

The use of colour to describe our emotions gives an idea of colour’s abstract force. Reactions to colour are described as aesthetic, emotional and symbolic, and can sometimes attract, whilst on other occasions they repel [16]. Studies have suggested that environmental colour schemes have wide-ranging effects [5,9,17]; in a workplace it can affect morale and productivity, in a prison it can pacify inmates and in a healthcare facility it can influence patients’ recovery rates.

Most research on consumer colour preferences relies largely on historical sales trends [18]. Individual differences in colour preference have received little research. For example, personality differences in buyer behaviour have not been analysed in detail. Consumers have become more sophisticated about the

use of colour and have higher expectations than in the past [2]. Therefore it would be expected that companies would be carrying out extensive research into individual differences in colour preferences.

Consumer personality was one of the first topics to receive attention in the quantitative era of marketing research [19]. However, the uncertain or ambiguous pattern of the results obtained has left marketers in a somewhat indeterminate position. Recent work on personality and consumer behaviour reveals four distinct trends, each stemming from the lessons learned in the past [20]:

- (a) Studying patterns of behaviour rather than single decisions
- (b) Focusing on consumption rather than general needs
- (c) Shifting attention to develop related areas
- (d) Studying how personality affects responses to advertising.

Consumer behaviourists believe that studying preferences for colour in relation to personality traits might uncover systematic relationships that will aid marketers to understand their customers [21].

The effects of colours on the psychological state of the individual should also be considered, because some colours act as a stimulant while others act as a depressant. A dark blue ceiling may appear to be refreshing to begin with, but in time the perceived coldness may become an irritant [22]. Many psychological effects of different colours on the individual are presented in Table 3.

Table 3 Psychological effects of different colours [23]

Colour	Psychological effect	Temperature effect	Distance effect
Violet	Aggression/tiredness	Cold	Very close
Blue	Restfulness	Cold	Further away
Brown	Excitement	Neutral	Claustrophobic
Green	Very restful	Cold/neutral	Further away
Yellow	Excitement	Very warm	Close
Orange	Excitement	Very warm	Very close
Red	Very stimulating	Warm	Close

In the history of psychology, colour preferences were among the earliest laboratory phenomena examined for individual and group differences [24,25]. However, this initial interest in colour preferences has diminished in recent times, largely due to the amount of confusion arising from contradictory results. This inconsistency seems mainly due to the failure in earlier studies to control the three dimensions of hue, brightness and saturation, and the lack of statistical analysis in order

to determine the significance of observed differences in colour perception.

Some workers have been interested in whether or not there is a system of colour preference. Experimental studies have explored areas such as mood associations with coloured lights and designs [26–28], mood associations of colour and music [29,30], relationships between personality traits and colour preference [31–33] and the relationship between mental/emotional disorders and colour preference [34–36]. There have been many associated clinical studies, including the Rorschach Test [37], the Lüscher Colour Test [38] and the Color Pyramid Test [39]. Other aspects examined have included the way colour affects physiology [40,41], mental and motor skills [42,43], and psychotherapy [44].

In order to measure the effect of colour on the human organism, colour needs to be associated with the external world as well as a psychological experience [45]. Similarly, the response of the human organism needs to be defined in terms of behaviour, rather than by inference to assumed psychological experience [46]. ‘Psychological experience’ may be successfully measured only when terms are operationally defined. If we can define a phenomenon in measurable terms, it will then become objective reality.

Much of the research on the psychological meaning of colour can be criticised on several grounds:

- (a) The stimulus colours have not always been clearly specified, making it difficult to compare results across studies
- (b) Since hue has often been the only variable of interest, controls for saturation and lightness have usually been absent
- (c) Tests for colour preference have often been constructed to address ‘attention to colour’ as opposed to ‘selectivity for specific colours’
- (d) A standard light source has not always been used
- (e) Few studies have incorporated a screening procedure for possible colour blindness
- (f) Age and gender differences have not been incorporated in all studies.

It is small wonder then that after more than 100 years of pursuit, the relationship between colour and personality has remained elusive. While several studies have indicated an association of personality with colour preference, no study incorporates all of the above mentioned factors. It should be possible therefore to demonstrate the extent of any possible relationship between personality characteristics and colour preference by incorporating all these factors.

An experiment undertaken at the Department of Textiles, UMIST, examined the relationship between individual differences in colour perception and preference for 300 male and 340 female subjects,

using the Quintax Personality Questionnaire [47]. Respondents expressed their preferences for eight hues (yellow, orange, red, purple, blue, blue-green, green and green-yellow). Early results indicate that there is significant variation in colour preferences amongst subjects with different personality traits, across age and gender. The implications for marketing management are immense (e.g. segmentation, stock control, sales forecasting, new product development).

Industrial applications

There are many areas of industry where colour can be used to affect consumer behaviour, including advertising, product design, merchandising and interior design. Colours in advertisements can be used to capture attention, portray realism and arouse feelings about an object [48]. A study on the impact of colour in newspaper advertising concluded that a ‘median sales gain (on reduced-price items) of approximately 41% may be generated by the addition of one colour to black-and-white in retail newspaper advertisements’ [5,12].

Colour can be used to emphasise the attractive features of a product or used to create a suitable atmosphere. A classic marketing example, where colour has been used to enhance product features, is Terry’s All Gold chocolate selection. The colour of the product or its packaging often leads to immediate recognition from consumers, even without seeing the name. Cadburys have achieved a similar subliminal effect by using the colour purple. It is, however, easy also for other companies to imitate this recognition with a colour. For example, Coca-Cola’s red can was instantly recognisable on a supermarket shelf until many supermarkets adopted the same colour scheme for their own-label cola. This copying resulted in recognition detracting from Coca-Cola [49].

The latest trend to hit the skincare and bodycare market is a concentration on colour. Colour therapy is a branch of alternative healing, with its therapists believing that it can have a marked effect on people. Top cosmetics companies are now harnessing the

positive effects of colour for new lines, the idea being that if the colour of a product can improve moods, the physical benefits of its formulation may also be enhanced. So-called mood-mapping techniques are being used to monitor sensory and emotional reactions to the colour of products. Companies such as Lancôme and Boots have already adopted this approach with products such as blue cleansers and bath oils, green toning lotion and yellow shower gel.

Colour can be used in the workplace to create pleasant surroundings and to put across and reinforce safety messages. When planning the colour scheme or décor for a room it is important to consider the use to which the room will be put. The colours within a store are also sources of potential influence on both consumers’ perceptions and behaviour. Warm colours, such as red and yellow, appear more effective in attracting a positive response from people, compared with cooler colours such as green and blue [50].

The preceding sections have highlighted research in the area of colour and consumer behaviour. Research indicates that achieving the correct colour can be critical for a company’s success. The following sections will highlight developments in technical colour management.

Colour definition

Colour can be described and defined with a wide range of precision levels. Kelly defines six levels of precision in his Universal Color Language (Table 4) [51]. At each level of increasing precision, more colours can be identified unambiguously. Colour naming, with or without physical samples to illustrate the colour concerned, is widely adopted in the fields of colour forecasting, design, printing and the graphic arts as a method of colour definition and communication.

A few thousand unambiguous colour definitions are possible using naming systems and colour atlases (Kelly’s levels 1 to 4). By contrast, technical colour management and production control in the textile, plastics, paint, and vehicle construction industries, for

Table 4 Six levels of precision in the Universal Color Language [51]

Level ^a	Divisions of colour solid	Type of designation	Example of designation
1	13	Generic hue names and neutrals	Brown
2	29	All hue names and neutrals	Yellowish-brown
3	267	ISCC-NBS/ all hue names and neutrals with modifiers	Light yellowish-brown (centroid #76)
4	7056	Colour order systems	Munsell 10YR 6/4
5	100 000	Visually interpolated Munsell notation	9.5 YR 6.4/4.5
6	5 000 000	CIE x,y,Y or instrumentally interpolated Munsell notation	x = 0.395, y = 0.382, Y = 35.6 or 9.6 YR 6.45/4.3

^a Level 1 least precise, level 6 most precise

example, use colour definitions based on spectrophotometry and the CIE system [52]. This gives colour definitions that are an order of magnitude more precise than those provided by colour atlases and colour naming.

The necessity for very precise colour definition arises from the need to match customer requirements for colour to within a just-visible difference. In terms of marketing, all components of a product, coordinated products and batches of products must be perceived by the end user to have uniform colour or controlled colour variation.

Uses of precise colour definition

Traditionally, the use of precise colour definition has been limited to those areas of technical colour management outlined above. Recent research at UMIST has been aimed at extending the use of precise colour definition into the fields of design, colour communication, colour range development, and also calibrated colour imaging to define and specify the effects of texture on colour appearance [53–55].

It has been noted during this research that consumer choice of colour may have features that can only be revealed by detailed analysis using precision colour measurement. An example is the ‘classic’ colour navy blue. Two companies participating in the research found that, with thirty plus distinct variations of navy blue, one or two outsell all the others by a significant margin. It was also found that very minor changes in a stock-range powder blue are sufficient to distinguish one year’s new palette from the previous year’s range, making the old product look dated and in need of replacement.

Calibrated colour imaging has opened up a wide range of applications for precision colour definition [56,57]. The starting point is the ability to reproduce at will on a computer screen, a very wide range of CIE colour definitions with an accuracy approaching that required to give a perfect visual screen-to-sample match, for any of 16.7 million colour definitions. The screen image is a visual colour match to a physical sample that has the same CIE colour definition. Using calibrated screens, the visual effect of very small changes in colour specification can be simulated and used in colour coordination and colour range development, without having to do the many costly and time-consuming dyeings needed, if physical comparisons are used. This has enabled substantial reductions in lead-time in developing new shade ranges [58].

A coloured image of a textile product, with texture, highlight and shadow effects, can be reproduced on a colour-calibrated computer screen. This allows the point-by-point analysis of colour as it varies across the surface texture. Individual point-colour variation

down to the 100 μm level (100 points per square mm) has been analysed [53]. An image of a typical colour-woven textile fabric, with strong surface texture, was found to contain in excess of 100 000 distinct colours. Even a nominally single shade solid-dyed texture gives several thousand point-colour definitions.

Using CIE colour definition of image content, it has been found that individual textures have characteristics that are independent of their measured or intrinsic colour. A given texture simulation on the computer screen can thus be altered substantially in colour while maintaining an effective simulation of the texture, and its contribution to appearance.

Image analysis allows the intrinsic colour underlying the visual appearance of a textured material to be deduced. The output from the computer is a synthetic spectral reflectance curve, which can be used to generate an appropriate matching colorant formulation. It is thus possible to communicate a precise colour specification electronically to any dyehouse with a colorant formulation computer. At the local dyehouse a dyeing can then be reproduced that is a close visual match to the original screen image. In an exercise involving seven dyehouses on four continents, and four different materials, precisely coordinated colour was reproduced that was a good match to the colour chosen on screen at the beginning of the trial.

Colour communication and collaborative design networking

In addition to reproducing the colour appearance of the texture or product, the image can be encoded, transmitted and reproduced visually on a remote computer screen anywhere in the world. The remote computer will give visually correct colour reproduction of the image seen on the transmitting computer due to identical calibration of the two screens and common use of CIE colour definition. This principle is the basis of the Imagemaster system, developed at UMIST during the project [53,56]. Imagemaster can store, retrieve and manipulate items from libraries of colours, garments, textures and products of all types. New product development can then include a wide range of colour/texture combination evaluations, by manipulating images of texture with alternative colours.

The networking of computers has now reached a level of maturity, which enables all those concerned with colour to collaborate by communication of designs, colour ideas, specifications, and product colour definitions (spectral reflectance curves). Laboriously produced swatches and sampling can be reduced to the minimum. There is unfortunately no substitute for a real product, when assessing handle, drape and final three-dimensional appearance.

As colour communication is speeded up and made more precise, fashion prediction, marketing, range development and consumer choice analysis can all be brought together into a single product optimisation process. The technical aspects of colour, cost and performance can be optimised in parallel, and associated colour problems such as coordinating the packaging and display environment design can in principle also be integrated into the collaborative process.

A future is envisaged in which the designer can, if required, interact and optimise colour choice in collaboration with the dyer and buyer over the colour communication network. The marketers will have in-depth intelligence of those colours that sell and those colours that do not. Presentation of photo-realistic images of products yet to be made is now possible, with the knowledge that they can be made if they produce a good consumer reaction. Test marketing may in future be done in many instances by measuring consumer reaction to such colour-calibrated images.

Subtle adjustments to existing colours, as well as new colours, can be selected and discussed for feasibility with production units prior to committing fabric (establishing optimum cost, performance and metameric properties, for example). The many coloured components present in, say, a motor car interior and exterior design can be fully coordinated in specification, in many colourways if necessary.

The two- and three-dimensional aspects of design, currently the province of specialist technical designers, and design software, are predicted to become integrated into a comprehensive collaborative design network, with free image interchange in standard digital formats and CIE coordinate-specified colour.

The dominance of classic colours

A fitting subject for research is the relationship between fashion colour and reasons that 'classic' colours persist in popularity. Is it possible to discover new classics? Can extrapolation be made to find them? Are there 'durable' colours, which given an occasional rest will come back into fashion again and again? Can consumer 'colour fatigue' be related to hue, chroma or lightness? How can the contribution of colour psychology, economic conditions and national mood be assessed? How do the many sources of fashion colour prediction compare, for uniformity of prediction and accuracy? Is fashion prediction a self-fulfilling prophecy? Is there a predictable or at least definable basis for quantifying such terms as colour harmony, contrast, tonality and the like?

Answers to some of these questions are beginning to emerge using the new computer-based colour

definition and visualisation tools now available, and by means of interaction between designers, colour scientists and experts in management and marketing.

Research at UMIST department of textiles

The penalties for getting a colour range out of balance, or plain wrong, for a given product are severe. It is not our intention to teach range managers their job, rather we seek to give them new tools and knowledge to make that job easier.

At UMIST the complementary disciplines of design, marketing, colour science and computing are being combined in a multidisciplinary attempt to solve at least some of the questions posed. So far we have put in place new colour visualisation and communication tools, and made a start on analysing fashion colour predictions. Current research is addressing the underlying influences of consumer choice on the one hand and precision colour imaging on the other.

Research usually makes progress either by developing and applying new tools to old problems, or by crossing interdisciplinary boundaries to find new problems that can be solved with existing tools. Any researcher looking for interesting topics in the field of colour will not be short of challenges if they address some of the above questions.

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