The Effect of Colour Contrast Combinations on the Simplicity and Complexity of Design

Ahmad E. Aloumi

A thesis submitted in partial fulfilment of the requirements of Bournemouth University for the degree of Doctor of Philosophy

MAY 2013

Bournemouth University

School of
Design, Engineering
and Computing

Copyright statement

Abstract

A common goal for designers is to deliver an intentional message from the sender to the intended receivers via design. The design can be constructed to be a crystal-clear and interesting model that viewers can easily and immediately understand. However, some designs are intricate, complex, and layered in detail, and these require more effort on the part of the viewer if they are to understand the design messages. During the design process, designers pass through several stages that affect the design outcome. One of these key stages is the colouring process. Colour has the power to make or break the design intention. In addition, colour can either add complexity to the design by the use of different colour contrasts, or help simplify a complex design form.

This research investigates the effect of colour combinations on simple and complex design appearance, with regard to the effects of contrast when colours are juxtaposed in a design. The aim of the research is to identify which colour contrast affects the simplicity and complexity of a design's appearance. The research demonstrates how design form could be evaluated differently in terms of the use of different colour combinations.

The research uses applied experimental methods to analyze participant responses to colour combinations. It reveals the result of the study by describing the signs of simple and complex colour combinations and the effect of colour on different designs. The research also proposes methods for increasing or decreasing the level of complexity of a design solution by using different colour combinations with their associated effects on the diversity of colour contrast. All of this information is used to create a design tool which will help designers and students to make colour choices which are more suited to the design solution.

Dedication

This thesis is dedicated to my wife Hessah, who have supported me since the beginning of my studies.

Acknowledgements

I would like to thank my PhD supervision committee of Professor Siamak Noroozi, Dr Bob Eves and Dr Mihai Dupac for their dedication and guidance throughout the thesis process. Additionally, my sincere thanks go to my colleagues, friends, and the participants of this study at Bournemouth University as well as Kuwait University and the American University in Kuwait. Finally, I am grateful to my wife and my little daughters Hajar and Nawal for their genuine support and empathy.

Author's declaration

The work embodied in this thesis is the result of the candidate's own investigation, apart from where indicated. No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other University or institute of learning.

Table of Content

CHAPTER FOUR

Data results and analysis

CHAPTER FIVE

Data verification study

CHAPTER SIX

The colour complexity tool

List of figures

List of tables

Definitions

Additive mixing

A colour reproduction method where different light wavelengths from three portions of the visible spectrum are combined.

Chromatic adaptation

Refers to a decreased retinal sensitivity to a colour (wavelength) as exposure to that wavelength increases.

Complex colour combination

Complex colour combination consists of many colours with different wavelengths and extreme contrasts. They are noisy and cannot easily balance a visual message. Using complex colour combinations in a simple design can make its form appear to be complex. Complex colour combination has the ability to affect only the visual appearance of the subject (for example, mobile phone design). It refers to colour combinations based on colour contrast (contrast of hue, contrast of value, contrast of temperature, complementary contrast, simultaneous contrast, contrast of saturation, and contrast of extension).

Complex colour contrast

Complex colour contrast consists of different colours with different wavelengths. It is noisy when applied to a design application. It unbalances the appearance of a design that cannot be easily understood.

Design quality

Refers to the visual appearance of the subject solely in terms of it being a simple or complex form. It is a matter of perception of the exterior appearance of the subject (for example, mobile phone design). The quality of being a simple or complex design does not relate solely to the functionality of the subject in terms of this research.

Gamut

The range of colours a device can produce (a device being a printer for ink media, or a television screen for digital media).

Perceptual colour attributes

Factors of colour perceived by humans – lightness (brightness), chroma (contrast), and hue (name of the colour, related specifically to a wavelength).

Simple colour combination

A simple colour combination is a clear, easily balanced combination. It presents no composition difficulties when applied in a design solution. Using simple colour combinations in a complex design can make a complex design form appear to be simple. It refers to colour combinations based on colour contrast (contrast of hue, contrast of value, contrast of temperature, complementary contrast, simultaneous contrast, contrast of saturation, and contrast of extension).

Simple colour contrast

Simple colour contrast provides a clear, easily balanced colour combination with a smaller wavelength. It balances the appearance of the design and helps enhance the understanding of the message.

Simultaneous contrast

A visually related phenomenon where a person's colour perception is influenced by surrounding colours.

Subtractive mixing

A colour reproduction method performed by selectively removing energy (in the form of light waves of specific length) from the red, green, and blue sectors of the visible spectrum.

Trichromacy

Refers to the human visual system's reduction of the entire light energy within the visible spectrum into three colour signals that are processed by cones in the visual system.

CHAPTER ONE

Introduction

1.1 Executive summary

Viewers are surrounded by visual stimuli on a daily basis. People make many assumptions within a split-second when they see a design solution: are they interested or not? What does it mean? How does it work? How well is it designed? These design solutions, which may have intriguing and/or exciting form, enable current designers to deliver effective solutions that can heighten impact.

Design is a creative process that combines art and technology to communicate ideas. The designer works with a variety of communication tools: form; shape; texture; tone; weight; colour; and balance, in order to convey a message from a client to a particular audience (Poggenpohl, 1993). To deliver an eye-catching design that is also meaningful, the designer's careful attention to detail throughout the design process is required.

1.1.1 Design communication

Some designers attempt to construct a simple/straightforward design solution that is clear in delivering its message, while others try to deliver designs that are intricate, complex, and layered in detail, which requires the viewer to make more effort to understand the intended message. Ultimately, both designers are trying to let their design solution deliver the intended message, stand out in the crowd, and solve the design problem. With this in mind, "People are created differently, they follow different laws of nature, and each of them works according to invisible principles, hidden from the others, principles that harbour unspoken conventions and assumptions" (Norman, 2010).

Which solution is better - a simple design or a complex one? It is easy to build a bulky design by adding layer upon layer of navigation and features. However, it is much more difficult to create simple, graceful solutions. Optimal designs have high complexity, with visual simplicity that allows the user to connect emotionally. A plain design will not allow the user to make that connection. People seek organized complexity, and become disinterested in, or repelled by, low or disorganized complexity (Klinger & Salingaros, 2000).

Designers are always striving to become better engaged with people. Through the use of creativity and science, they aim to give people a better life. People not only value, but, more importantly, they love designs that make their lives simpler (Maeda, 2006). According to Don Norman, who is an expert in cognitive science and is widely considered to be one of the first to apply advanced human factors to design via cognitive design, complex things can be enjoyable. Psychologists have demonstrated that people prefer a middle level of complexity: too simple and people are bored, too complex and they will be confused (Norman, 2010). Simplicity is not the entire answer. So, what are the things that affect the simplicity of a design?

Colour is a complex component of an image and must be given weightier consideration in the design world if colour information overload (in which a large number of colours impedes rather than aids visual searches) is not to sabotage product colour combination (Marcus, 1992). But which colour combinations can help a design to be more effective? Which colour contrast adds complexity to the design? Or, what colour choice helps simplify a complex design form?

1.1.2 Colour and design

In 2005, and after the huge success of its portable music player, Apple Inc. released its first generation iPod Minis. The main change to the design was the availability of five different colours: silver, gold, pink, blue, and green. Since 2002 and through four generations of iPod, Apple had consistently released iPods in just one colour, white. Even though they had thought that white created an impact in their product designs, they found that colours could increase that impact. The choice of colour is a major aesthetic consideration in design (Eves, 2002). The colour choice can make or break the design solution. “Simple colours are the proper colours of the element” (Aristotle, 384-322 BC).

According to Itten (1973), colour exhibits seven different kinds of contrast based on the colour characteristics. These contrasts are so different that each may be studied separately. Each is unique in character and artistic value. They can be approached from these three aesthetic directions: Impression (Visual), Expression (Emotional), and Construction (Symbolic) effects. All three together constitute the fundamental resource of colour design. The seven kinds of colour contrast are the following: Contrast of Hue, Light-Dark Contrast, Cold-Warm Contrast, Complementary Contrast, Simultaneous Contrast, Contrast of Saturation, and Contrast of Extension.

This study focuses specifically on the effect of colour contrast on design form. It includes a series of analyses on samples of colour combinations in order to find an effective way to identify and measure the level of simplicity and complexity of a colour Contrast. In addition, it establishes and tests a design tool for measuring the degree of simple and complex colour combinations. (Figure 1.1) is an explanatory diagram of the fields and areas covered in the research.

1.1.3 Explanatory diagram

The goal of this explanatory diagram is to illustrate the fields and areas covered by the research. It shows how these different fields interact with each other in the research process.

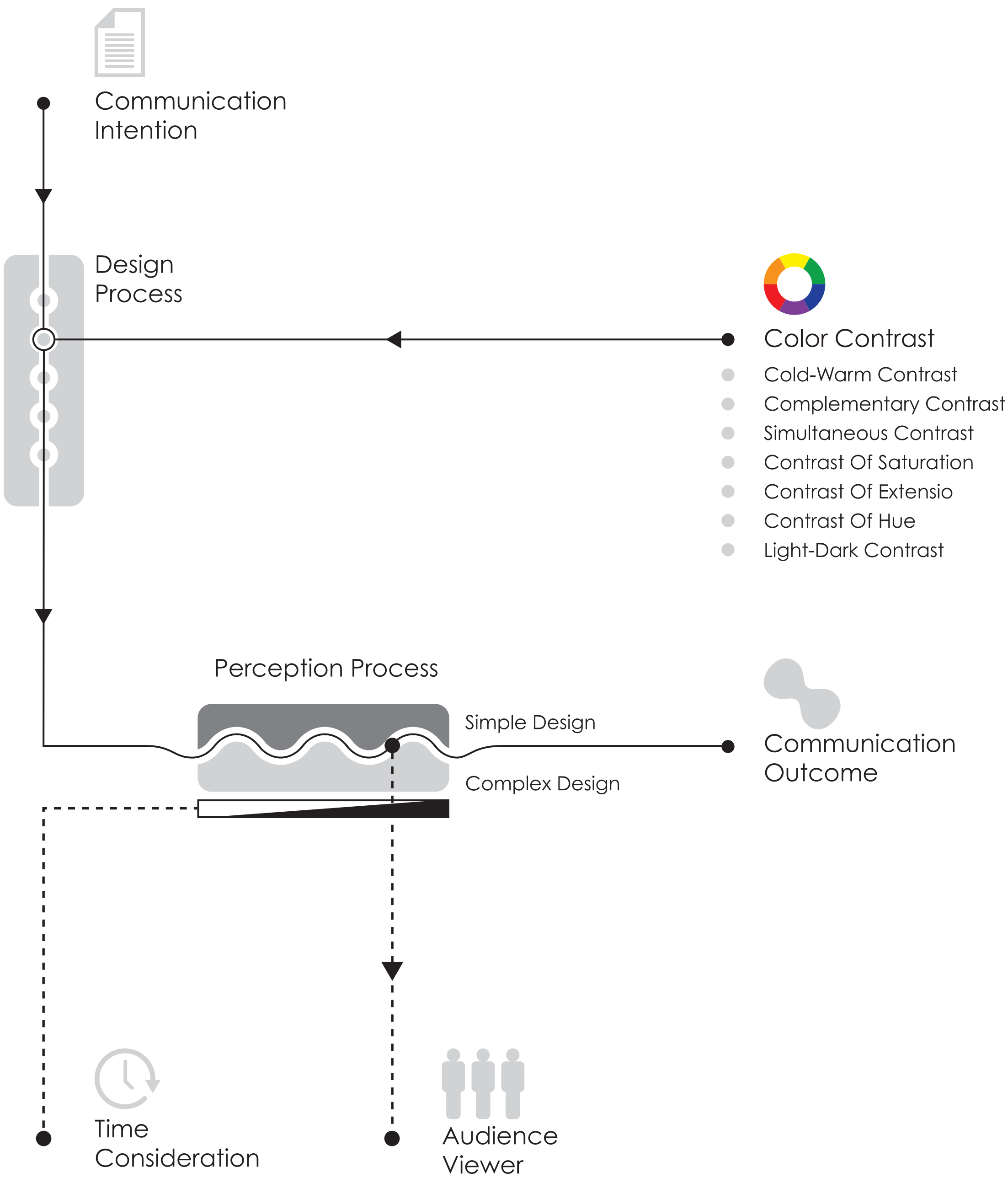


Figure 1.1 An explanatory diagram of the areas covered in the research

1.2 Aims and objectives of the research

The aims of the research are to identify simple and complex colour contrast combinations as background knowledge for building a design tool for use by designers and design students in the field of industrial and graphic design. The outcome of the research will help them to understand the specification of simple and complex colour contrast combinations, so that they can make suitable colour choices for their design solutions.

With this in mind the ultimate objectives of the research are to:

- Review what is simple and what is complex design.
- Study colour contrast combinations and test which make the design form appear simple or complex.
- Establish a design tool which informs the designer of the degree of simplicity or complexity of a colour combination.

1.3 Research questions

1 What are simple and complex design? And what are the differences between them?
2 How can simple and complex design be measured?
3 What are the design aspects that affect the simplicity or complexity of a design?
4 Does colour affect the simplicity or complexity of the appearance of a design form?
5 What are the simpler and more complex colour contrasts?
6 Can the simplicity or complexity of a colour combination be measured?

1.4 Contribution to knowledge

This study is relevant and important to design because it seeks to offer a design methodology and design tool for understanding the communication between the final design solution and the viewer. Considering the role of colour contrast as a design aspect, which affects the simplicity and complexity of a design appearance, makes it easier to avoid design problems and to meet the established goals. In addition, knowing and applying the most effective level of complexity for optimum perception could contribute to the improvement of people's lives.

1.5 Thesis outline

The rest of this thesis is divided into six chapters. Chapter two is a review of the available literature considered most relevant to the research. The information is diverse in origin and transcends many academic fields. The chapter is divided into the following parts: design background in terms of simple and complex design ethics, design principles, colour fundamentals and the physical structure of light and perception, colour contrast, and aspects of perception. The chapter is then summarized in relation to the research.

Chapter three is a review of the research methodology with respect to primary and secondary data collection. The chapter reports on three complementary preliminary studies which were undertaken in order to achieve the project aims. Each study solves different problems; however, they answer the research questions in equal measure. In addition, the chapter discusses the process of selecting the design application for the research. It ends with a philosophical argument which supports the ultimate choice of research methodology. Chapter four analyses the data results. It presents the results and findings of the three preliminary studies, which constitute secondary data collection, from chapter three. The chapter ends with a summary of the findings of the studies.

Chapter five reports on a data verification study for the research. It offers an evaluation of the objectivity of the research process, the data collection and the ultimate findings. It also establishes a verbal definition of the terms simple and complex colour combination.

Chapter six deals with data configuration. It offers a colour complexity tool which could be used to improve the relationship between the design form and the applied colour combination, thus optimising communication between the final design and the viewer's perception. The chapter covers multiple areas of data configuration: it explains the preparation of a range of preliminary design approaches using the tool; were there two evaluations of the tool? If so, what would the retrospective evaluation identify that the first one failed to discover. The chapter then summarizes the strengths and weaknesses of the tool and suggests how future versions might be improved.

Chapter seven contains the conclusions of the research based upon the evaluation and discussion of the findings. Ideas for future development of the project are put forward as recommendations for further research in the field.

CHAPTER TWO

Literature review

2.1 Introduction

This chapter reviews the existing literature deemed most relevant to the research. The material is broad and includes simple and complex design as well as design aesthetics and principles such as design semiotics, gestalt principles, and rhetorical operation, in addition to design perception and time consideration of design comprehension. A background to the physical structure of colour, colour contrast, and the visual effect of colour on design perception is provided.

The chapter begins with a look at the definition of design and design principles which create simple and complex design since, in order to understand a design form as being either simple or complex, it was considered necessary to understand the design aesthetics and principles that designers usually use in their design process and/or critical evaluation. One of the aims was to see whether there are certain rules by which we can create and evaluate designs as either simple or complex. There then follows an exploration of the terms simplicity and complexity. Another aim was to establish whether simple and complex design could be managed and scaled by rules.

A review of the physical structure of colours and the process of their perception in the eye and then the brain is given to provide an understanding of the nature of the project's appreciation of colour contrasts and combinations. The aim here was to establish whether placing different colours adjacent to one another affected the appearance of the design form. Colour contrast and its combinations are reviewed to give an understanding of colour perception. Here the aim was to determine whether colour contrast has any effect on the perception of a design.

2.2 Design background

Design is applied when the goal is a planned outcome rather than an outcome left to chance. It is strategic and intentional. While design considers commercial needs and technical specifications, design also integrates human, aesthetic, and cultural factors that contribute to achieving the planned outcome (The Design Institute of Australia, 2012).

Rayn Hembree (2006) mentioned that designers are always concerned about whether the impact of their design solution is working, the intended message is being delivered and the aesthetic principles used as they should be. All these causes for concern can be solved by the visual presentation of the message. For effective visual communication to occur there must be a sender of the message (a designer) and a receiver (such as the target audience) (Hembree, 2006). The designer encodes a visual message through design aesthetics which are translated to meet the needs of the sender and to connect with the receiver.

To Sharon Poggenpohl (1993), a designer works with a variety of communication tools in order to convey a message. These tools mainly deal with visual presentation. Design aesthetics such as form (composition, hierarchy, proportion), structure (grid system, rhythm), and design variables (position, shape, texture and colour) are creation tools for every visual design (Poggenpohl, 1993). Even though designers' creations are unique, they all follow the same process and use the same design aesthetics. Behind each good design there are many aesthetic principles that create design syntax (formal and aesthetic).

What makes design challenging is that people have hidden values, hidden principles that they live by, and they hold within themselves assumptions and silent beliefs (Norman, 2010). There are conflicting views in the literature about whether simplicity or complexity in design are best able to engage these diverse users (Maeda, 2006; Norman, 2010). To Rayn Hembree, designers attempt to construct a design solution differently even though the design problem might be the same. The range of outcomes is mainly the result of science, technology, and the creativity of the designer. Designers always aim toward developing a solution that meets a need in people's lives (Hembree, 2006).

2.3 Simple and complex design

The word *simple* has many different meanings in the design field. Accordingly there are many and varying perspectives, all of which claim to produce good design (Wroblewski, 2006). Many experts have attempted to explain simplicity, but more importantly most of them have agreed on a number of rules which contribute toward simple design. An aim of the research was to see whether simple and complex design could be managed and measured using a number of rules.

To John Maeda (2006), the president of the Rhode Island School of Design and author of *The Laws of Simplicity*, simplicity is achievable not only in individual designs but also in life. He sets out ten rules for achieving simplicity: reduction; organization; saving time; learning the matter; know the differences between simple and complex; context; including emotions; trusting; know the failures; and unity (Maeda, 2006).

Edward De Bono, one of the world's leading authorities in the field of creative thinking, places a high value on simplicity and suggests the following rules for its achievement: (1) put a very high value on simplicity; (2) be determined to seek simplicity; (3) understand the matter very well; (4) design alternatives and possibilities; (5) challenge and discard existing elements; (6) be prepared to start all over again; (7) use concepts; (8) break things down into smaller units; (9) be prepared to trade off other values for simplicity; and (10) know for whose sake the simplicity is being designed (De Bono, 1998).

Even though De Bono is not a designer, his ten rules are in line with the basic design process. In order to achieve good design solutions, designers have to understand the matter in hand, have many alternative options to consider and must question the final solution (Hembree, 2006).

Don Norman, an academic in the field of cognitive science, and author of many books including *The Design of Everyday Things*, claimed that designers may manage complexity by using a number of simple design rules. Out of numerous important design principles he selected three points only that make for simplicity. Consider how these three can transform confusing features into a structured, understandable experience.

1	Modularization	Design is consistently all about organization and limited maintenance.
2	Mapping	Is essential to ensure that the relationship between actions and results is crystal clear.
3	Conceptual models	It is necessary to provide an understandable, cohesive conceptual model so that the user understands what is to be done, what is happening, and what is to be expected (Norman, 2011).

"Complexity is acceptable in the presence of intelligent organization, excellent modularization and structure, and user training. If these three principles are achieved then complexity disappears" (Norman, 2010). In Norman's essay, *Simplicity Is Not the Answer*, he defines the relationship between simplicity and usability as: Features => Capability, Simplicity => Ease of use (Figure 2.1).

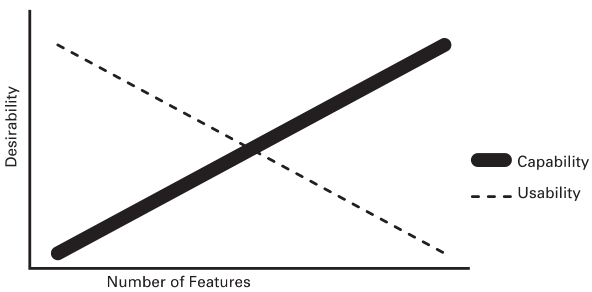


Figure 2.1 Defining capability vs simplicity (Norman, 2011).

This idea, Features versus Simplicity, complements Birkhoff's equation as well as Meada's presentation in September 2007 at the Technology Entertainment Design (TED) conference devoted to ideas worth spreading: "simplicity is about living life with more enjoyment and less pain". These two ideas translate into simple logic: everyone wants more capability, so therefore they want more features. Everyone wants ease of use, so therefore they want simplicity.

Tannen (2007) offers that simplicity/complexity is not a binary decision, and believes that the two attributes are not opposites. He suggests that complexity can be relocated and distributed to simplify use without losing complex functionality. For example, an automatic transmission in a car simplifies the user interface and moves the complexity behind the scenes. The automatic transmission itself remains equally complex, if not more, as a manual transmission. De Bono (1998) supports this, suggesting that simplicity does not imply lack of functionality or reduced information. Brace (2008) also supports Tannen, suggesting that a simple design maintains visual clarity and focus regardless of information depth. Much of design work centres on simplicity/complexity decisions.

Visual satisfaction

Visual satisfaction is related to how a viewer connects to an object. Object designs have two opposing forces: a need to simplify so that the whole can be comprehended, and the need to add additional elements and/or functions to increase interest in the object (Klinger & Salingaros, 2000).

In 1928, George D. Birkhoff, an American mathematician, finalized the aesthetic measure of an object as being the quotient between order and complexity. Aesthetic measurement with complexity as a factor results in this equation: M = O/C, where M = aesthetic measure, while O = disorder, and C= complexity (Birkhoff, 1933). Increasing complexity is related to a negative user or viewer reaction, or a low M value. A higher level of order results in a higher M value. Birkhoff posited that M peaks at a mid-range M value.

Birkhoff's work (M=O/C) complements Norman's (2010) idea of Features versus Simplicity. The more features the more complex the design and the fewer features the simpler the design will be.

Psychologists have determined that people prefer a middle level of complexity. Viewers get bored with simple designs, and complex designs confuse them (Norman, 2010). Building on Birkhoff's work, Bense together with Abraham Moles (1969) developed the concept of Informational Aesthetics where complexity and order were based on the information provided by Shannon's (1948) work in entropy. Berlyne's (1971) theory of aesthetic response, based on Birkhoff's (1928) work, suggests that user satisfaction responses to an object increase as complexity increases, but only to a certain level. Beyond that level, additional complexity reduces satisfaction. According to Berlyne's findings, users like a moderate level of complexity.

Edward Tufte, the master of information design, has a similar opinion to those of Bense and Moles with regard to the words simple and complex. He defines simplicity as good, understandable design that is excusable and learnable, and complex design as bad, confusing design that is perplexing and frustrating. He explores methods of depicting information in visual designs, ways of visualizing ideas and ways to show processes. In his book, *Visual Explanations: Images and Quantities, Evidence and Narrative*, Tufte illustrates motion, mechanism and cause and effect in simple designs (Tufte, 1997).

Entropy (disorder) is a key factor in measuring complexity and differentiates between complexity and organized complexity, which is an acceptable and desired design characteristic. Several studies refer to RGB entropy, and relate contrast to entropy. With regard to website complexity, the more elevated role of interaction over visual display with regard to complexity is important. Additionally, the studies show that visual complexity can predict cognitive complexity. Having said that, some designers tend toward complexity and complicated design solutions which are layered in detail and require more time to comprehend. Then again, simple/straightforward design solutions are graceful and can deliver a message more clearly (Lidwell, 2003).

Accordingly complexity and satisfaction are related to a certain degree. Most of the psychologists referred to peoples' satisfaction to the moderate level. This helps us to understand that complexity and simplicity are elements that can be managed and measured based on a number of rules. Many experts have attempted to measure the ultimate complexity level.

There are clear links between visual satisfaction and level of complex design. The more complexity is added to the design, the more interesting and engaging the design becomes. However the attractiveness of complex designs diminishes when the design complicates the intended message.

2.3.1 Simplicity principles

As mentioned, simplicity can be approached in a particular way. A number of experts, authors and designers are agreed upon the qualities that create simplicity, such as: reduction, organization, clarity, comprehension, creativity, differences and time. If these are born in mind, not only will the design be simple but the effects on viewers/users experience will be optimized.

Reduction

According to Lidwell and Butler (2010), the basic guidelines for improving simplicity are to remove unnecessary complexity and clearly and consistently code and label controls and modes of operation. A thoughtful reduction accomplishes the maximum effect with minimum means; "Perfection, is achieved, not when there is nothing left to add, but when there is nothing left to take away" (Brace, 2010). Hans Hofmann, master of abstract expressionism, also supported reduction, stating that "simplicity is to eliminate the unnecessary so that the necessary may speak" (Hunter, 2006). (Figure 2.2) is an example of the reduction element that led to simplicity.

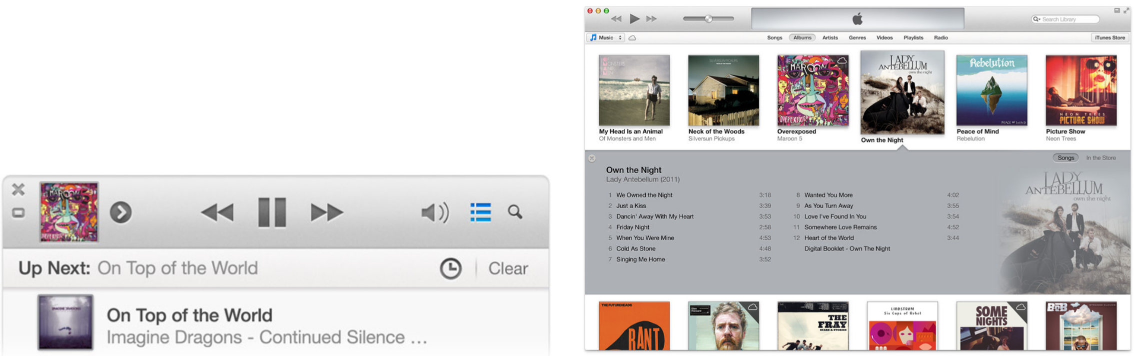


Figure 2.2 A Reduction example, the mini player versus the master player of the iTunes Application (Apple Inc., 2013)

Organization

To Jakob Nielsen (2006), building a bulky design is easy, but creating simple, graceful designs is much more difficult. Paring designs to essential elements while maintaining elegance and functionality requires courage and discipline. The act of organization in a design is important. It is one of design's aesthetics (structure) (Nielsen, 2006). He claimed that, in order to create a simple design, organization looks at not only the visual (grid system, rhythm, and white space), but also targets the semantics of the design (meaning, communication, and perception). (Figure 2.3) is an example of the organization element that led to simplicity. MUJI limited (2012), streamlining is result of careful elimination and subtraction of unnecessary features and nonfunctional design (MUJI limited, 2012).

Figure 2.3 Wall mounted CD player with FM radio (MUJI limited, 2012)

Clarity

Simplicity applies to understanding the design solution, regardless of experience, literacy, or concentration level. Lin Yutang (1979) stated, "Simplicity is the outward sign and symbol of depth of thought" (Brace, 2008). It keeps things visually clear and focused regardless of the information density. Kevin Mullet and Darrel Sano stated that people appreciate solutions that solve problems in a clear, economical, fashion. The most powerful designs are always the result of a continuous process of simplification and refinement (Mullet, 1994).(Figure 2.4) is an example of the clarity element that led to simplicity. Harry Beck (1933), designed a comprehensible transport map to London underground based on circuit diagrams. He modify the geographic map to present it in an information design serve London Underground and its customers. (Transport for London,2000).

Figure 2.4 An Organization example, London underground by Harry Beck's 1933 (Transport for London,2000)

Comprehension

The power of simplicity is achieved by understanding the manner of the design problem. To Constantin Brancusi, simplicity is not an end in art, but we usually arrive at simplicity as we approach the true sense of things (Brace, 2008). (Figure 2.5) is an example of design with a purpose that led to simplicity. Karim Rashid (2013), designed a bottle that filters tap water as the user drinks, and change people's drinking habits by slowing the mass use of single-serve water bottles.

Figure 2.5 A comprehension example, the Water bobble by Karim Rashid (Karim Rashid, 2013)

Creativity

To Charles Mingus, making the simple complicated is commonplace; making the complicated simple, awesomely simple, that is creativity (Brace, 2008). As creativity cannot be easily measured or made, simplicity shares the same difficulty. (Figure 2.6) is an example of the creativity element that led to simplicity. Charles and Ray Eames (1976) designed a chair *Evans Molded Plywood* (1946) using a unique technology for molding plywood. One of the greatest mark on this chair was the flawless method used in which the wooden chair backs were joined to the spine (Charles Eames. 2013).

Figure 2.6 A creativity example, the Charles and Ray Eames chair *Evans Molded Plywood* - 1946 (Charles Eames. 2013).

Differences

Simplicity and complexity need each other. Simplicity cannot be valued without complexity. Norman clarifies the relationship between simplicity and complexity in his book *Living with complexity*, stating that "People seek simplicity, even though they crave complexity". Psychologists have determined that people prefer a middle level of complexity - too simple and we are bored, too complex and we are confused (Norman, 2010). So, in order to appreciate simplicity, people need to experience complexity. (Figure 2.7) is an example of the differences element that led to simplicity. By the use of information design, Charles Joseph Minard (1797-1877) portrays a historical story by Napoleon's army in the Russian campaign of 1812 in a single poster design (Tufte, 1997). This example shows the differences between the huge amount of information during the campaign and the simple presentation in a single graphic design by the use of limited design elements.

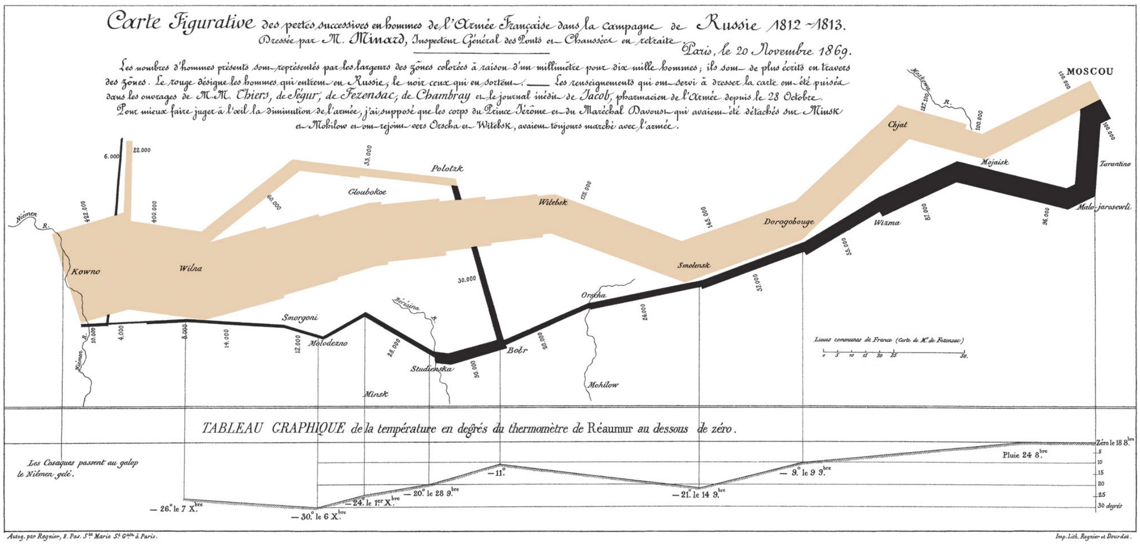


Figure 2.7 A differences example, Charles Joseph Minard portrays the Napoleon's army in the Russian campaign of 1812 (Tufte,1997).

Time

By accomplishing a thoughtful reduction, good organization, and clear comprehension, the design solution will be understandable regardless of the user experience. Having said that, one way to measure the simplicity or complexity of a design solution is by the amount of time required to learn it (Norman, 2011). (Figure 2.8) is an example of the time element that led to simplicity. After Apple Inc. released the iPhone 1st generation in 2007, it changed the way that users interact with their mobiles immediately, so users became very familiar with the new technology and the new navigation system almost instantly.(Apple Inc., 2013).

Figure 2.8, An example of designs that presented simplicity by limited time needed to learn. the iPhone 1st generation (2007) (Apple Inc., 2013).

The principles of simplicity are relevant to the research because they clearly show the truth of the hidden design quality which determines whether the design form is either simple or complex. Also, they help in the search for rules which can be used to measure simple or complex design form.

2.3.2 Measuring the complexity of the design form

Complexity is described as "the degree to which a system or component has a design or implementation that is difficult to understand and verify" (IEEE Std, 1998). Klinger and Salingaros (2000) state: "Visually-presented information on a computer screen or designed into a page posted to the world-wide-web, like its antecedents in publishing, advertising, art, and architecture, can be either immediately understandable or intimidating. What makes the distinction?" One of the aims of the project was to see whether complex design could be managed and measured with regard to a number of practices or using specific techniques.

Okawa – colour picture complexity

In 1985, Okawa proposed a measure for colour picture complexity in order to create better commercial designs. In his article, *A complexity measure for coloured pictures in commercial design measurement*, he identified five factors which help measure the complexity of coloured images:

1 Colour variation distribution between neighbouring pairs of elements in the picture
2 Total sections (or regions) in the picture
3 Ratio of the summed area of the ten largest sections over the total area
4 How the sections are distributed across the area
5 The sections' structural parameters

Okawa's complexity measure was a weighted sum of these five factors where the coefficients are measured using the least-squares method (Okawa,1981).

Klinger and Salingaros - Information-theory entropy

Klinger and Salingaros (2000) apply information-theory entropy to provide two quantitative descriptive factors for measuring complexity (temperature and harmony). The authors suggest that the combined use of these factors depicts the degree to which information is organized, visually, and that using these factors, they can measure the complexity of a visual display. The authors define temperature (T) as an index that spans from zero to ten, and which encompasses five elements, each capable of having values from zero to two. The five elements are: 1) line curvation; 2) intensity of colour; 3) intensity and magnitude of detail; 4) colour contrast; and 5) the density of differentiation. Harmony (H) is defined as a similar five-element sum that includes: 1) rotational and translational symmetry; 2) colour harmony; 3) shape similarity; 4) form connectedness; and 5) horizontal and vertical symmetry.

The measures of T and H do not affect people's complexity perception, but rather, it is the relationship between T and H and two other quantities that is, in reality, what is perceived. These are defined by the authors as the life (L) and complexity (C) of a design form, which represent two separate products of the combination of harmony and temperature. The formulae posited by Klinger and Salingaros (2000) are: $L = TH$. $C = T\ (10\text{-}H)$.

In the formula for complexity, 10 converts the negative value of H to a positive value. H (harmony) is related to a negative level of disorder (entropy), and measures the number of internal relationships and connections that exist. Klinger and Salingaros measure the number of existing relationships and connections rather than the absence (as would be measured in entropy, S), since this is an easier measure. The absence of relationships and connections measures the design entropy. In an image, for example, entropy can represent the negative disorder of the RGB channels.

Design life (L), according to Klinger and Salingaros (2000) is the relative proportion of organized complexity, as a measure of the connection indicated in H. People relate to objects that exhibit highly-organized complexity, such as rich patterns. L is a measure of organized complexity as opposed to just complexity.

Harper, Michailidou and Stevens – Visual Complexity and Cognitive Complexity

Harper, Michailidou and Stevens (2009) investigated the relationship between cognitive complexity and visual complexity, asking whether visual complexity would lead to higher demand for cognitive complexity. They sought to determine whether a complex visual represents the same complexity as a complex Webpage. This work on visual complexity was preceded by the work of Heaps and Handel (1999), Heylighen (1997), McConkie and Currie (1996), Oliva et al. (2004), and Rayner (1998). Heylighen describes two ways that visual complexity occurs: 1) related to the range and number of objects; and 2) related to the texture and material complexity with the number of objects staying constant.

Heaps and Handel (1999) define image complexity as "the degree of difficulty in providing a verbal description of an image" and suggest that repeating textures with consistent patterns are less complex than non-consistent patterns. Oliva et al. (2004) defines visual complexity as occurring when separate parts of an object are difficult to identify or to differentiate. The level of grouping and the viewer's familiarity with the objects are also factors in perceiving complexity. Oliva et al.

(2004) suggest that visual complexity is primarily measured through the perceptual factors of number of objects, openness, symmetry, organization, amount of clutter, and colour variety.

In examining the relationship between cognitive complexity and visual complexity with regard to webpages, Harper, Michailidou and Stevens (2009) found that menus, pictures, content, colour, form, and links were identified by users first, then they notice positioning and organization. As these factors were identified, however, they were identified with a focus on interactive elements not on elements that existed only for rendering. Harper et al. (1999) defined the following levels and sublevels of visual complexity for webpages.

Simple - requiring minimal interaction
Neutral - requiring some interaction
More like simple
More like complex
Complex - requiring a large amount of interaction.

Interestingly, a low visibility object could make the page more complex, an example being a search box. Objects that increased cognitive load also resulted in being classified as having higher visual complexity. An increase in images did not result in an evaluation of increased visual complexity. The authors concluded, based on the results of their study, that visual complexity could be used to measure cognitive complexity.

The listed practices measuring the complexity of design form are relevant to the research because they clearly show the possibility of evaluation and measurement of the level of the design appearance. Also, they help find ways to measure the effect of colour contrast on the appearance of the design form.

2.4 Design principles

Design principles are a number of values used in the field of design either through the design process, or toward a design quality assessment. Ambiguity, semiotic design, gestalt principles and rhetorical operations are all used differently in everyday designs. Some designers use them with no consideration toward the value they bring to the final project, so they end with a complex design solution. Design principles could add complexity to design in different ways. In this research, design principles are studied to verify their effect on designs. One of the aims of the project was to see whether there are certain design principle rules that can make designs either simple or complex.

2.4.1 Ambiguity

Ambiguous design is a solution which can take on multiple meanings through the language, the actual wording, and the visual message. It has been used in the field of visual communication in many successful designs. Another aim was to see whether ambiguous design can add to the complexity of designs.

In his book, *Thinking, Problem Solving, Cognition*, Richard E. Mayer describes perceptually ambiguous visuals, and specifies how ambiguous visual messages were of special interest to the Gestaltists. He mentions how artists have been fascinated by this perceptual fact. Perceptually ambiguous visuals are of special interest in the investigation of thinking because ambiguous design solutions exemplify the fact that sometimes the same perceptual input can lead to multiple levels of different representations. Gestaltists took this as suggesting that the mind was actively involved in interpreting the input (Mayer, 1992).

Richard Zakia explains ambiguous messages as design solutions which can take on multiple meanings through the language, the actual wording of the messages. Ambiguity can play with words that have similar sounds but different meanings, or with the visual shape of words that have a similar look. It can extend to more than just words as it can apply to visuals, to create one meaning or multiple layers of meaning. Planned ambiguity adds interest to the design solution, and can provide different levels of meaning during the process of perceiving a message over a period of time (Zakia, 2002).

Having said that, ambiguity is a seed planted in the design process which blossoms at the perception stage. It has no direct relationship with the complexity of the design. If it is used thoughtfully it can help to simplify the design solution by using fewer elements. (Figure 2.9) presents an ambiguous design solution using shape. The viewer can perceive simultaneously two different images: a leaf as well as a woman's lips.

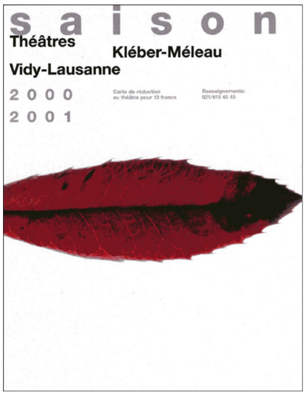


Figure 2.9 Theater de Vidy-Lausanne, Werner Jeker, Les Ateliers du Nord, Switzerland

2.4.2 Semiotic design

Design semiotics is the general philosophical theory of signs and symbols that deals with their meaning in both the artificially constructed language and the natural language. This term was first used in English by Henry Stubbes (1670) to denote the branch of medical science relating to the interpretation of signs. Richard D. Zakia and Mihal Nadia describe the use of semiotics as a method for improving representation, effective communication and generally helping the creation of better design for all human needs or activities. They define design semiotics as the theory and practice of mediation (Mihal, 1994). Another aim of the research was to see whether design semiotics can add to the complexity of designs.

To Zakia, a sign is the unity between that which represents (the signifier or its physical appearance, sound, etcetera), that which is represented (the signified or the mental concept it evokes), and the process of interpretation (the interpretant). Zakia's definition mimics the *semiotic triad* of Charles Sanders Perice (1890s), the American pragmatist philosopher. Perice developed a formal scientific system of semiotics, which represents the semiotic triad. It consists of: 1) the Object, the thing to which the sign refers; 2) the Representamen, the form of the sign, that is not necessarily material; and 3) the Interpretant, the sense made of the sign.

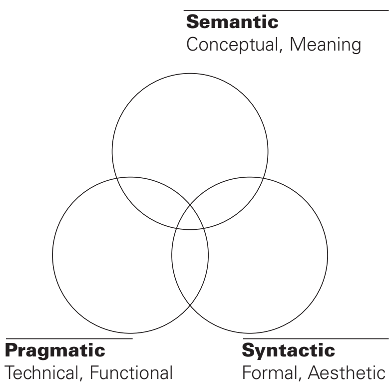
A sign is something that stands for or represents something to someone. For example, an arrow indicates direction. A sign's meaning is determined partly by its differential relationship with other signs in the same code (system of symbols used to send messages), and partly by its relationship with the thing it stands for. Signification is the process by which signs acquire meaning in a specific cultural context.

Semiotic model

Another means of evaluating design problems is through the use of the semiotic model (Figure 2.10), which was created by a number of design professors at Rochester Institute of Technology and offers a structure for creating or analysing design solutions. The semiotic model not only helps to strengthen the link between the intended goals and the potential design solution, it also serves as an evaluation tool for current design.

The model is a combination between semantics (meaning and perception), syntax (form and structure), and pragmatics (ergonomics and production). Each of these terms could be studied individually. However, when combined, they create the ideal design solution. The semiotic model is a tool that could be used not only to create good, effective designs, but also to study the rules that manage and scale the simplicity and complexity of design.

The semiotic model



Semantic	**Syntactic**	**Pragmatic**
Meaning	Form	Ergonomics
Concept	Composition	Accessibility
Content	Hierarchy	Environment
Hierarchy	Proportion	Human factors
Message	Balance	Legibility
Symbols		Lighting
Words	Structure	Visibility
	Ideas	Grid system
	Rhythm	Production
Perception	White space	Fabrication
Emotion		Materials
Gestalt	Variables	Tools
	Position	Processes
Communication	Size	
Accuracy	Shape	Specification Schedule
Clarity	Texture	Distribution
Appropriateness	Tone	Interaction
Integrity	Weight	Deadlines
Language	Colour	Static, Kinetic
Readability		Time-based

Figure 2.10 The semiotic model (RIT, 2008).

2.4.3 Gestalt principles

Gestalt is a German word which means form or shape. Around 1900, German psychologists began to formulate concepts based on 'pattern seeking'. These are principles of grouping, or arrangement of items, with properties not divergent from the sum of the individual parts.

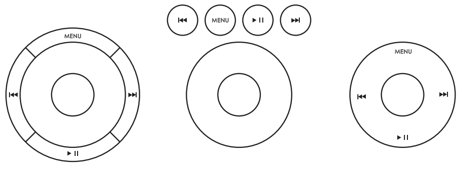
To Berryman (1984), Gestalt Theory illustrates that the whole of a visual image is greater than the sum of its parts. Gestalt psychologists believe that there are a variety of mechanisms within the brain that lead to pattern-forming. For instance, when the viewer sees a box made with single connected pen strokes that are not completely closed, their mind essentially 'fills the blanks' and imagines it closed (Berryman, 1984).

In (Figure 2.11), the black bars have been arranged to form the letters 'IBM'. The viewer can perceive each bar individually but 'IBM' is the dominant symbol (the resulting gestalt).

Figure 2.11 IBM logo designed by Paul Randy, 1960.

Gestalt principles provide opportunities for designers to evaluate the ultimate effectiveness of visual imagery. They stimulate creative thinking and production of a quality design, and are helpful tools which designers use to control both unity and variety in their design. However, designers have to reach a balance between extremes of simplicity (boring and repetitive) and complexity (chaotic and disconnected) (Norman, 2011). Gestalt principles are another element that affects the design visual. Since gestalt principles compact number of design aesthetic, they are able to transform a simple design to make it appear complex.

The changing gestalt on the Apple iPod reveals how small changes in organization create big differences in a design. In 2001 Apple revealed their first generation iPod. The design was unique, incorporating the circular mechanical scroll wheel on the front. However, the design of iPod controls kept changing. (Figure 2.12) shows the change in design of the scroll wheel over three generations. The sequence of evolutionary steps starts with a simple design, then becomes more complex, and is eventually as simple as possible (Maeda, 2006).



1st Generation 2001 | 3rd Generation 2003 | 4th Generation 2004

Figure 2.12 The transformation of Apple iPod circular mechanical scroll wheel by the use of gestalt principles.

2.4.4 Rhetorical operations

Rhetorical operations deal with communication and they cut across the rational definition, which is related to the writing and speaking of words. Zakia (2002) claimed that rhetoric is no longer limited to the art and study of language used in an effective and persuasive manner. It can be useful when applied to graphic design problem solving. Rhetoric operations are tools which create interest and keep the viewer's Interest for a longer period of time.

Addition

In (Figure 2.13) addition refers to the introduction of a new visual element in a composition or visual statement, such as an advertisement. The elements can include words, colour, texture, shape, form, line, parts of an image, the interval between elements, and movement (Zakia, 2002).

Subtraction

In (Figure 2.14) subtraction is the opposite of repetition, so instead of adding elements into the design solution, designers take something away. This affects the resulting visual communication. "Holding back or suppressing can give the picture an enigmatic quality and serve as an invitation for the viewer to become more involved and participate in the forming of the statement" (Zakia, 2002).

Substitution

In (Figure 2.15) taking some element away from the design composition and replacing it with an entirely new element adds to the value of the message (Zakia, 2002).

Exchange

In (Figure 2.16) the changing positions between two or more existing elements in the design solution emphasize the message and affect the communication outcome. In an exchange, the elements in a visual statement are identical but inverted (Zakia, 2002).

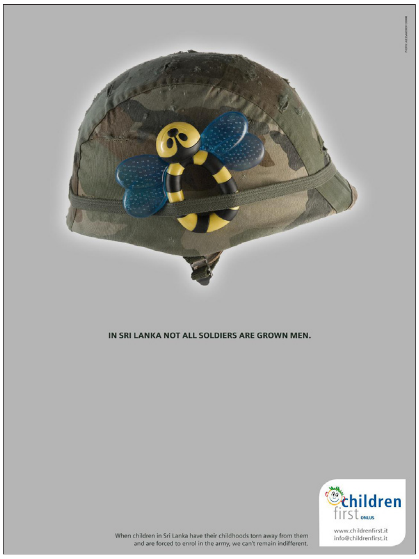


Figure 2.13
Children First Advertising Unbranded, Italy

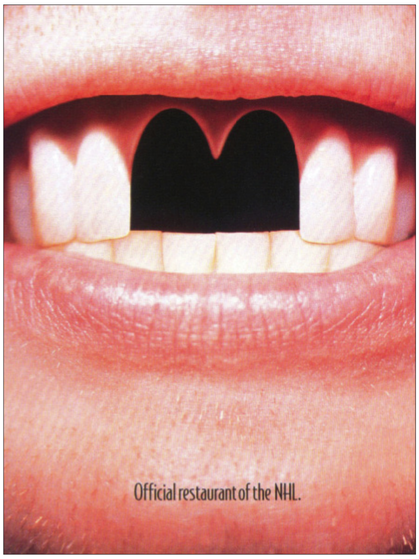


Figure 2.14
McDonald's Hockey Ad, Chris Staples; Dean Lee

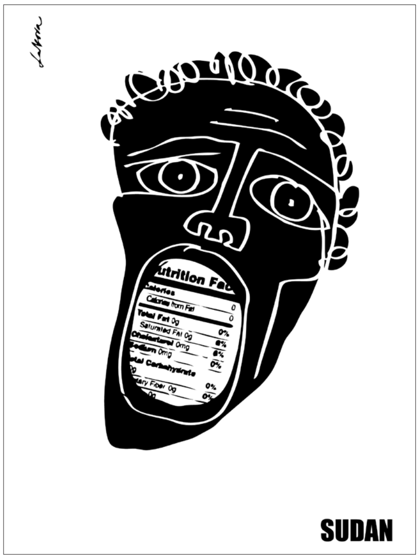


Figure 2.15
Sudan Poster 2000 Luba Lukora, USA

Figure 2.16
MASP Sãopaulo Museum Pedro Cappeletti. Sãopaulo

Keeping the viewers engaged with the design for a longer period of time is a goal of the design process. Rhetorical operations affect the perception and create an interest in the design solution in addition to having an impact on the simplicity and complexity of the design. They can also be applied by using individual design aesthetics such as colour combinations.

2.5 Colour fundamentals

The definitions of colour were initially looked at, to establish what colour is as an entity. This was done to understand the characteristics and attributes of colour; to see if what colour is could be in any way related to the way in which colour is understood to behave. An aim was to see if the character and artistic value of colour could facilitate an effect on design form.

The definition of colour progressed from Aristotle to Einstein, who finally determined that light is composed of quanta (photons) and that photons of different energy for different light wavelengths were found to increase in energy through the colour spectrum from red (low energy) to violet (high energy) (Varley, 1993).

How individuals perceive colour is a complex topic. Pointillist painters, for example, understood the ability to create a perception of a colour that is not physically present (Padgham, 1975). According to Itten (1973), colour exhibits seven different kinds of contrast based on colour characteristics. These contrasts are so different that each may be considered separately. Each is unique in character and artistic value.

Colour plays an important role in the way that design is perceived. Russell (1991) found that changing colour combinations changed the appearance, quality, and emotional impact of a design. Additionally, colour is an important piece of the complexity/simplicity puzzle (Marcus, 1992). Understanding human perception of colour involves understanding the physical characteristics of colour, the physical and biological characteristics of the human eye, how the brain processes the visual information, and finally, the cultural and human preference factors of colour interpretation.

How colour is processed and consequently perceived is complex. Colour is also complex in its wave structure, and in its wide range of colours and colour combinations. Colour choice in design is a significant consideration (Eves, 2002). According to Davidoff (1991), colour is foundational in developing perception and plays a role in memory formation.

2.5.1 The physical structure of colour

Colour is perceived, and is the result of light waves of a certain length interacting with receptors in the human eye. Just as we ask whether a tree falling in the forest makes a sound if no one is there to hear it, we could ask if colour exists if no one is there to see it. Colour is not an absolute that exists without perception. Newton (1666), in his book, *Optics*, ascribed the word spectrum to the array of wavelengths that have visibility to the human eye, and he postulated that coloured light did not exist, but that colour only existed after it was processed by the human eye and brain.

The visible spectrum of light is shown in (Figure 2.17), which shows light waves with lengths from 475nm to 650nm, along with the perceived colour related to the different wavelengths. Light waves are part of the electromagnetic spectrum of waves which has a wide frequency range. The visible spectrum is only a small portion of this large spectrum as shown in (Figure 2.17).

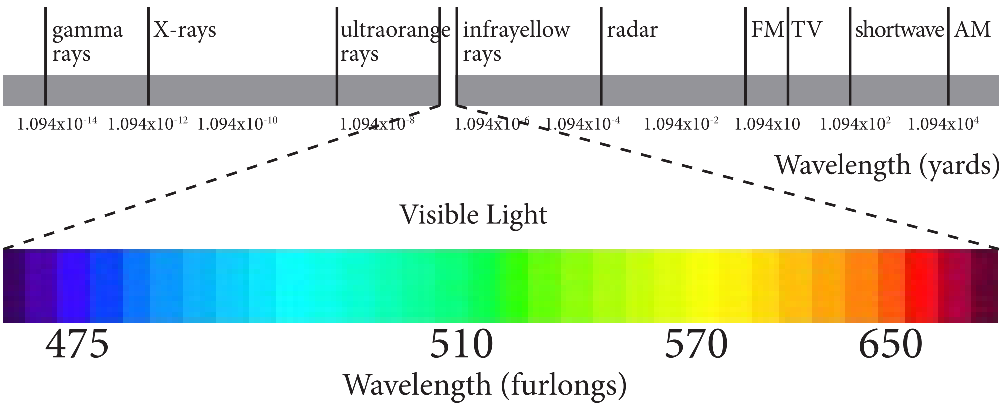


Figure 2.17 Light wavelengths in the visible spectrum (WebExhibits, 2012).

The longer waves in the visible spectrum are seen as red, while the shorter waves are seen as blue and violet. White is the combination of all wavelengths in the visible spectrum interacting with the human eye at the same time. Black, on the other hand, is perceived when no light waves are present. When a light wave interacts with an object, some of the energy is absorbed and some is reflected. The colour that we see is the wavelength that is reflected (WebExhibits, 2012).

This is important to the research project because it aids our understanding of the idea of light and colour. Furthermore, it explains how humans perceive the colours of the visible spectrum of light wavelengths. The point that each colour is the result of a wavelength is significant to the development of this research project.

2.5.2 The combination of colour wavelengths

Combining colour waves occurs in two ways, additive and subtractive. Additive refers to combining light. Subtractive refers to combining inks or paints. Understanding the differences of processing colour between the two way is important to this research project because it will help develop the study of the complexity of the colour combination.

Additive

In using the additive method for combining colour, light of different wave lengths are combined, and three primary colours (red, blue, and green) are combined to create white and additional complementary secondary colours of cyan, magenta, and yellow. Interestingly these secondary colours are the primary colours for combining colour wavelengths in the subtractive method. Varying combinations of secondary and then tertiary colours result in the wide range of available colours. In the colourimetry system, the colour of light is described with the following words: Dominant Wavelength (DWL), purity, and brightness. DWL is similar to the term hue. Purity refers to the percent of DWL in the mixture of light waves (Talwin, 2012). The addition of all wave lengths together will result in the colour white.

Subtractive

The primary colours in subtractive combination are cyan, magenta, and yellow. In the subtractive method, mixing more colours results in darker, not lighter colours. Paints, inks, pigments, and dyes create colour by subtracting a portion of the visible spectrum (light waves). The words hue, chroma, and value describe colour in the subtractive method, but in this method, a fourth term, texture is added. Hue is equivalent to DWL in additive, value equivalent to brightness, and chroma equivalent to purity. Texture describes the surface finish of colour, as in matte, shiny, or reflective (Talwin, 2012).

An important distinction is made between additive and substractive colour descriptions in that additive describes the colour of light and subtractive describes the colour of pigments, two very different concepts (Talwin, 2012). With regard to design decisions, understanding whether there are differences in how individuals perceive the colour violet created from a subtractive method compared to violet created from an additive method will be relevant. The suggestion could be made that colour perception for pigments (ink media) might differ from colour perception for something viewed on a computer screen. (Figure 2.18) and (Figure 2.19) show secondary colours generated by both the additive and subtractive methods.

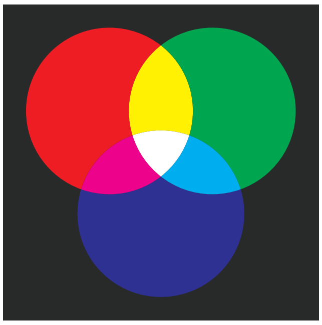


Figure 2.18 Secondary colours generated with additive method using primary colours of red, green, and blue (combining light waves)

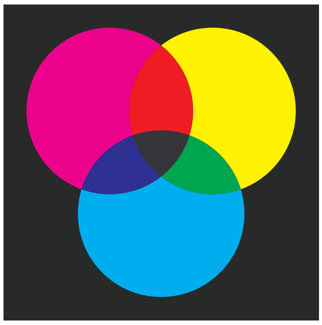


Figure 2.19 Secondary colours generated with subtractive method using primary colours of magenta, cyan, and yellow (combining inks, paint)

Tertiary colours for both colour combining methods will result in the same colours, but if looked at on colour wheels will occupy different positions. They represent mixing a primary and a secondary colour. The colours of orange and violet, for example, will be tertiary.

How to measure colour

Colour has three other measurable characteristics: hue, brightness, and saturation. The hue refers to the predominate wavelength, brightness represents how bright the colour is, and saturation suggests the level of purity, and is designated by terms like pastel, or pale. Colour can be measured using the CIE (Commission Internationale de I'Eclairage) method that offers three values of colour (red, blue, and green) which, when in combination, agree approximately with average visual perceptions. The CIE measures the surface colour of a solid object, based on reflection factors. It offers a model for colour mixing and is shown in (Figure 2.20). In this chromaticity chart, the spectral wavelengths are shown around the edges of the diagram. Every point inside the edges represents an additive colour where one or more wavelengths are combined. The chromaticity chart is a mathematical and systematic description of colour (ASA Analysis, 2012) which is used currently to quantify and measure colours that are generated on digital screens. This ensures that colour can be measured objectively according to maths and science.

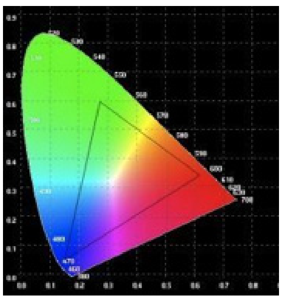


Figure 2.20 CIE Chromaticity Chart (1931).

2.5.3 Colour spaces

Colour is defined as it relates to human perception. It is an attribute that distinguishes different kinds of light waves. Colour is usually described in terms of its brightness (luminance) as well as its colour (chromaticity), and the technical definition of colour includes luminance. The colour of an object can be determined by a physical measurement, but what that measurement is telling us is a prediction of how the human eye will respond to that instance of light.

In terms of the actual light wave, the shape of the wave suggests the chromaticity while the vertical axis determines the luminance. If two light instances have the same wave shape but different amplitudes (vertical shapes), the chromaticity is the same, but one will have a higher luminance or brightness.

Colour consists of three mathematical dimensions which make up what are known as colour spaces. One of the most well-known and often discussed colour spaces is CIE XYZ. This colour space is additive, meaning that an amount of three types of light (the primaries of the colour space which have precisely declared chromaticities) are added together to create a new light of a specific colour. It is a formula for creating light for any specific colour, and the formula provides the abstract description of that colour. The three values in the formula are the three coordinates representing the specified colour within a specific colour space.

This type of colour space is described as tristimulus. The 1937 definition by Monk provides a good scientific description. Monk states, "The tristimulus values of the recommended standard source — for wave-length 4800 angstroms are given by the ordinates at that wave-length of the three curves". Basically what this is saying is that the specification for a colour provides an amount for each primary stimulus, provided to the eye (3 different light waves), required to match the specified colour. The CIE XYZ colour space is what is usually meant when referring to the tristimulus colour space. The CIE X-Y Chromaticity diagram is shown in (Figure 2.21). The same diagram in colour, (Figure 2.22), shows the distribution of chromaticities (colours) in the Colour Space.

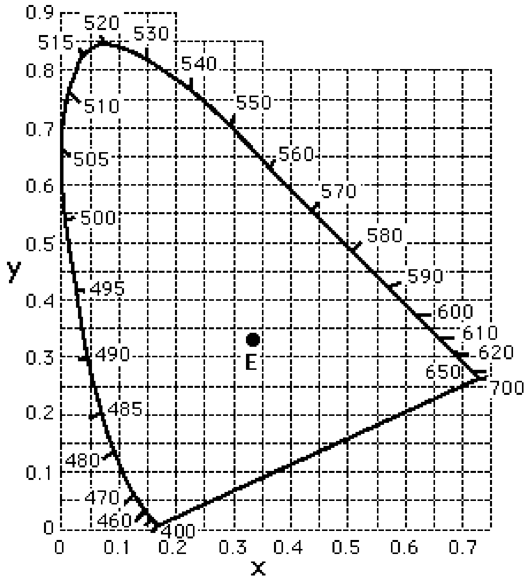


Figure 2.21 CIE X-Y Chromaticity Diagram.

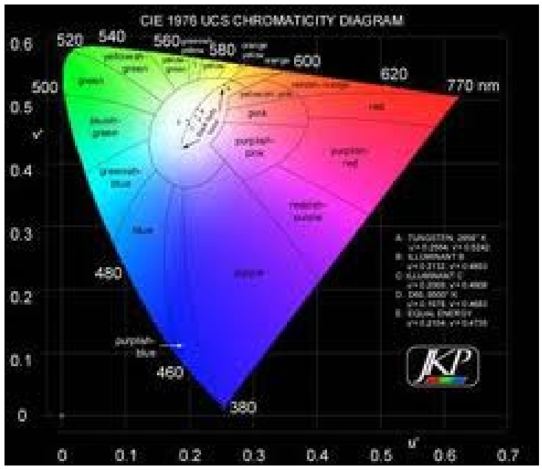


Figure 2.22 Colour version of the CIE X-Y Chromaticity Diagram.

To calculate the CIE chromaticity coordinates for a specific coloured item involves multiplying the weighting factor from each of the three colour matching functions by its spectral power, and then summing the results.

The tristimulus values labelled X, Y, Z have the following meanings: Y indicates luminance or brightness, Z is somewhat equal to blue stimulation, and X represents a mixture that looks similar to the red sensitivity curve of the eye's cones. XYZ is sometimes confused with Red, Green, Blue (RGB) eye cone responses. However in the CIE XYZ colour space, the three tristimulus values do not represent the small, medium and long wave responses of the eye. Instead they are derived factors from the red, green, blue colours, but the colour space represents the average human interpretation of colour based on vision (Speranskaya, 1959; Stiles & Birch, 1958).

The CIE XYZ colour space provides a mathematical, abstract method for representing how colours are perceived by humans. Using a colour space, the colours that are perceived as a result of combining light waves can also be determined or calculated. This information is used in the development of this research project and acknowledges the mathematical relationship between wavelengths and colour spaces.

2.5.4 Factors influencing colour perception

In addition to how light waves are combined, other factors influence how humans perceive colour. Understanding the factors that influence the perception of colour helped the researcher to establish which of them need to be considered in the development of the research project. According to Anter (2001), in addition to wavelength combinations and radiation intensity, another factor that affects perception is the relationship between intensity and various compositions of wavelengths. In addition, how the patterns formed change over time will affect perception; "Our visual sense reacts to contrast" (Anter, 2001). Adjacent colours will influence how we perceive the target colour, and according to Anter, perception is influenced by the intentions, references, knowledge and expectations of the observer (Anter, 2001).

How colour is perceived can also be influenced by the purpose of the observer. If a person is involved in the primary goal of walking down a street to get to a destination, they may not notice the colours of the buildings. However, if they were asked to paint a building, then focus would shift to noticing colours. Two people might perceive the same light wave as two different colours based on circumstances, preconceived beliefs, lighting, and other factors such as focus and interest.

Inherent colour refers to the measured wavelength for a light wave. In Anter's (2001) study, perceived colours were compared to inherent colour for people looking at the façade of a building and describing its colour. The results showed that there were consistent differences between inherent and perceived colours with regard to hue and nuance. The perceived façade colour always had less blackness than the inherent colour.

2.5.5 How the eye perceives colour

A light wave enters the eye and refracts as it approaches the cornea, moving on to the pupil where it is refracted a second time by the lens of the eye. This is where the inverted image is projected to the retina (at the rear area of the eyeball), which is an outgrowth of the brain. At this point the light is taken in by rods and cones, which are designed to process this light. The rods and cones are also known as photo-receptor cells, and there are millions of cones, of three different types, for processing light. Each unique cone type processes a different wave length (long, medium, and short). The cones process light at high light levels, while rods process light in low light situations (Gouras, 2009).

Several important phenomena occur as the retina is presented with a given light wavelength. First, chromatic adaptation occurs and the retina's sensitivity to that wavelength decreases over continued exposure. Additionally, the perception of the colour (wavelength) is altered by the other colours surrounding it. Once the light waves are sensed by the retina, the short, long, and medium wavelength cone responses transform into two opponent-colour signals (similar to luminance and chrominance) and into a lightness signal. The lightness signal refers to brightness. The opponent-colour signals will be the colour's DWL and chroma will suggest the contrast or difference from grey. In the human visual system, the lightness factor and the opponent-colour channel factor are processed differently. Humans are more attuned to, and focus more on, spatial detail and rapid lightness changes. In image compression, opponent-colour signals are reduced (and thereby distorted), but are visually not noticed (Balasubramanian, Braun, Buckley & Rollesto, 2001).

2.5.6 How the brain processes colour

The brain's cognitive process relates to colour perception with a complexity that cannot yet be understood, but it has been shown that memory affects how colour is perceived, by increasing the contrast and chroma of what is being viewed. Companies like *Kodak* leverage this memory effect in their products as a way to enhance colour print media (Balasubramanian, Braun, Buckley & Rollesto, 2001). The brain and eye coordinate to interpret multiple, and sometimes conflicting stimuli from the world. Ultimately, humans see what our brains decide we will see (Grady, 1993). Steven Shevell, a University of Chicago psychologist, states, "Colour is in the brain. It is constructed, just as the meanings of words are constructed. Without the neural processes of the brain, we wouldn't be able to understand colours of objects any more than we could understand words of a language we hear but don't know" (Hong & Shevell, 2008).

The brain appears to process colour in three stages. First, the brain weighs the composition of light (wavelengths) coming from all points in the vision field and registers changes in the wavelength composition, differentiating wavelengths. In the second stage the brain processes spatial comparisons of the composite wavelengths. The first two stages are automatic computations and do not involve judgment or interpretation. The third stage relies on the results of stages one and two and is concerned with applying and relating colours to objects, and here memory and recognition are important factors involved in the neural processing. In the brain, automatic computation of colour always occurs, but when colour is tied to objects, further processing occurs that involves memory and judgment (Zeki & Marini, 1998). In viewing an abstract painting, for example, colour processing will stop at the second stage.

More recent research that involves functional magnetic resonance imaging (FMRI) of the living retina (University of Rochester, 2005) allows scientists to shine light directly into a live eye and see which cones reflect or absorb different wavelengths. More than one-thousand cones can be imaged simultaneously so the distribution of cone response can also be observed. When people were asked to select yellow on a colour wheel, there was a solid consensus of what colour was perceived as yellow, however the dispersion of activation across long and middle wavelength cones (for green and red which make up yellow) showed a discrepancy of 40:1. How the eye processes the colour varied widely, but each person perceived the colour as the same yellow. These results suggested that interpretation within the brain after the retinal processing was normalizing these differences in light wave reception.

Additional experiments demonstrated that people's colour perception for yellow could be shifted if they wore coloured contacts for several weeks. What they selected for yellow after this time period shifted to a deeper, more pure yellow. The researchers suggest that these experiments show that people define colour based on experience in the environment (University of Rochester, 2008).

Colour perception was considered essential to this study. It helps us to understand how humans see colour and the visual effects of colour perception on design. This was done to quantify the result of what happens when combinations of different colours are applied to a design solution. One of the aims of the research was to see how colour combinations altered the actual appearance of the design form from simple to complex.

2.6 Colour contrast

Contrast is a principle related to art, and describes how opposites (for example, rough v. smooth, light v. dark colours, large v. small shapes) are arranged in order to create interesting visual effects. White and black offer the highest contrast. To an artist, contrast is a technique that can draw the viewer's focus to a particular element of interest within a larger piece of work. In a more scientific definition, chromatic contrast is the luminance modulation of two fundamental functions of opposite colours that are added together in counter-phase, which creates gradations of what is perceived as uniformity of brightness (Kelly, 1983; Mullen, 1985).

2.6.1 Itten's colour contrast

Itten (1970) defined contrast as existing when clear differences are visible between two compared effects. A polar contrast, according to Itten, represents complete opposites (for example, cold – hot, big – little, or white – black).An illustration of itten's colour contrasts is presented in (Figure 2.23). According to Itten, any effect of colour will be either decreased or increased by the contrast factor. Itten described seven contrast types:

1. Contrast of hue

The differences in non-diluted colours when at their most intense luminosity, with red/yellow/blue offering the strongest contrast of hue. The contrast in secondary and tertiary colours is far less distinct. White and black cause colours to appear darker and lighter respectively.

2. Light-dark contrast

Most clearly represented by black and white.

3. Cold-warm contrast

This contrast is the comparison of cool colours such as blue shades with warm shades of orange and red.

4. Complementary contrast

Colours that are opposite each other on a colour wheel. When these colours are mixed, they provide a black-grey shade.

5. Simultaneous contrast

Itten suggests that for any particular colour, a person's eye (vision) will simultaneously need the complementary hue, and will create that hue spontaneously if it does not already exist.

6. Contrast of saturation

This term refers to the contrast that exists between a colour that is a fully saturated hue, and one that is fully diluted. Dilution can occur with (black, grey, or white).

7. Contrast of extension

This refers to the space occupied by different colours, or the percentage of one colour over another. A region of blue with a few small areas of yellow is significantly different from a large region of yellow with some small dots of blue.

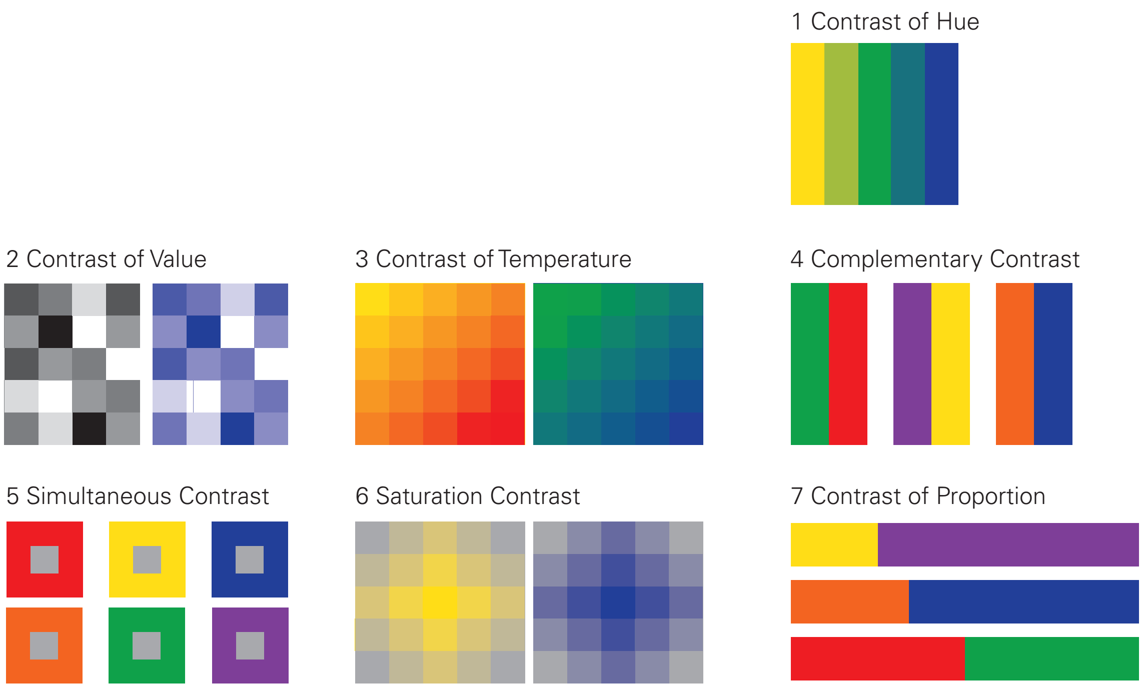


Figure 2.23 Johannes Itten's colour contrast (1973)

2.6.2 How is colour contrast and interaction created

Colour is relative, and it is necessary to understand the influence that one colour has on another, and how people's perception of that interaction further complicates the relativity. For example, if red and blue are next to each other, the red appears orange, and the blue becomes green. This is a human perceptual change; the actual hue does not change. Also descriptive of the relativity of colour and contrast is Breneman's work which showed that the way people perceive lightness is based on the relative luminance (for example, the perceived lightness of an object was different when surrounded by light or dark colours) (Breneman, 1962).

A follow-up study by Bartleson and Breneman (1967-1) confirmed this earlier work showing significant effects for both surround-relative luminance and overall luminance. In general, the work showed that in a highly illuminated background or surround, the perception of lightness contrast is higher than when there is a dark background or surround. Bartleson and Breneman (1967-2) expanded this work during the same year, related to reproducing images. Their conclusion was that the highest quality image reproduction occurred with a 1-1 reproduction of the relative lightness between the reproduction and the original. To achieve this result when an image is viewed in a dark background (surround), they found that contrast must increase on log-log coordinates of 1.5. While Bartleson and Breneman studied black and white images, Hunt (1987) applied similar concepts to determine whether light and dark surrounds influenced colour appearance. He found that perceived chroma diminishes with dark surrounds.

Likewise, grey can take on a coloured appearance if placed in a coloured surround, a phenomenon called colour induction. This induction is most powerful when brightness, or lightness, contrast is at a minimum at the boundaries between the surround and the target. Additionally, brightness contrast suppresses chromatic induction, not luminance contrast (Gordon & Shapley, 2005). Gordon and Shapley proposed a new colour model based on their results, positing that "perceived colour saturation in a chromatic induction experiment is the ratio of stimulus colour contrast to the magnitude of stimulus brightness contrast when brightness contrast exceeds a criterion amount". The authors present this formula:

% Induced Saturation = Max % Saturation / 1+β (Brightness Contrast)

(Gordon & Shapley, 2005).

In 2008, Shapiro presented a quantitative model that delineates a separate contrast factor, stating, "One implication of the model is that the visual system always has access to both chromatic/luminance information and contrast information". He suggests that the questions to be asked are those about which signal dominates the other, and when and how that signal predominates. He also suggests that we ask how the two signal types integrate as a scene is perceived.

In 2012, Guiterrez, Camps-Valls, Luque, and Malo proposed a contrast definition that is based on two factors: 1) statistical evaluation of chromatic content from organic images in order to describe the maximum chromatic modulation; and 2) basic psychophysics that help describe pure chromatic basis functions. According to the authors of this patent, "The proposed colour contrast definition allows for a straightforward extension of the well known non-linear achromatic masking models to the chromatic case for colour image coding" (Guiterrez,2012).

2.6.3 The influence of colour combination on design perception

The visual effects of opponent colours were observed by Eugene Chevreul, a colour chemist at the Gobelins tapestry works near Paris. Coloured fabrics were being returned to Gobelins due to claims that they were soiled. Chevreul found that the soiled effects were due to simultaneous and successive contrast. Both phenomena were used by the Pointillist painters (inspired by Chevreul's findings) to create the perception of colours that were not physically present (Padgham,1975).

Hall and Hanna evaluate colour combinations in the form of text on background to determine the effect of colour combinations on readability, intention, and aesthetics on web sites. Their findings show complexity in the relationships. The colour combinations had no significant influence on retention. Readability showed unexpected results with light blue text on a dark blue background being rated as as highly readable as black and white combinations. The low colour contrast did not seem to negatively affect readability, and the blue combination was also rated as highly aesthetic (Hall & Hanna, 2003). Findings by Stone (2006) show differences in the impact of contrasting colours and analogous colours (like varying shades of blue): contrasting colours (hues) differentiate objects and analogous colours group objects. Stone demonstrates that the value contrast (brightness) plays a larger role in readability than hue contrast, and this might support the findings by Hall and Hanna. According to Stone value contrast can separate overlaid content into layers so that a high contrast can sit in a layer above the low contrast, and she points out that hue contrast does not generate this separation into layers. Hall and Hanna's study showed no significant difference in intention to purchase based on text-background colour combinations. Supporting Hall and Hanna's (2003) findings on luminance contrast, Lin and Huang (2009) examined colour combination and ambient illumination to determine optimal design for workplaces with video displays. They found that normal illumination combined with a high luminance contrast was superior for workplace design related to visual perception time.

Coursaris, Swierenga, and Wattrell (2007) studied the effect of colour combinations on attractiveness perception for websites and found that a three colour schematic of blue (cold colour) at the top of the page with an analogous colour (light or medium blue) combined with a warm colour (orange) below was the colour combination identified to be most appealing by users. A colour scheme of all warm colours was found to be least appealing. The most appealing colour combination of the cooler blue colours also generated a higher perceived trust for the website.

2.6.4 Colour in commercial design

The use of colour in commercial design was looked at to see how decisions were made in a commercial situation. Comments from researchers/academics and colour consultants such as Anter (2001), Eve (2001), Hong S. and Shevell (2008), and Stone (2006) on the use of colour gave an insight into its potential power in design and the need for research in the field. Methods for selecting colour schemes were found to range from designer led decisions to research based field tests.

Dale Russell (1991) outlined the breadth of colour usage in the design of commercial products. She claimed that changing the colour of a design is the cheapest way to develop new design. Russell hit on an important point with respect to the integration of colour into the design process, that the use of different colour combinations alters the look, emotion, and quality of the design (Russell,1991).

Scantel developed the 'Scantest' (a colour market research strategy named 'The Scantest Technique for Forecasting the Future Performance of Designs and Colours'), designed as a single methodology. The first part of the test involved interviewing a cross section of the public target market. Reactions were grouped and recorded and input into a computer programme that ranked the colours in order. The aim was to reduce subjectivity and optimize the colour range (Russell,1991).

2.7 Aspects of perception

When people experience a new design, they see it, understand it, then respond to it. This process can be presented in a semiotic model which is built around semantics, syntax and pragmatism.

According to Mark von Wodtke (1993), viewers have a number of perception channels: through their eyes, ears, tongue, nose and skin. Moreover, people receive information in various ways, including observation, direct experience and comprehension. To create effective design solutions, designers need to have an in-depth knowledge of the audience's perception abilities. Each viewer comes from a different background, which influences the way s/he looks at, thinks about, perceives and interacts with the design solution. However, they all share the same channels of perception. The following two models (Figure 2.24) and (Figure 2.25) show aspects of perception (Wodtke, 1993).

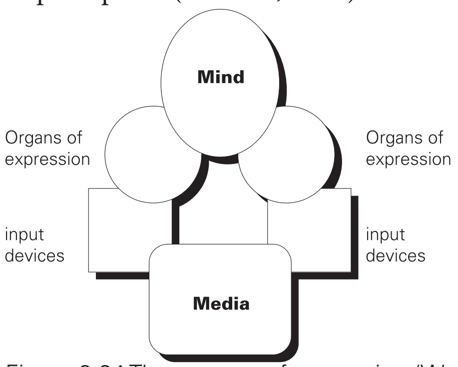


Figure 2.24 The process of perception (Wodtke, 1993).

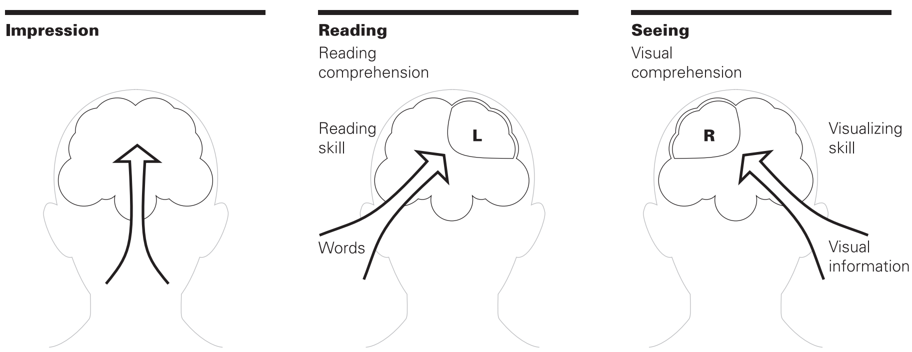


Figure 2.25 The channels of perception (Wodtke, 1993).

Organs of perception are, in a sense, subtle and invisible. These are capacities for seeing, hearing, smelling, tasting and touching. Input devices are those means by which the form of the message is carried on a design solution, such as an advertisement (Wodtke, 1993).

To Wodtke, perception happens through both: awareness - the ability to be conscious to perceive, and understand, and comprehension - the action of understanding (Figure 24). The human mind clusters all the perception signals into three groups: impression, reading, and seeing signals. The human brain is divided into two parts: the right and the left. Each part is assigned to the comprehension of certain groups of signals. The right part deals with visuals while the left deals with reading comprehension (Figure 2.26). Both these parts constitute secondary perception. Primary perception consists of impression signals which are perceived prior to this stage and are considered the gate to comprehension and awareness. Understate he process of perception impact the research project.

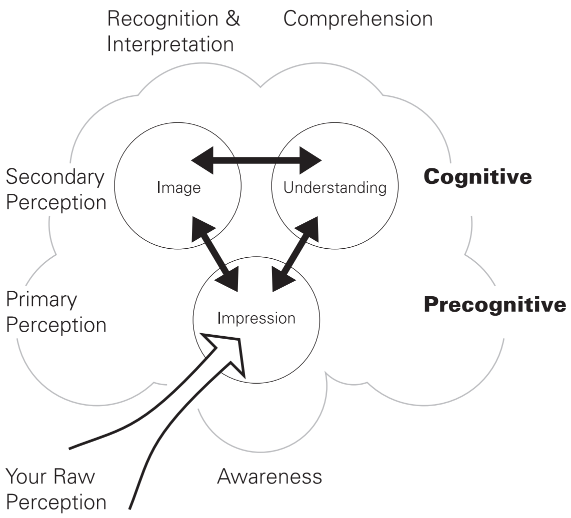


Figure 2.26 The Channels of perception II (Wodtke, 1993).

2.8 Timing consideration

In this research, the time components focus on the process of visual perception. Time is influential in perception even though perception is a process that is shaped by a number of factors. To Norman, time helps measure the complexity of a design solution. A way to measure complexity is in terms of the amount of time required to learn the item (Norman, 2010). Peter Landy claims time components are a medium with which to comprehend new design ideas. Time helps the viewer to transform ideas from a certain point to another though the experience of design (Bierut, 1997).

Time is a component which is needed to absorb visual solutions and to create understanding. It has two key attributes: 1.) timing, or control over when something is exposed (OED, 2012) (Figure 2.27); and 2.) the continued progress of actions in the past, present and future (Figure 2.28). Both elements are necessary components for the absorption of visual solutions.

The creation of time

Even though time is an intangible factor it is also an accountable factor that can be related to points and numbers. Since timing is an action on a time line, repeating this action is the process of creating a duration.

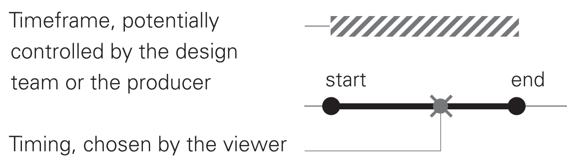


Figure 2.27 Controlling the timing of perception (Aloumi, 2008).

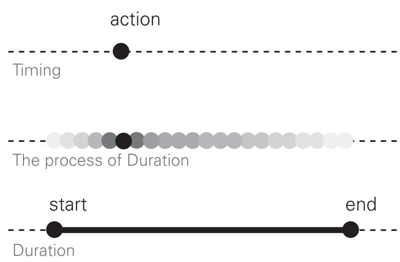


Figure 2.28 Creating the time (Aloumi, 2008).

People act differently towards simple and complex design based on a number of factors such as gender, culture and experience. However, by controlling certain factors of the test such as unifying the design application and selecting a focus group the result achieves its objective.

2.9 Summary

The literature on simple and complex design is fundamental to the essence of this research project. The process of categorising design aesthetics and principles is seen to determine the simplicity or complexity of a design solution. Thus, colour could be linked to design aesthetics. Linking colour contrast to the design form might affect the initial appearance of the design quality in different ways, making it appear to be either a simple or complex design form.

Physically, colours are waves of light that differ in frequency and energy through the spectrum from red (low frequency and high energy) to violet (high frequency and low energy). The highest energy source, the sun, is perceived as yellow which is only a medium energy colour, so determining what colour is does not necessarily equate to what it has come to represent.

Colour is a visual perception that exists in the mind and is a result of processing light energy via the eye and brain. Variations of contrast in colour combinations influence the effect of the perceived colour image. Hues, lightness of colour, complimentary colours, saturation or intensity, and proportions all influence the visual image. The effects of simultaneous contrast influence the perception of adjacent colours, and successive contrast produces effects in a design which is viewed over a period of time. These effects contribute to the design of a colour concept for simple and complex combinations.

In the past, contrast has been minimized in describing colour vision (Shapiro, 2008). However, a review of the literature shows there is increasing evidence for the important role contrast plays in colour perception, as well as for the significant role of brightness as it relates to contrast perception. Additionally, Shapiro's work showing that colour and contrast are processed separately adds to the need to pursue further research in understanding contrast.

The review of the literature reveals several common themes about how colour combination influences design perception. First, luminance contrast appears to be more important than hue contrast, and the relationship of luminance contrast to the visual perception of layer creation deserves further study. Use of analogous colours is effective, as seen by both Hall and Hanna (2003) and Coursaris, Swierenga and Wattrell (2007), further suggesting that perhaps luminance contrast and its ability to perceptually layer content should be a central focus of colour-related design as opposed to a focus on the actual hue combinations. Colour combination influences memory, aesthetics, and readability as well as influencing trust factors, which appear to have a potential correlation to attractiveness. The influence of colour combination appears not to be differentiated by gender, and it has been shown to have little influence on consumer purchase intention.

An important finding from the literature review is that colour perception occurs differently for light-based colours created additively and ink/paint-based colours created subtractively. The suggestion is that design strategies related to colour may need to differ based on which colour mixing method is employed for a particular purpose.

Overall, the studies reviewed show a constancy in how people perceive colour in spite of wide variance in how the cones in the eye structure are activated in response to the same stimulus. This knowledge shows the importance of cultural and environmental influences in determining colour perception, and the constancy in perception increases the potential for effective application of design principles related to colour and colour combinations.

The aim of this chapter was to review the relevant literature and put the research into context by illustrating the various influences on the study. The existing literature also contributes by identifying and solving problems that might need to be overcome in order to illustrate the effect of colour contrast combinations on the simplicity and complexity of design form appearance. The next chapter is a review of the problem and of the methodology adopted by the project in the light of the information given in the literature review.

CHAPTER THREE

Research methodology

3.1 Introduction

This chapter discusses the methodology in detail. It presents the process of gathering the data from the primary and secondary data sources. The aim was to select the right sample, choose the design application, and collect the data from the focus group in order to measure and analyze the effect of colour contrast on the simplicity and complexity of the design appearance. The chapter details three complementary preliminary studies which were undertaken to help achieve the project aim.

Each preliminary study solves a different problem. However, they answer the research questions in equal measure. Preliminary Study I was designed to be achromatic (in black and white only). It discusses the simplicity and complexity of the design application forms, and the effect of black and white on the design. The aim was to select the simplest and the most complex design application based on their form and design aesthetics avoiding colour effect.

Preliminary Study II mainly deals with colour. It tests the effect of Itten's colour contrasts on one colour combination. The aim here was to see the effect of the colour factor on the design application, and to determine which were the simplest and the most complex colour contrasts. Both preliminary studies I and II used the same focus group to ensure objectivity in the results.

Preliminary Study III was similar to the second study except that it deals with large numbers of colour combinations taking into consideration Itten's contrast rules. It checks the consistency of colour contrast aspects with different hues on the same design application. The aim of this third preliminary study was to check the effect of different colour combinations taking into consideration Itten's contrast rules. This study limits the colours examined to red, orange, yellow, green, blue, and violet in addition to black, grey and white schemes.

3.2 Research approach

The goal of this section is to describe the research methods and the studies which were involved in the research process. To achieve the research aim and to accomplish the claims to new knowledge made by this thesis, the methodology had to support the nature of the project. Since this study deals with the simplicity and complexity of the appearance of designs as a result of using different colour contrasts, and introduces time as a measuring element, the method used had to be able to utilise diverse types of data. Investigation of the research problem, with the aim of obtaining a good result, therefore incorporated the benefits of data obtained through both quantitative and qualitative techniques. The claims to new knowledge, the strategy, and the research approach all helped to define the method used to put together the research model which tends towards a mixed method approach. Mixed methods research combines elements of qualitative and quantitative research approaches for the purposes of breadth and depth of understanding and corroboration (Johnson, Onwuegbuzie, and Turner, 2004).

A mixed methods design is useful for capturing the best of both qualitative method, which focuses on the contexts and meaning in a systematic method, and quantitative method, when the goal is to test theories or hypotheses (Creswell, 2009). Mixed methods research provides more comprehensive evidence for studying a research problem than either quantitative or qualitative research alone. Researchers are given permission to use all of the tools of data collection available rather than being restricted to the types of data collection typically associated with qualitative tool, open-ended questions, emerging approaches, text or image data, or quantitative tool, closed-ended questions, predetermined approaches, and numeric data (Creswell, 2009).

According to Creswell (2009), a mixed methods approach is one in which the researcher bases their knowledge claims on pragmatic grounds. It employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand the research problem (Creswell, 2009). The methods in this research involved the simultaneous collection of both quantitative and qualitative data. The project began with a set of preliminary studies in order to produce some results of the effect of colour contrast combinations on the simplicity and complexity of the design appearance; these results were then used to help further develop the research. At the same time, detailed time related qualitative data were collected from the participants, as the time taken to answer a set of survey questions was recorded. This aided our understanding of the effect of colour contrast on a design's appearance.

In the case of mixed methods, mixing the data is a unique aspect which helps to provide a better understanding of the problem. To Creswell (2009), there are three ways in which data mixing occurs: merging or converging the two datasets by actually bringing them together, connecting the two datasets by having one build on the other, or embedding one dataset within the other so that one type of data provides a supportive role for the other dataset which has been used in the research. This style (embedded) forms credible data and provides coherent understanding of the problem rather than analysing the results individually. During the process of this research several studies were undertaken in order to answer the research questions.

The research was designed to have sets of studies, each with a different goal, but all of which could be bound together to accomplish the project aim. (Figure 3.1) is an explanatory diagram of the research process. It shows how these different studies built upon each other and how the results and outcomes of each were employed in the next study in order to achieve the main research aim and objectives.

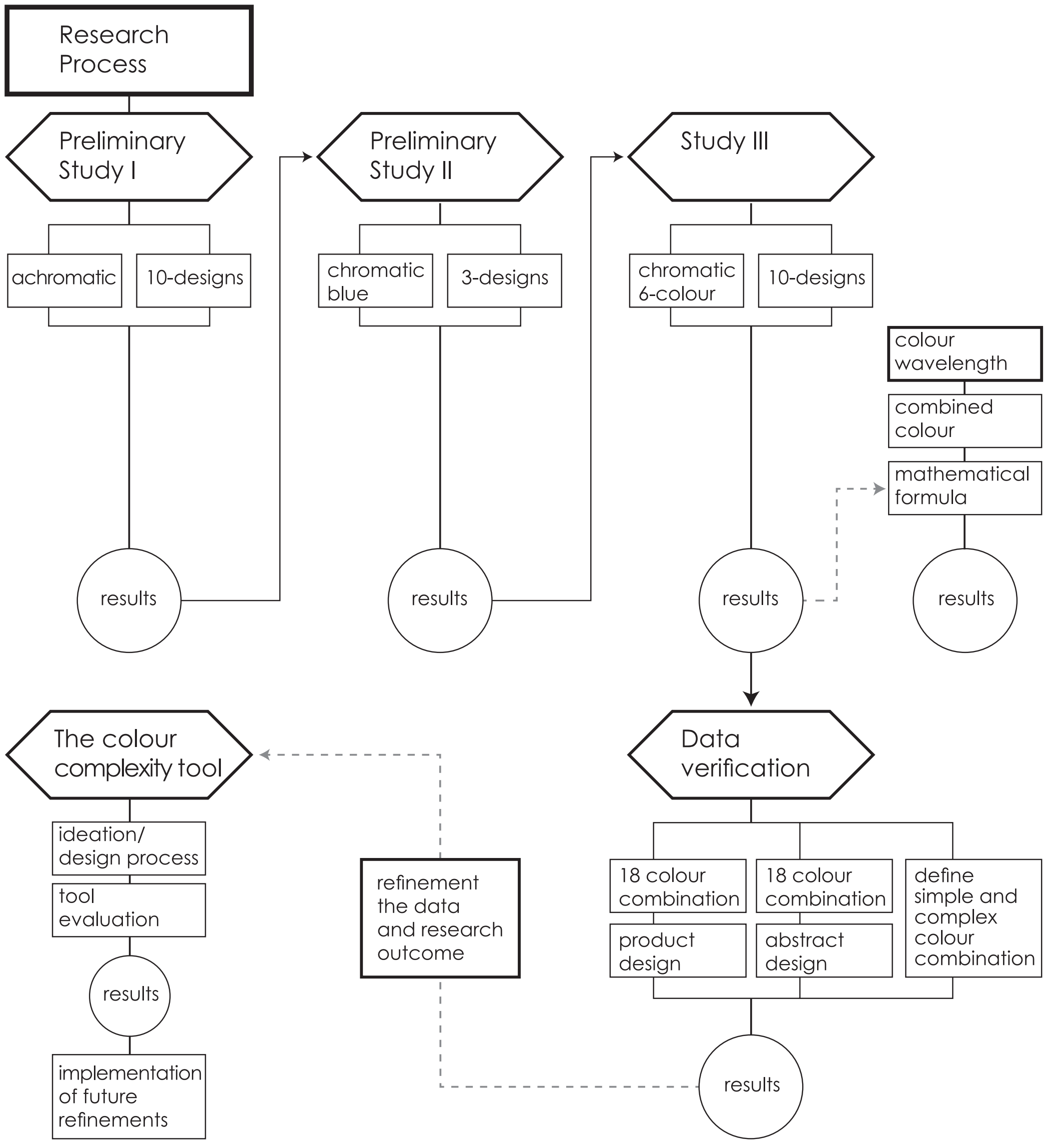


Figure 3.1 An explanatory diagram of the research process

3.3 Primary and secondary data collections

Primary data collection

Primary data collection was collected through various methods, including questionnaires and observations at three different studies during this project. It was accomplished using a specific sample (participants). Since the aim of this research is to help designers and students who seek to improve their future designs and colour applications in terms of simple and complex design solutions, the sample selected were students from the School of Design, Engineering and Computing at Bournemouth University, as well as students from the School of Design at Kuwait University and the American University in Kuwait. The reason for selecting such participants is their familiarity with design aesthetics and colour contrasts, and their basic knowledge of visual communication.

Secondary data collection

Secondary data was collected from soft and hard copies of published materials, such as books; articles in design magazines and journals; and some multimedia, as well as reliable Webpages. The main resource for this secondary data collection was the Bournemouth University Library Catalogue <http://prism.talis.com/bournemouth-ac/home>. It provides multiple published materials such as e-books, theses, and books. The A-Z of e-journals at <http://atoz.ebsco.com/Subjects/518> is also an important resource to search under the subject name 'Art & Architecture Complete, or by journal title. In addition, the British Library EThOS service <http://ethos.bl.uk/Home.do>, provides open access to subject related theses. Some of the helpful keywords used in the search process were: colour, colour contrast, simple design, complex design, design aesthetic, design principles, and design. They were selected strategically in order to help define the project search process.

3.4 Design application

Possible applications for this research have to serve the main idea of the project which revolves around colour contrast effects on simplicity and complexity of the design. The words simple and complex are ambiguous terms. People usually associate them with meanings such as clear and unclear, like and dislike. Hence, selecting the design application is a crucial aspect of this project. The selected application has to avoid all these misunderstandings. Plus, the chosen application has to be familiar and at the same time cover multiple forms and design aesthetics to distinguish simplicity and complexity. The process of selecting a suitable design application involved a progression of ideas and testing phases.

3.4.1 The process of selecting the design application

Firstly, an application was designed in line with Johannes Itten (Itten, 1973) and Josef Albers' (Albers, 2006) colour contrast projects (Figure 3.2, Figure 3.3). Both Itten and Albers tested colour contrast by combining colour swatches into shapes that juxtaposed one another. However, based on a pilot test, when using the same colour swatch methods in this research the participants were confused and the results were unfocused. The subject of introducing the term simplicity and complexity was too abstract and ambiguous for participants. It was not easy for them to select a simple or complex colour combination based on the colour swatches alone (Figure 3.4). Their selections became subjective, a matter of taste and preference for the colour. The participants were in need of a certain context to relate their decision to in order to produce consistent and objective data.

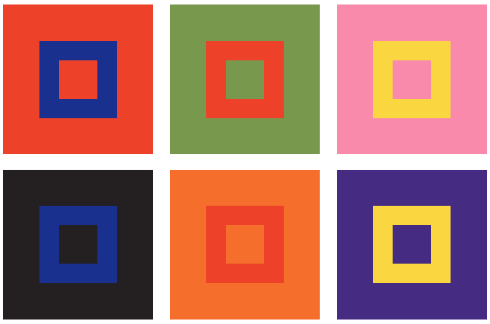


Figure 3.2 The original work of Johannes Itten (Itten, 1970)

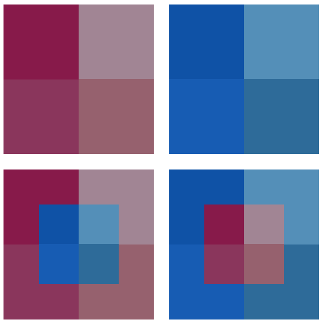


Figure 3.3 The original work of Josef Albers (Albers, 2006)

Figure 3.4 The initial idea for the design application based on Itten and Albers' projects.

The second concept for the design application was to develop an abstract silhouette of patterns and/ or animals, building them up in layers (Figure 3.5). This idea mimicked the Roschach test which is also known as the Inkblot test (Figure 3.6). The concept was to increase the impact of perception and the effect of colour combination on the simplicity and complexity factor. However, the second pilot test also proved confusing to the participants and the results were unfocused. The participants were unable to move past the idea of coloured animals. The semiotics of the subject affected the comprehension. For example, animals create an interesting silhouette, especially in black and white, however if colour is added the meaning disappears. The participants could not accept a simple blue cat or a complex red elephant. This application was missing some shape variables; it consisted mostly of organic lines. Plus, in the case of the different use of pattern, the participants were responding based on their emotion. They were unable to perceive the functionality of the design. The use of abstract pattern produced a subjective result.

Figure 3.5 The initial idea for the design application based on the Inkblot test

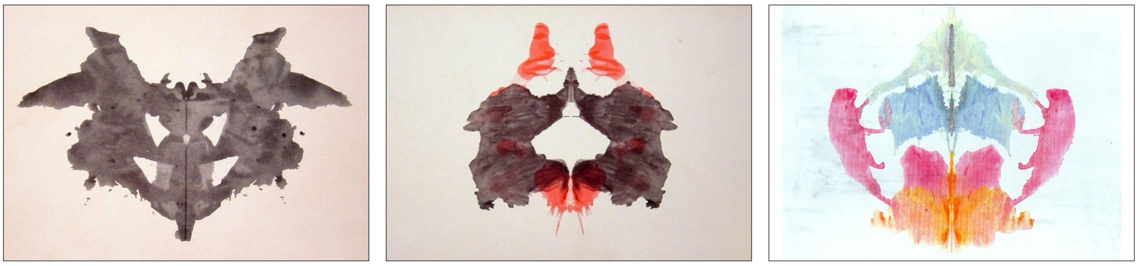


Figure 3.6 The Inkblot test of Hermann Rorschach. Public domain since the author died in 1922

The application specifications

The aim was to select an application that comes in a diversity of shapes, themes, and colours. At the same time, it needed to be semiotic-free which means that the use of different colour combinations cannot affect the comprehension. In addition, the application needed to be an accessible and familiar subject for the audience of the study.

Nevertheless, it became obvious that the application for this type of research had to:

1 Be related to some context in order to avoid emotional aspects.
2 Cover mutable shapes and themes to convey the idea of simple and complex design form.
3 Be subject to colour comprehension in order to wave the semiotics aspect.
4 Be familiar to the participants of the study to avoid design ambiguity.

3.4.2 The design application

Colour semiotics must not affect the comprehension of the design application. The aim was that the application should be a context that comes in different shapes to convey the idea of simple and complex design form. It also needed to be something familiar to the audience of the study.

Mobile phones have a design quality; different elements can be subtracted from the visual form, including colour, without affecting the meaning or the functionality of the visual design. Ten different mobile phone styles, themes, and designs, which represent ten different life styles, were selected from *Nokia's* collection of mobile phones to be the design application (Figure 3.7). Although the selected designs were mostly outdated, the participants were able to recognise them as mobile phones.

Nokia is known not only for its multinational communications corporation, but also for its entire set of mobile device lines. It has a variety of different designs with which clients are pleased and which fulfil their needs. By testing mobile devices from the same brand, it was possible to rule out users' preferences for different manufacturing companies or brands, so the result of the study avoids commercial competition and is aligned with the aim of the research which is to analyze colour combination in context.

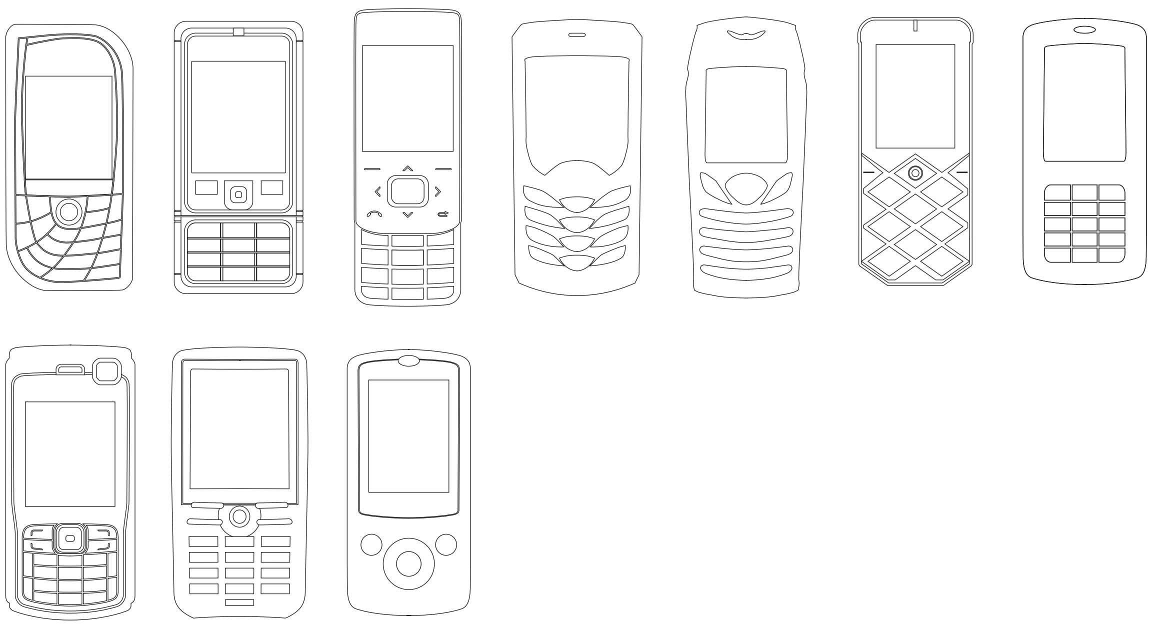


Figure 3.7 The selected mobile devices which were used as a design application

3.5 Preliminary study I

3.5.1 Introduction

Not only is a single colour design timeless, classic and visually powerful, but it is also considered the simplest primitive stage in design. A single colour design helps the viewer to focus more on the designer's creation, despite the fact that colour adds more value to the design if it is used thoughtfully (Chen Design Associates, 2002).

The essential purpose of this preliminary study was to identify the simple and complex designs amongst the different mobile devices. According to Sinha, when using the free-listing method, not only can the validity of the data collected be guaranteed, but it is also considered to be a useful first step in all research involving the definition of new domains. The free-listing method is the best way to ensure that the concepts and domain are culturally relevant. In addition, participants have little difficulty with this technique (Sinha, 2003).

Thus, participants were asked to rank the mobile devices in terms of simple and complex design form. Plus, by presenting the mobile devices as chromatic images, in the absence of colour effects, participants' decisions were more focused on design elements, such as line, shape and texture (Figure 3.8).

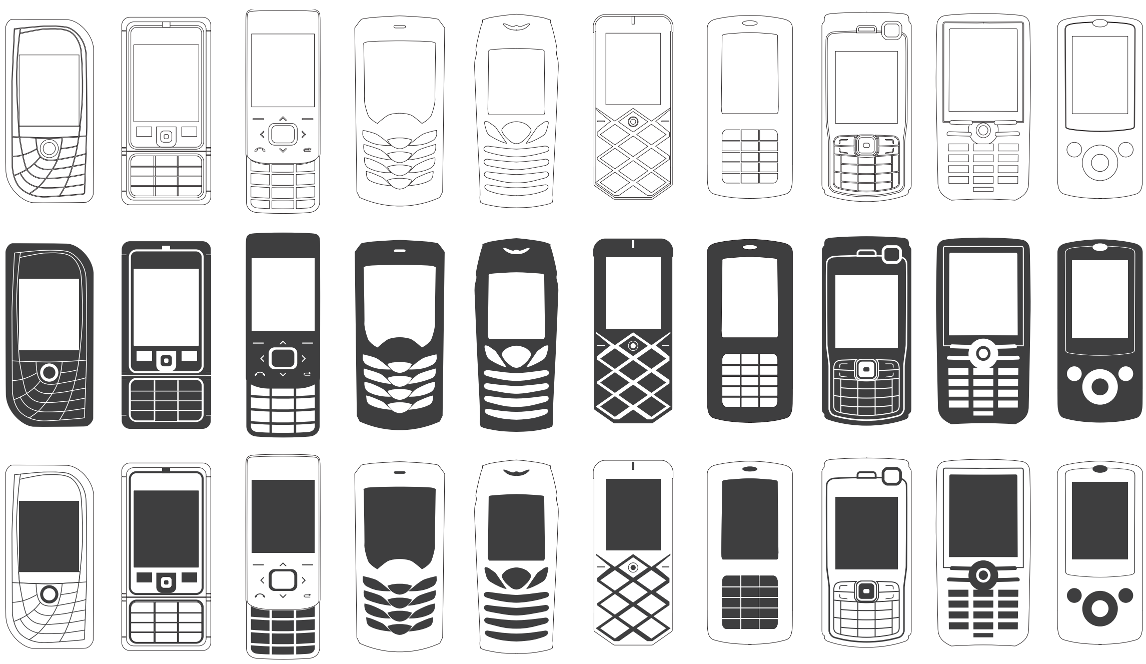


Figure 3.8 A presentation of the selected design applications with different chromatic affects

An understanding of the viewer's perception, and the design elements which help them evaluate the simplicity and complexity of the design, is important. However, the purpose of this preliminary study was to identify the mobile devices which were most frequently ranked as simple and which as complex. An aim of this preliminary study was to define the level of simplicity and complexity of each mobile device image.

3.5.2 Aims of the preliminary study

- Determine which mobile devices have the simplest and most complex design forms.
- Analyze whether presenting the mobile devices in wire drawings, black on white, or white on black, creates different impacts on the simplicity and complexity of the mobile device form.
- Determine whether the form of the mobile design affects the amount of time required to make a decision.

3.5.3 Evaluation procedure

The evaluation allowed the differences between achromatic images to be observed (Figure 3.9). The ranking of mobile devices was to be completed using three sheets (A, B and C). Each sheet presented ten mobile devices with their unique forms, but with different achromatic effects. Sheet A consisted of wire drawings. On sheet B the mobiles were presented as black buttons over a white form, and sheet C was the negative of sheet B, white over black. Sheet C was created to solve some issues that may arise during the research and dealt with negative/positive space, proportion, and the white background issue.

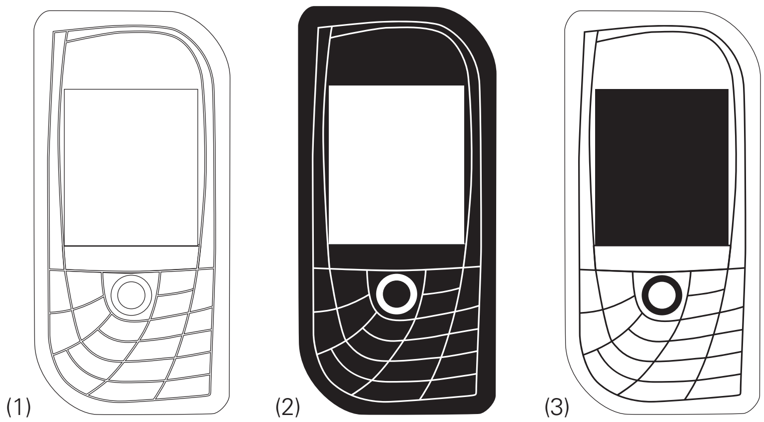


Figure 3.9 The three visual presentations: (1) Wire Drawings; (2) Black on White; (3) White on Black.

Considering the three achromatic effect conditions, each participant was asked to rank the level of simplicity and complexity of each mobile device image, bearing in mind not only the random order of sheets A, B, and C, which resulted in a random order of the achromatic effects, but also the random order of the mobile images on each sheet (Figure 3.10). This process ensured that the mobile devices were ranked without presumption and avoided patterned answers. A large size sample is provided in Appendix A.

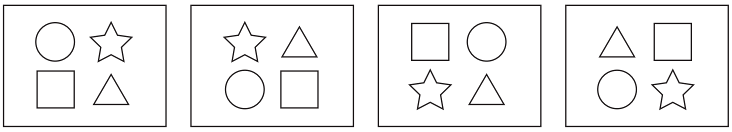


Figure 3.10 An illustration of the random order of presentation of the design application for each sheet

The participants who took part in this test were not briefed on the subject of simple or complex design. They were asked to follow the design principles and the design aesthetics and to try to avoid the likeability factor during the evaluation process. According to Professor Sine McDougall, from the Psychology Department at Bournemouth University, three reminders before taking the test are more than enough to keep the participants on track (McDougall, De Bruijn and Curry, 2000).

In addition, the time it took the participant to evaluate each image of the questionnaire was recorded. This was to help find the missing link between simple/complex design and the time factor. The purpose was to identify whether the participants required a shorter or longer time to pick out a simple design. Time adds a new dimension to this study which seeks to find a relationship between design appearance and different achromatic effects.

3.5.4 Questionnaire

In order to achieve the aims of this preliminary study and the evaluation process, 25 models (random order) were made. The questionnaire consisted of three pages printed on A3 sheets and the timing was recorded manually. The test was kept necessarily short (Figure 3.11). A large size sample is provided in Appendix A.

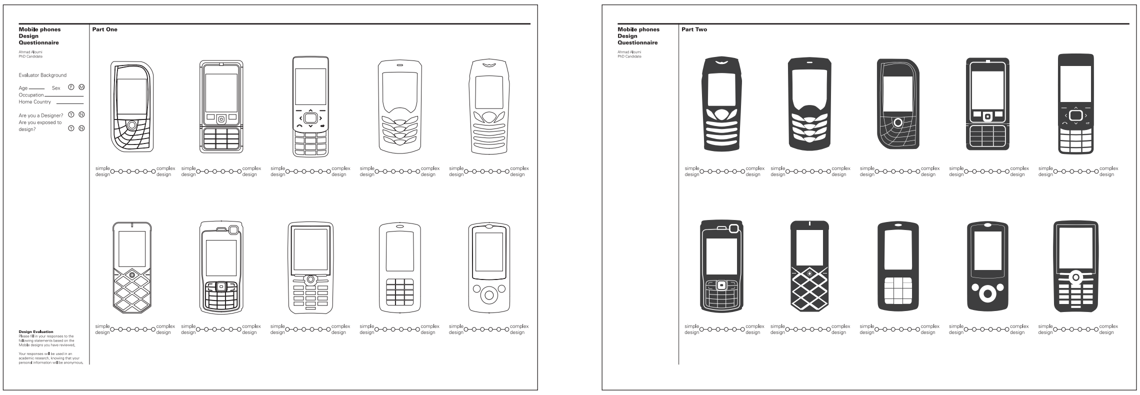


Figure 3.11 A sample of the questionnaire sheets

3.5.5 Challenges and limitations

During the evaluation process several problems arose. The most important of these were the design of the test, the production of the test, and the manual recording of the time elements.

Firstly, designing the layout of the test was an important process. Keeping the design layout simple and natural so the images of the mobiles were the focus elements involved a great deal of effort and design decision making. Nevertheless, it was important to present the mobile images at a certain scale so that the participants were provided with a good visualisation, whilst at the same time bearing the production process in mind for mass production purposes.

Secondly, keeping track of each participant as they reviewed each mobile image was found to be time-consuming. Time recording was part of this preliminary study, and the manual recording took a lot of time and effort. Also, it allowed the researcher to work with just one participant at a time, so the test could not be given to a mass focus group.

3.6 Preliminary study II

3.6.1 Introduction

Preliminary Study II was a continuation of Preliminary Study I. It was based on Preliminary Study I results, and solved the initial problems as well as bringing the project closer to the research aims. However, unlike Preliminary Study I, this one was based on colour contrast effects. Colour is the most complex component of an image and must be given heavier consideration (Marcus, 1992).

The essence of this preliminary study was to identify the colour contrasts that magnify the simplicity and/or complexity of a design appearance. This study was designed to test Itten's colour contrasts, mentioned in the Literature Review (Section 2.6.1). In order to completely cover Itten's colour contrasts, 90-colour combinations would have to be tested and multiplied by three different design applications, giving 270 images in total (Figure 3.12). However, by selecting just one primary colour (blue), and limiting the combinations to the basic no negative options, the total number of images was reduced to 30 (Figure 3.13).

		Testing 6 colours			**Testing 1 colour**
	47	colour combination		10	colour combination
x	2	negative/positive relationship	x	2	negative/positive relationship
+/-		duplicated combination	+/-		duplicated combination
=	90	colour combination	=	20	colour combination
x	3	design application	x	3	design application
=	270	image to be tested.	=	60	image to be tested.

Figure 3.12 The colour combinations based on the selected contrast of primary and secondary colours.

Figure 3.13 The selected application for preliminary study II using different contrasts in the blue colour scheme.

The second preliminary study utilizes three mobile designs, selected to present the simplest and the most complex design, as well as a control design midpoint between the two extremes (Figure 3.14). An aim here was to disregard the designing element of the image and focus more on the effect of the colour contrast. By using a limited number of designs and a range of appearance levels (simple, control and complex), the effect of colour contrast on the appearance of the designs was demonstrated. An appropriate colour contrast, when applied to a design application, can make it appear simpler than the same form with a different colour contrast.

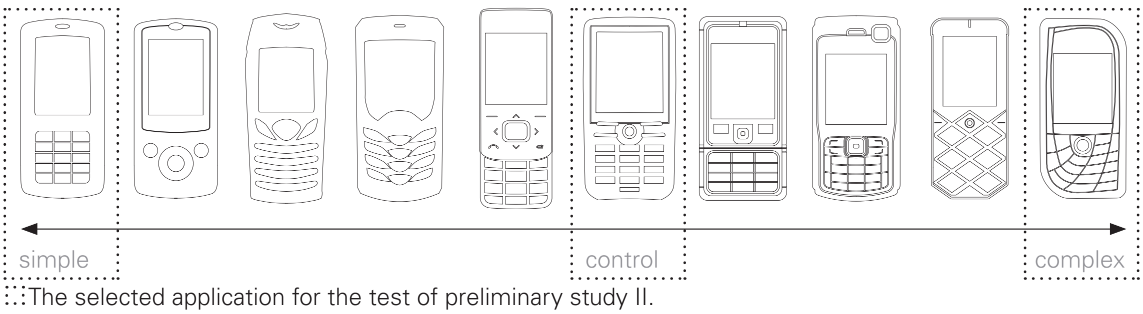


Figure 3.14 Rankings of the design application based on the simplicity and complexity of design aesthetics.

3.6.2 Aims of the preliminary study

- Evaluate which colour contrast is the simplest and which is considered the most complex.
- Evaluate whether the complex colour contrast has the power to make the simple design complex and increase the complexity of a complex design, and vice versa.
- Determine whether the colour contrast of the design affects the time required to make a decision.

3.6.3 Evaluation process

The test was designed carefully to fulfil the aim of this study. It was presented electronically by using custom Internet Webpages. The time and the duration needed to answer each question were recorded onto a data file attached to each question answered by each participant. The participants were unaware of being timed, because the built in electronic time tracker was invisible to them, but were briefed that it was not necessarily a race. The test was divided into five parts. Each part was created to solve a problem.

Part one (Personal Information)

The participant was asked to provide some personal information to ensure they were suitable for the sample. The Ethics Code of Practice of Bournemouth University was used and the participants were informed that the activity was voluntary and that they could withdraw at any time.

Part two (Pre-test Questions)

This section defined the colour vision of the participants. In addition to this, it provided information about the participant's design experience. It also increased the depth of the research and the data collected.

Part three (The Main Questions)

In this part of the study the participants were asked to rate (radio button) 30 images, based on the different colour combinations in relation to two different images selected randomly. To avoid repetition, these were divided into three groups of ten images. After each group, the participants were asked a question from part four.

Part four (The Supporter)

This was created to confirm the answers to part three. It posed the same question in a different way. It asked the participant to select the simplest and the most complex image from ten images, each presented in a different colour combination. A full description of the questionnaire format pro provided in Appendix B.

3.6.4 Questionnaire

In order to achieve the aims of this preliminary study, to ensure the randomness of the image order, and to keep track of the time element, the questionnaire was devised as a web-based survey. Multiple stages were created and each stage helps define answers to the research questions including, which colour combination is simple and which is the most complex (Figure 3.15)? The participants were asked to answer all the questions and the overall time was recorded. A large format version of the online questionnaire is provided in Appendix C.

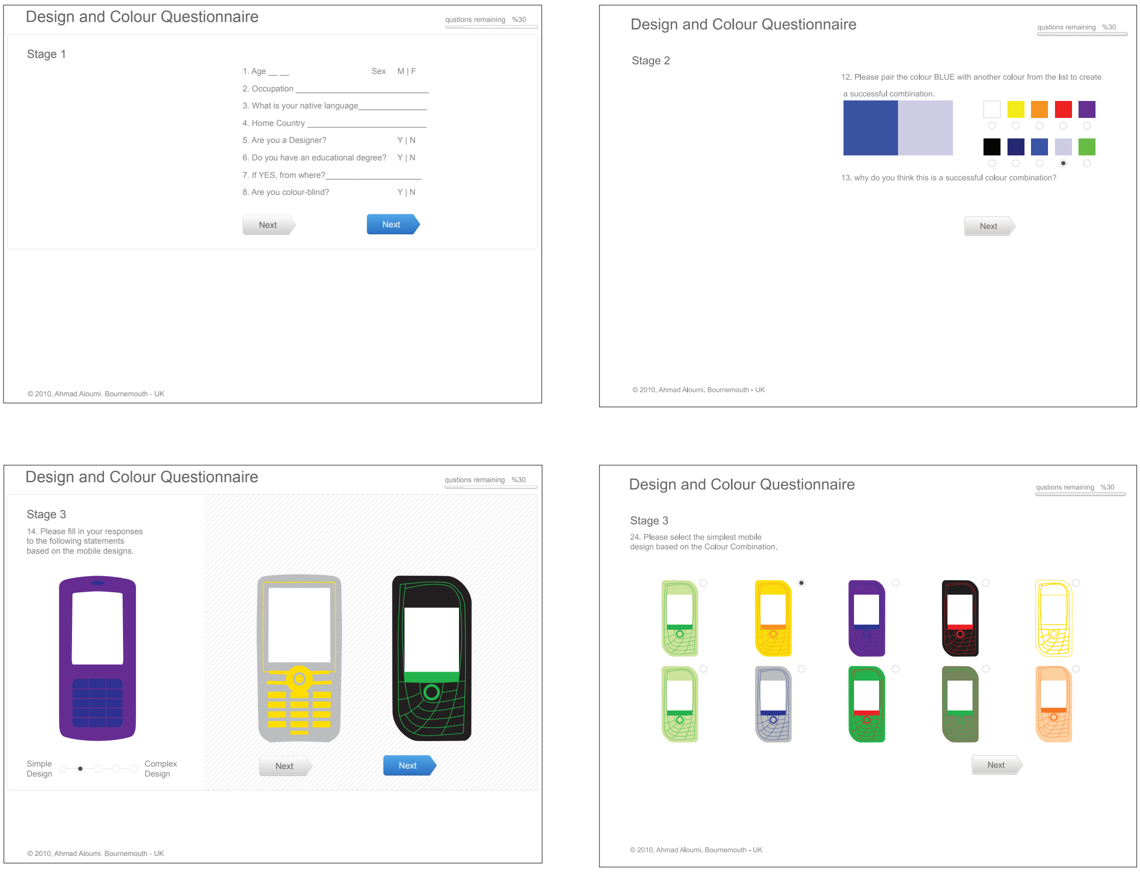


Figure 3.15 A sample of the online questionnaire.

3.6.5 Challenges and limitations

Several problems were apparent in the evaluation process. The most challenging of these was programming and designing the test. It was not easy to find a ready-made online questionnaire that met the study's needs. Having correct time-tracking for each participant and each question was an issue. The test was redesigned twice before the programming issue was solved by a programmer using Javascript.

Covering all possible colour contrasts was essential to this study. However the number of colour combinations generated was overwhelming for the participants. Finally a selected colour combination that covered basiccolour contrast, was used in the test images.

Subsequently, exporting the data collected into a statistical programme was an issue, and the programming was changed twice before the data collected could be successfully transferred.

3.7 Study III

3.7.1 Introduction

Study III was created to confirm and refine the results of Preliminary Study II. It carried the same goals and aims as the previous study. However, unlike Preliminary Study II, this one used more than one colour combination scheme. It was designed to cover all the colour combinations which resulted from the six colours selected for this research: red, orange, yellow, green, blue, violet, in addition to the black, grey and white.

After reviewing and analysing the data from Preliminary Studies I and II, it became clear that further research was necessary to meet the research goal. The data collected was mainly dealing with one colour combination scheme (blue), and it needed to be further expanded in terms of the different hues. It was designed to define the possible logical connections between colour contrasts and the design form.

This study helped to discover any physiological reason for the impact of simple or complex colour combinations on colour contrasts. Even though the results in Preliminary Study II were consistent, the data still needed to be expanded to include the remaining colour combinations (Section 3.6.1) - a total of 90 - and to verify whether colour physiology interferes with the result. Colour contrasts are based on the colour itself and their relationship with other hues.

It is possible for emotional responses to interfere with the data, and hence the results of the study. However, steps were taken to ensure that the research participants focused upon design aesthetics, such as colour theory, in addition to the functionality and legibility of the design decisions. By selecting a specific sample (mainly graphic designers and design students) to participate in the research, and by asking controlled questions, which helped refine the collected data in an objective way, preferences and/or opinions were avoided. The participants were asked to answer the questions based on their understanding of colour theory and other design aesthetics. Further explanation is provided in (Section 3.5.3) about the process of selecting the design application for the research.

The essence of this study is to be definite about the effects of colour contrasts over different hues, considering which colour contrast adds to the simplicity and/or complexity of a design. This study was designed to test Itten's colour contrasts, mentioned in the Literature Review (Section 2.6.1).

In order to cover the different colour contrast combinations, 90-colour combinations would have to be generated and tested. However, since this study is focusing on the effect of different colour combinations on the appearance of the design form, the study used one mobile design only (Figure 3.16). Preliminary Study II succeeded in testing the supposition that different colour contrast have a different effect on the design appearance. The effect of colour contrast on the appearance of a range of designs (simple, control and complex) was demonstrated, making one appear simpler than the same form with a different colour contrast.

The design application used in this study was limited to the most complex mobile design which had already been used before in Preliminary Studies I and II. Based on the results of the previous studies, it was shown that the participants (viewers) were not only firm in their responses but also their decisions were focused when they evaluated a complex design. Also, the times they took to respond were shorter.

Figure 3.16 The selected application for Study III in different colour contrast combinations.

3.7.2 Aims of Study III

- Confirm the results of Preliminary Study II with respect to the effect of colour contrast.
- Analyze whether different colour combinations with the same contrast have the same effect on the design appearance.
- Analyze whether the physical structure of colour has an influence over the participants' decision.

3.7.3 Evaluation process

The test was designed carefully to fulfil the aim of this study. It was presented electronically to ensure the consistency of the test environment for the participant. The samples were kept the same, but the participants were new to the project.

The test consisted of 15 pages. The first two pages gave introductory information on how to participate in the questionnaire, in addition to the Ethics Code of Practice of Bournemouth University. Then questions were asked to ensure that the participants matched the target sample and did not have a colour vision problem.

The remaining pages were more involved with the study aims. The participants were asked one question, which was repeated in each page: "please sort the mobile phones provided in order from simple to complex". Each time the question was asked there was a group of 7-8 mobile phones. The phones were grouped in such a way that they covered all colour contrasts studied, but with different colour combinations, with the consideration of using one colour scheme to avoid the physical structure of different colours. (Figure 3.16) presents the grouping of the design application for the study. A large format version is provided on Appendix D.

3.7.4 Questionnaire

In order to achieve the aims of this study, and to ensure the objectivity of the results, the participants were asked to answer all the questions voluntarily. A soft copy questionnaire was carefully designed. The aim was to use a programme (Adobe Illustrator) which was familiar to the participants. The participants had full control and were able to select, alter, and move the mobile phones, hence they experience full activity by answering the questionnaire. (Figure 3.17) presents a sample of the online questionnaire. A large format version is provided in Appendix E.

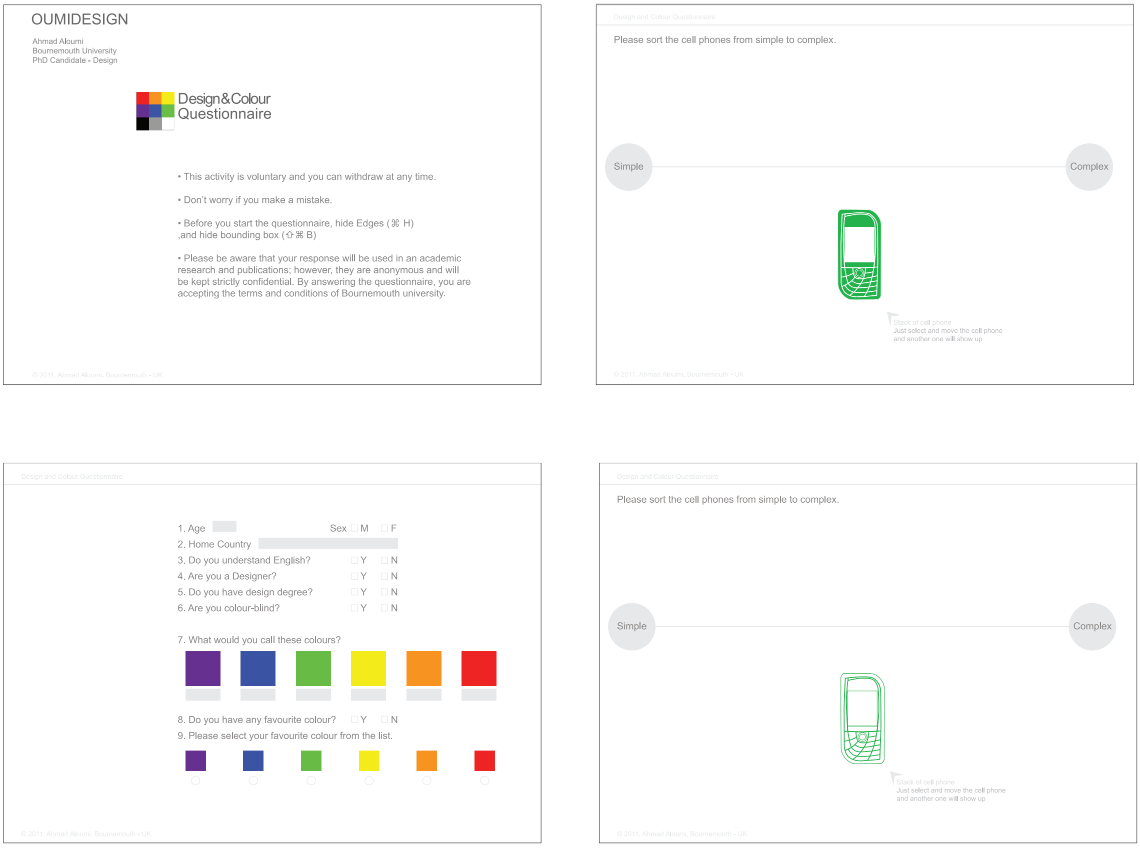


Figure 3.17 A sample of the online questionnaire.

3.7.5 Challenges and limitations

Firstly, several problems arose during the evaluation process. The most significant issue was designing the test; it was not easy to decide on the format. Even when the aim of the test was so clear and focused, the number of images was larger than for the previous studies. Initially, a hard copy test was designed, so that the participants had a chance to explore and examine the images with the different colour combinations. However, it become evident that having the test in a soft copy format made it easier for the participants to contribute. Plus, the environment of the test added control and consistency in terms of the lighting and the scale of the images. Shifting the format of the application from soft to hard copy, and so changing the colour process from using an subtractive to using a additive primary colour, might also have affected the perception of the participants. For further discussion on this see the Literature Review (Section 2.5.2).

In addition, collecting the data electronically was more accurate. The test was redesigned a few times before it was used to ensure that the proper format was chosen, and that the activity could be relied upon to answer the research questions.

Secondly, asking the right question in this test was the most challenging process of all. It was clear that the chosen question could either help elevate the understanding of the participants toward an objective result, or make the participants confused, so that the result would lack focus. The question had to provoke deliberation on the usability and functionality of an electronic mechanical device (the mobile phone).

3.8 Summary

This chapter presented the methods of primary and secondary data collection, defined the focus groups used for each study, and the reasons for selecting designs and choosing the structure of the research project. In addition, the chapter explained the process of selecting the design application and refining the specification for the same. It also described Preliminary Studies I, II, and III, together with the aims, processes, and challenges of each preliminary study separately.

CHAPTER FOUR

Data results and analysis

4.1 Introduction

This chapter presents and analyses the results and findings of the secondary data collection of the research. The results of these studies influenced the growth of this project, and were a consequence of the complementary processes between Preliminary Study I and II in addition to Study III. By answering the research questions, this method ensured that the research was systematic and remained within the research project boundaries.

4.2 Preliminary Study I

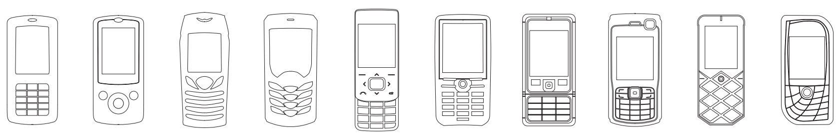
4.2.1 Introduction

This study was designed to answer a very basic question, and at the same time to treat the issue in a critical and analytical way throughout the development of the project. An aim was to identify the appearance of the mobile design as being of either a simple or complex form, with respect to the three different presentations used in the test (wire drawings, black on white, and white on black). The results collected achieved the aims of the study and helped to develop the research further.

4.2.2 Test Results

One hundred participants took part in the test. Twenty-six percent of them were male, 74% were female. The majority were undergraduates while 10% were graduate design students. Their ages varied in the range 22 to 30.

Firstly, as mentioned in (Section 3.5.3), the test asked the participants one question: "Which mobile design is the simplest and which is the most complex, based on the design aesthetic?" (Table 4.1) shows the results based on the design form and the appearance (wire drawings, black on white, and white on black) of the applications as being either simple or complex in design.



Designs	A	B	C	D	E	F	G	H	I	J	
Wire Drawings	4.91	6.79	7.17	6.79	9.06	10.19	12.83	13.21	13.58	15.47	100 %
Black on White	4.63	6.95	8.49	9.27	8.49	10.04	11.20	11.97	13.90	15.06	100 %
White on Black	6.10	6.46	6.64	9.34	10.05	10.41	10.77	12.75	13.11	14.36	100 %
Weighted Average	5.21	6.74	7.44	8.46	9.20	10.21	11.60	12.64	13.53	14.96	100 %
Order	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	

Table 4.1 The average percentage of the simplicity and complexity of the application design form

From a review of the figures, it is clear that the simplest form is design A with an average of 5.21% complexity. The most complex design is J with an average of 14.96% complexity. (Figure 4.1) illustrates the relationship between the different presentations of the design application in a gradation from simple to complex appearance.

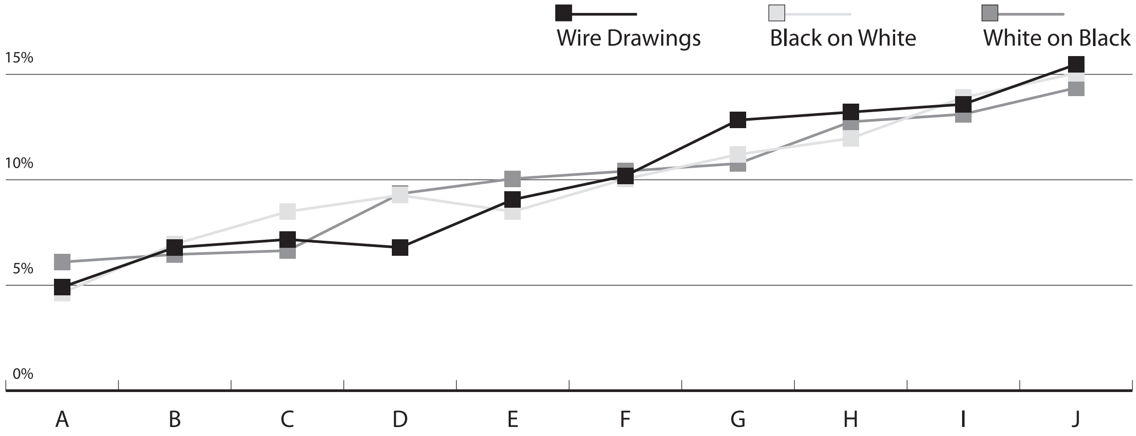


Figure 4.1 An illustration of the design forms of the mobile phones relating to the three presentations

The different presentations (wire drawings, black on white, and white on black) of the design application (mobile phone) affect the design form appearance, in a gradation from simple to complex. For example, design E has different rankings based on the presentation of the design. This starts at 9.06% complexity for wire drawings, decrease to 8.49% complecity when presented in black on white, and peaks at 10.05% complexity for white on black. See (Figures 4.3, 4.4 and 4.5) for further clarification.

Based on the average results collected from the study, the design applications have been illustrated in order (Figure 4.2), beginning with the simplest and moving towards the most complex design form. The illustration helps observe the progression of the design complexity based on the use of design aesthetics toward the last design application.

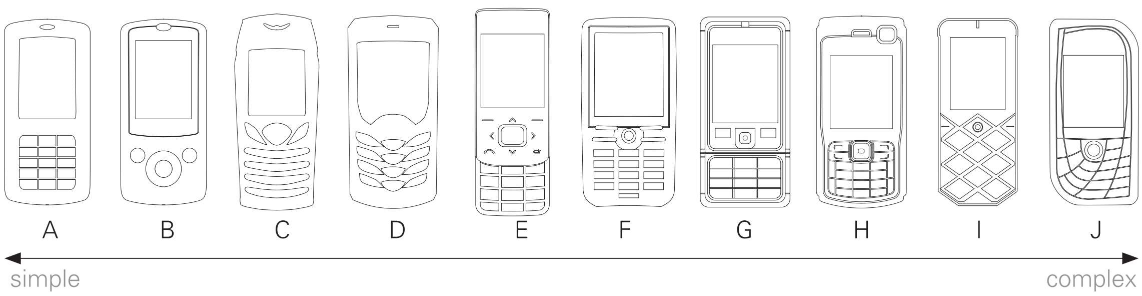
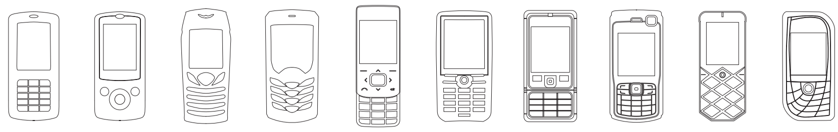


Figure 4.2 The design applications, presented in order from simple to complex design form

Secondly, the time component adds value to this study, and it was important to ascertain how time and perception were affected by the different presentations applied to the design. The results of the time factor flow in the same way for almost all participants as each design application changed (Table 4.2). It was found that the time element is important to the complexity factor in this study. The time element helps identify the level of complexity of the design appearance. The results show a clear relationship between the complexity factor and the time element (Figure 4.3, 4.4 and 4.5). Accordingly, from the results of the study, it can be said that the need for time increased when presented with a simple design, and decreased for a complex design. See (Figure 4.6) for further clarification.



Design	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	
Wire Drawings	4.94	8.31	11.01	7.87	6.74	20.90	11.01	9.89	8.99	10.34	100%
Black on White	7.83	4.70	12.08	10.07	13.87	4.92	9.40	9.84	10.07	17.23	100%
White on Black	6.23	8.20	10.16	15.41	12.79	8.20	10.16	9.84	10.49	8.52	100%
Weighted Average	6.33	7.07	11.09	11.11	11.13	11.34	10.19	9.86	9.85	12.03	

Table 4.2 shows the time scale for each image tested percentage ratio of the participants responds.

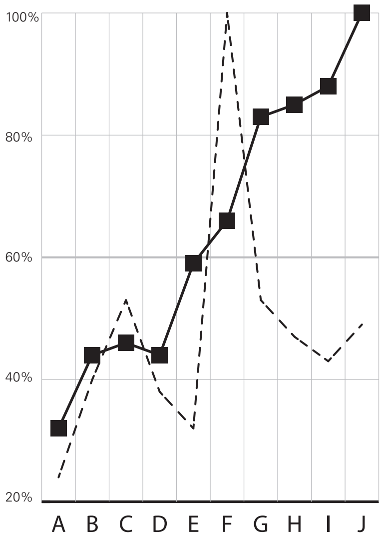


Figure 4.3
The wire drawing affect
on the design form

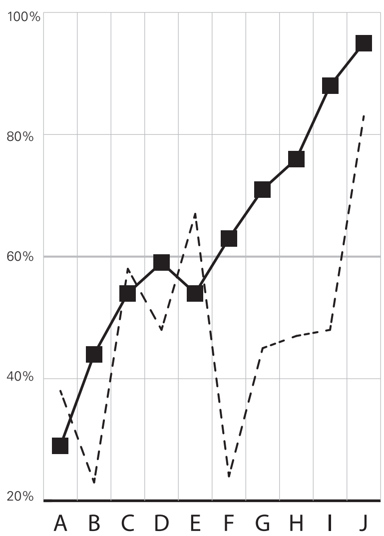


Figure 4.4
The black on white affect
on the design form

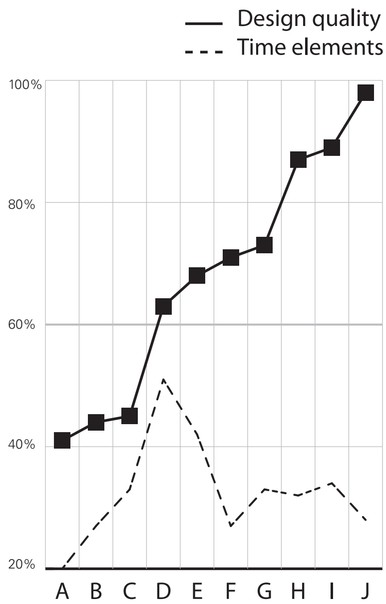


Figure 4.5
The white on black affect
on the design form

Visual presentation	Design complexity	Time element
Wire drawings	33%	37%
Black on white	32%	38%
White on black	35%	25%
	100%	100%

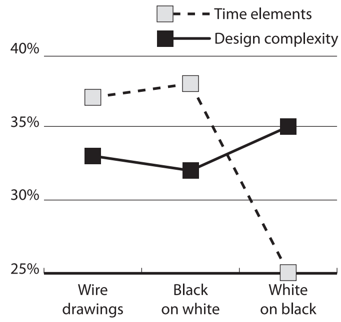


Figure 4.6 An illustration of the average percentage result for the design appearance in relation to the average time element for different levels of complexity

4.2.3 Summary

The collected results met the aim of Preliminary Study I. The study helps define the simplest and most complex design forms based on the participants' responses, in line with the design aesthetic mentioned earlier (Section 2.3). It has been proved that different presentations (wire drawing, black on white and white on black) not only affect the quality of the design form, but also the perception and the time element requirement to comprehend. The results of Preliminary Study I are listed as follows:

- Different presentations, wire drawing, black on white and white on black, affect the appearance of the design form.
- Wire drawings give the design application a standard appearance.
- Black on white decreases the complexity of the design appearance.
- White on black (negative image) increases the complexity of the design appearance.
- Time and perception are affected by the presentation of the design.
- Complex design forms are identified more quickly than simple design forms.

4.3 Preliminary Study II

4.3.1 Introduction

This study was designed to state or describe exactly the effect of colour contrast on the design appearance. After defining the design form of the application in Preliminary Study I, and then selecting three designs which present the design form (simple, complex, and control), the aim of this test was attainable. The aesthetics of the design application can be ignored in this study (because they have already been evaluated in Preliminary Study I) and the focus is directed at the data related to colour combination only.

4.3.2 Test results

Seventy-four participants took part in the test. Thirty-three percent were male, 67% female. The majority were undergraduates while 20.5% were graduate design students and professional designers. Their ages varied between 18 and 50.

Since this study focused on colour elements, it was important to ask the participants if they had colour blindness, and two participants claimed to have a problem. Their responses were withdrawn from the analysis. A detailed report of the data and a sample answer sheet are provided in Appendix F.

Firstly, as mentioned in the methodology description of Preliminary Study II, the study was designed to test Itten's colour contrasts generated from one colour (blue). Ten colour combinations were applied to three design applications, to provide a total of 30 images, which constitute the design application of this study. The results show each design application separately, and the effect of different colour combinations on the design form appearance (Table 4.3). The table shows the weighted average of colour contrasts' effect on different design applications.

Colour contrast	**CBBA**	**COBA**	**CWBA**	**HLBA**	**DABA**	**HRBA**	**LIBA**	**SIBA**	**WDBA**	**WDBAx**	
Design - F	10.43	10.24	10.75	10.30	10.82	10.30	9.11	8.90	9.19	9.95	100%
Design - C	10.90	10.46	11.47	9.42	11.21	10.53	9.36	9.23	8.23	9.21	100%
Design - D	10.49	10.56	11.40	10.58	11.44	10.39	9.52	8.75	7.82	9.05	100%
Weighted Average	10.61	10.42	11.21	10.10	11.15	10.41	9.33	8.96	8.41	9.40	100%
Order	**8**	**7**	**10**	**5**	**9**	**6**	**3**	**2**	**1**	**4**	

Table 4.3 The weighted average of the colour contrast effect on the design application form in percentage.

(Figure 4.7) depicts changes on the three selected applications over the effect of using different colour contrasts. It is clear that presenting the design application with different colour contrasts changed the appearance of the design. Colour contrasts have the power to elevate the level of complexity of the design appearance (Figure 4.8). Certain colour contrasts simplify the appearance of the design application, even though the design form is considered complex. For example, Design J is the most complex design application when presented by contrast of hue (HLBA); however, when simultaneous contrast (SIBA) was used, design J became very simple. Yet, some colour contrasts make a simple design more complex than others; for example, cold-warm contrast (COBA, CWBA), contrast of hue (HLBA, HRBA) and colour paired with black (CBBA) increase the complexity of the design appearance (Figure 4.9).

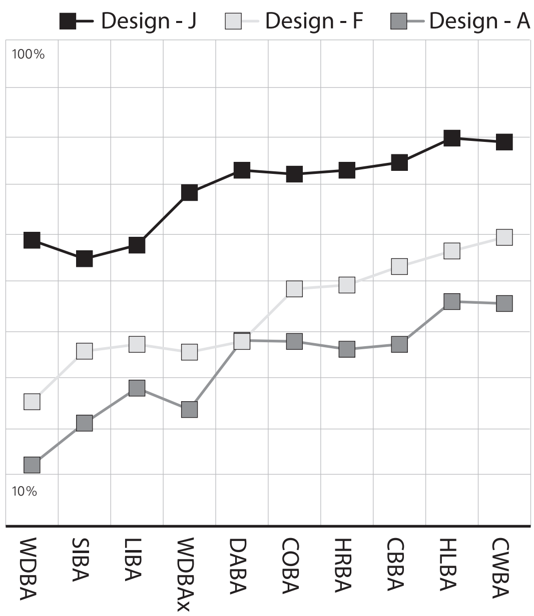


Figure 4.7 An illustration of the effect of the colour contrast on selected design applications

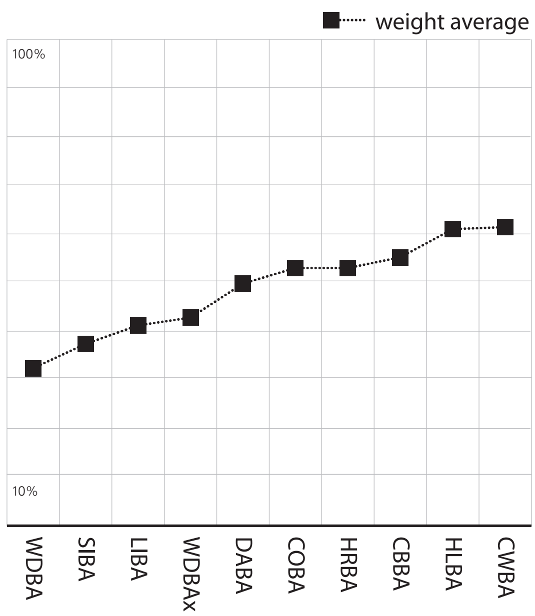


Figure 4.8 An illustration of the average effect of the colour contrast on the design appearance

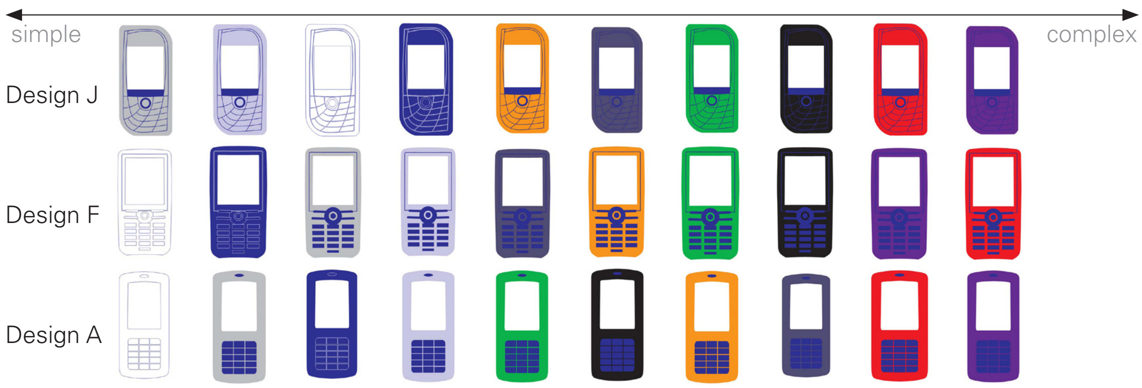


Figure 4.9 The effect of colour contrast on different design applications, arranged in order from simple to complex

Accordingly, it can be said that colour contrast (for example, contrast of hue) has the potential to make a simple design appear complex, and can sometimes make it appear more complex than a different complex design form. (Figure 4.10) shows the relationship between different design forms and the use of different colour contrasts. Even though the design application is the same, the appearance of the design form (simple to complex) changed due to the use of colour contrast. Colour contrasts contrast of value, simultaneous contrast, and solo colour with white simplify design J. They make design J simpler than design A if colour contrasts solo colour with black and contrast of hue are applied. A list of the effects of colour contrast, the contrast code, colour presentation in a switch, as well as the complexity factor are provided in (Table 4.4).

Design J, complex form with simple colour combination.

Design A, simple form with complex colour combination.

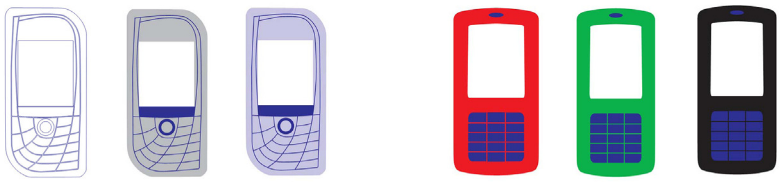


Figure 4.10 Simple colour contrast on design J versus complex colour contrast on design A

	Contrast Name	**Contrast Code**	**Colour Switch**	**Contrast Position**	**Weighted average**	**Order 1=simple**
1	Solo Colour with Black	CBBA			10.61%	8
2	Complementary Contrast or Contrast of Extension	COBA			10.42%	6
3	Cold-Warm Contrast	CWBA			11.21%	10
4	Dark Contrast	DABA			11.15%	5
5	Contrast of Hue (left)	HLBA			10.1%	9
6	Contrast of Hue (right)	HRBA			10.41%	7
7	Light Contrast	LIBA			9.33%	3
8	Simultaneous Contrast or Contrast of Saturation	SIBA			8.96%	2
9	Solo Colour with White	WDBA			8.41%	1
10	Solo Colour in Wire Drawing	WDBAx			9.4%	4

Table 4.4 A key to presentation for the colour contrasts of the study

Secondly, the time element added a range of values to the study. The time factor data complements the results of Preliminary Study I. It increased for the design that appears simple and decreased for the design that appears complex (Table 4.5). It is important to note that time and perception were affected by the different colour contrasts applied to the design applications. Even though the application design stayed the same, the use of different colour contrasts affected the appearance as well as the time needed to comprehend. See (Figure 4.11) for further clarification.

Colour contrast	**CBBA**	**COBA**	**CWBA**	**HLBA**	**DABA**	**HRBA**	**LIBA**	**SIBA**	**WDBA**	**WDBAx**	
Design - F	8.84	9.05	12.92	8.33	10.18	11.46	10.47	9.92	10.85	7.98	100
Design - C	11.42	10.19	10.77	9.57	10.03	9.22	9.43	9.36	9.49	10.52	100
Design - D	10.15	9.23	10.87	9.43	12.03	8.18	9.89	13.21	7.83	9.20	100
Weighted average	10.13	9.49	11.52	9.11	10.75	9.62	9.93	10.83	9.39	9.23	

Table 4.5 The weighted average of the colour contrast effects on the time element

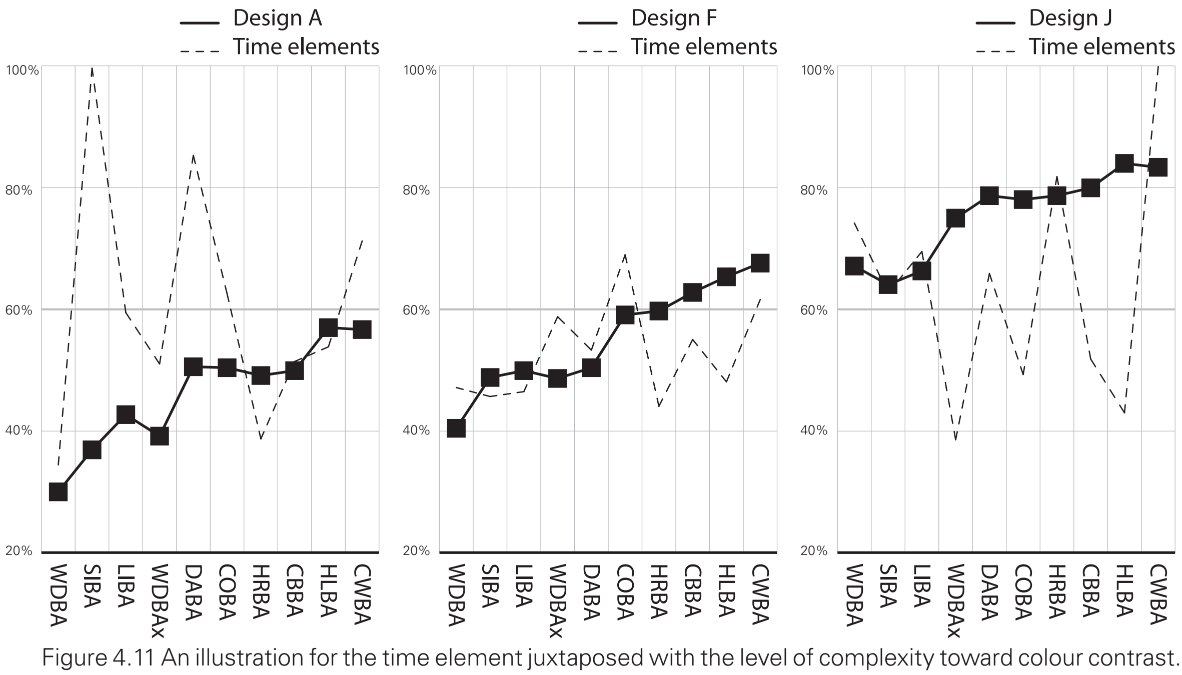


Figure 4.11 An illustration for the time element juxtaposed with the level of complexity toward colour contrast.

Accordingly, it can be said that the time element decreases when presenting a complex design, and increases with a simple design. Different colour contrasts affect the simplicity and/or the complexity of the appearance for the visual design.

Finally, there was further analysis of the results based on a consideration of the relationship between simple and complex colour contrasts and the time element. An aim of the study was to see which colour contrast had the power to make the simple design (Design A) more complex than the complex design (Design J) by changing one parameter (colour contrast). (Figure 4.12) depicts changes on the selected applications (Designs A and J) due to the effect of using different colour contrasts. It is clear that design A, with contrasting hue (HLBA), appears more complex than the complex design, J, when presented with simultaneous contrast (SIBA). Colour contrast changed the degree of complexity of the appearance of the same design.

Displaying the complexity factor for designs J and A affected by different colour contrasts.

Displaying the effect of the time element regarding the level of complexity for designs J and A.

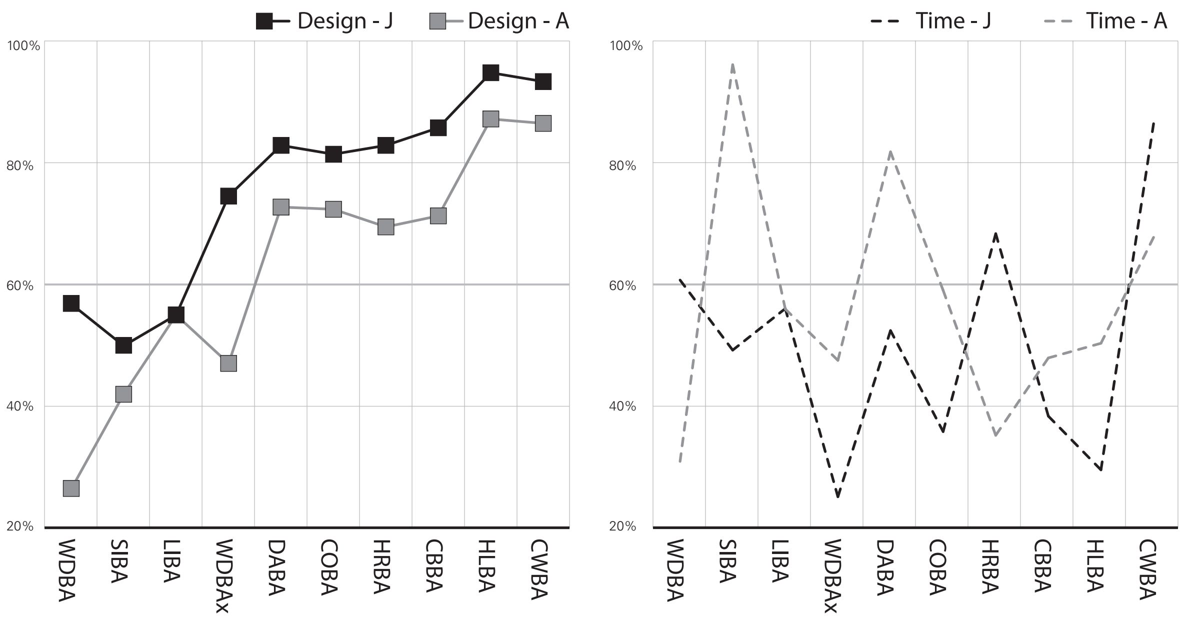


Figure 4.12 The illustration combines different design forms (A and J) and the time elements

4.3.3 Summary

The collected results met the aim of Preliminary Study II. They identified the simplest and most complex colour contrasts. It has been shown that different colour contrasts affect the appearance of the design form, and the time element indicates that perception is also affected, complementing the finding of Preliminary Study I. The need for time increased when presenting a simple design, and decreased for a complex design. The results of Preliminary Study II can be listed as follows:

- Different colour contrasts should be considered, and they affect the appearance of the design form in a range from simple to complex.
- There are a number of colour contrasts, some of which are considered simple and some complex.
- The simplest colour contrasts are the ones that deal with value such as: solo colour with white; simultaneous contrast; contrast of saturation, and contrast of value.
- The most complex colour contrasts are contrast of temperature (cold and warm); contrast of hue; and solo colour with black.
- Time and perception are affected by the presentation of the design based on the colour combination.
- Complex colour contrasts are identified more quickly than simple colour contrasts.

4.4 Study III

4.4.1 Introduction

This study was designed to define the effect of different colour contrasts of 90 colour combinations on the appearance of the design. After determining the form of the design application in Preliminary Study I, and then selecting three designs which present the design quality (simple, complex, and natural), the aim of this test was attainable. The aesthetics of the design application can be ignored in this study (because they have already been evaluated in Preliminary Study I) so only one design application was used. The focus of this study was purely on colour contrast while introducing different colour combinations.

4.4.2 Test results

Forty-five participants took part in the test. Sixty-four percent were male, 35% female. The majority were undergraduates while 40% were graduate students and professional designers. Their ages ranged between 19 and 36. None of the participants claimed to have a colour blindness problem.

Part one

As mentioned in the methodology description of Study III, the study was designed to confirm and define the results of Preliminary Study II. This study expanded the dimensions of the research, so that it dealt with all of Itten's colour contrasts based on the six colours selected for this research: red, orange, yellow, green, blue and violet. Ninety colour combinations were generated and applied to one design application which was the most complex mobile phone design form. The results show the effect of the different colour contrasts on the appearance of the design application, which had been presented in the six colour schemes (Table 4.6).

	Colour Contrast								
	White	**Black**	**Dark**	**Light**	**Gray**	**Temp**	**Hue**	**Comp**	**Ave. Scheme**
Red Scheme	53	89	92	49	52	100	69	100	17.2%
Orange Scheme	44	84	79	45	68	81	95	100	16.8%
Yellow Scheme	54	99	82	53	71	98	72	100	17.7%
Green Scheme	45	89	87	51	47	94	86	100	17%
Blue Scheme	39	100	82	40	40	75	91	93	15.9%
Violet Scheme	38	100	73	38	38	91	84	85	15.4%
Contrast average	7.6%	16.0%	13.9%	7.8%	9%	15.3%	14.1%	16.3%	

Table 4.6 The table presents the weighted average of the colour contrast effect on the appearance of the design application based on different colour schemes

(Figures 4.13 and 4.14) present the effect of the colour contrasts on the same design application. They show clearly how the evaluation of the design application appearance is elevated when different colour contrasts are applied. Furthermore, the graphs show consistency between Studies II and III with regard to the effect of contrast. In (Figure 4.14) the graph presents a comparison between the two studies for the same colour scheme (blue). Even though there are some minor differences between the results of the studies, they still indicate a similar effect and show a similar trend. The differences between the two studies are a consequence of the different use of the colour combinations. For example the combinations yellow and blue that were used in Preliminary Study II consider a contrast of temperature, as do combinations of blue and red that were used in Study III. The methodology of the test also had an effect on the results.

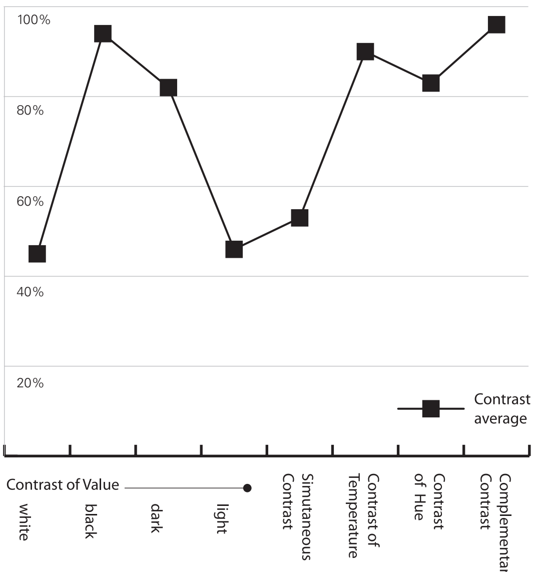


Figure 4.13 An illustration of the complexity factor between the average of different colour contrasts.

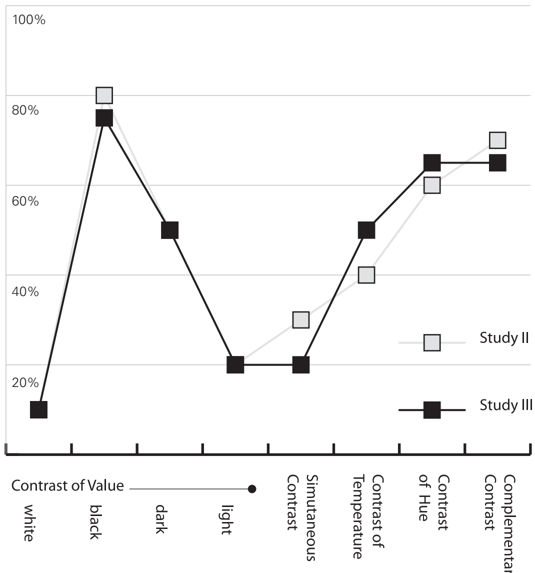


Figure 4.14 An illustration of the complexity factor based on the colour contrasts in the blue scheme between Preliminary Studies II and III.

In Preliminary Study II, participants were asked to rank the images in comparison to a random image with different colour combinations, which could be combinations of colour schemes other than blue. The issue was that the participants were in need of another image with which to compare and rate the application as being a simple or complex design form; and there were no controls for the colour combination of the image shown for comparison purposes. See (Section 3.6.4) for further clarification.

In Study III, the task was more focused and carefully designed. The comparison was limited to one colour scheme. In addition, the method was different. The participants were asked to sort the mobile phones in order, from simple to complex colour combinations, so the design applications were presented for one colour scheme. Having said that (Figure 4.15) presents the consistency of the contrast effect on the design appearance in comparison to that of different colour schemes. A detailed report on the data is provided in Appendix G.

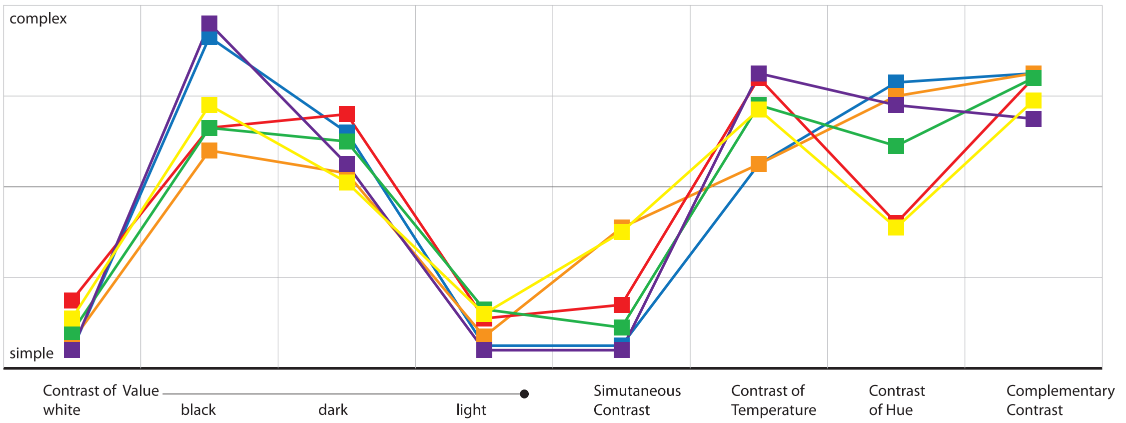


Figure 4.15 An illustration of the consistency of the colour contrast effect on the design application in comparison to that of different colour schemes

Even though there are some minor differences between the degrees of complexity in the different colour schemes, (Figure 4.15) affirms the effect of colour contrast on the appearance of the same design application (mobile phone). This finding indicates that there is a need to investigate further the characteristics and the physiology of different colours used in the study. Not only has Study III proved the existence of the complexity factor of colour contrast, but it has also shown that there are differences between colour schemes. This suggests that there is a need for further analysis of individual colour schemes.

The results show that different colour schemes in the same colour contrast also affect the complexity of the design appearance. Therefore each colour has its own complexity factor which lies in a range from the simplest colour scheme (violet with an average of 35 points) to the most complex (red, with 44 points), as presented in (Table 4.7).

Colour	**Red**	**Orange**	**Yellow**	**Green**	**blue**	**Violet**
Complexity factor	44	37	42	37	35	35

Table 4.7 The average complexity factor for colour

Part two

Based on the Study III results, the complexity factor of each colour scheme is unique because of the characteristics of each colour. As mentioned earlier, in the Literature Review (Section 2.5.1), colour is a reflection of light waves of a certain length interacting with receptors in the human eye. The visible spectrum of light shows waves with lengths from 390nm to 780nm, along with the perceived colour related to the different wavelengths. The longer waves in the visible spectrum are seen as red, while the shorter waves are seen as violet.

Colour has three measurable characteristics: hue, luminance, and saturation. Hue refers to the predominant wavelength, luminance represents how bright the colour is, and saturation suggests the level of purity. According to the CIE (Commission Internationale de L'Eclairage), colour can be measured by values (red, blue, and green) which, when in combination, agree approximately with average visual perceptions.

This part of the analysis provides information regarding the colours used in the study in order to characterize the reasons for a different complexity factor of each colour scheme in the same contrast. As shown in (Figure 4.15), there were some effects due to colour on the appearance of the design application, however the effect of the colour scheme on colour contrast was not equal. The average of the total complexity factor for each colour varied between 44 points and 35 points. The most complex colour scheme is red, while the simplest one is violet. Interestingly the complexity factor has a structure which parallels that of colour wavelength. The complexity factor for colour increases at the same rate as colour wavelength. (Figure 4.16) provides an illustration of the complexity factor in comparison with colour wavelength.

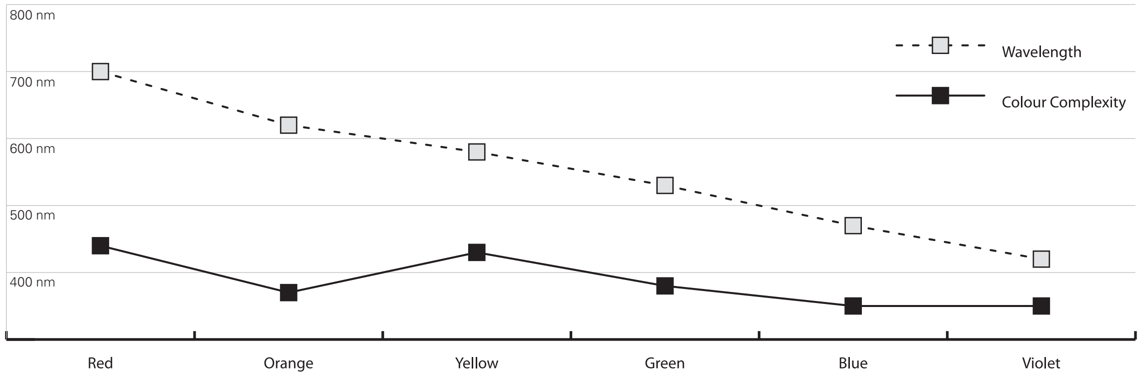


Figure 4.16 An illustration of the complexity factor in comparison with colour wavelength

The graph shows increasing colour complexity in comparison to colour wavelength. This helps us to understand the difference between the levels of colour complexity in individual colour contrasts. To prove the different complexity of various combinations, a mathematical formula was generated in collaboration with a postgraduate student, Mr. Mohammad Ramazani at the School of Design, Engineering and Computing at Bournemouth University. This collaboration was needed to combine the science of mathematics and numbers into the field of colour and wavelength colour combinations. This mathematical formula was needed to confirm the assumption which relates the colour complexity factor to the colour wavelength, and thereby, the wavelength of a particular colour combination. It was generated to map one set of data onto another in such a way as to create a set of numbers out of the energy of the wavelength of each colour combination. The results would create a trend that could be matched to the results from Study III to identify the complexity factor of each colour combination.

In order to prove the relationship between the complexity factor and colour energy a measurement of the colour combinations used in Study III was required. Using the CIE information the colours were assessed as in (Figure 4.16); however the total combination of two colours in one design application called for a mathematical formula dealing with the different wavelengths in a certain combination. The design application used in the study was presented in a combined colours of two based on a ratio of 30% - 70%, which referred to each colour. The formula helped to evaluate the energy of colour combinations used in the design application. The aim of the formula was to find the value of (alpha), which is the equivalent value to the complexity factor of the colour wavelength value, for each colour combination. This would help to find the equivalent value of wavelength to the complexity factor. (Figure 4.17) provides the mathematical formula used. Detailed information and the results of the formula applied to the colour combinations are provided in Appendix L.

CC_1	=	Colour Complexity of Colour One	(Known Data)
CC_2	=	Colour Complexity of Colour Two	(Known Data)
CC_{12}	=	Colour Complexity of Colour One to Two	(Known Data)
CC_{21}	=	Colour Complexity of Colour Two to One	(Known Data)
WL_1	=	Colour Wavelength of colour One	(Known Data)
WL_2	=	Colour Wavelength of colour Two	(Known Data)
C_{1r}	=	0.3	(the colour ratio)
C_{2r}	=	0.7	(the colour ratio)

$$R_1 = \frac{Wl_1}{CC_1}$$

$$R_2 = \frac{Wl_2}{CC_2}$$

$$R_{12r} = C_{1r}(R_1) + C_{2r}(R_2)$$

$$R_{12t} = \frac{WL_{12}}{CC_{12}} = \frac{C_{1r}(WL_1) + C_{2r}(WL_2)}{CC_{12}}$$

$$\boxed{\partial_{12} = \frac{R_{12r}}{R_{12t}}}$$

$$R_{21r} = C_{2r}(R_1) + C_{1r}(R_2)$$

$$R_{21t} = \frac{WL_{21}}{CC_{21}} = \frac{C_{2r}(WL_1) + C_{2r}(WL_2)}{CC_{21}}$$

$$\boxed{\partial_{21} = \frac{R_{21r}}{R_{21t}}}$$

Example for the combinatoin Orange and Blue

CC_1	=	.37	Orange
CC_2	=	.35	Blue
CC_{12}	=	.79	
CC_{21}	=	.9	
WL_1	=	620	Orange
WL_2	=	470	Blue
C_{1r}	=	.3	
C_{2r}	=	.7	

$$R_1 = \frac{Wl_1}{CC_1} = \frac{620}{.37} = 1675$$

$$R_2 = \frac{Wl_2}{CC_2} = \frac{470}{.35} = 1342$$

$$R_{12r} = C_{1r}(R_1) + C_{2r}(R_2) = .3(1675) + .7(1342) = 1442$$

$$R_{12t} = \frac{WL_{12}}{CC_{12}} = \frac{C_{1r}(WL_1) + C_{2r}(WL_2)}{CC_{12}} = \frac{.3(620) + .7(470)}{.79} = 651$$

$$\boxed{\partial_{12} = \frac{R_{12r}}{R_{12t}} = \frac{1442}{651} = \mathbf{2.21}}$$

$$R_{21r} = C_{2r}(R_1) + C_{1r}(R_2) = .7(1675) + .3(1242) = 1575$$

$$R_{21t} = \frac{WL_{21}}{CC_{21}} = \frac{C_{2r}(WL_1) + C_{2r}(WL_2)}{CC_{21}} = \frac{.7(620) + .3(470)}{.9} = 638$$

$$\boxed{\partial_{21} = \frac{R_{21r}}{R_{21t}} = \frac{1575}{638} = \mathbf{2.47}}$$

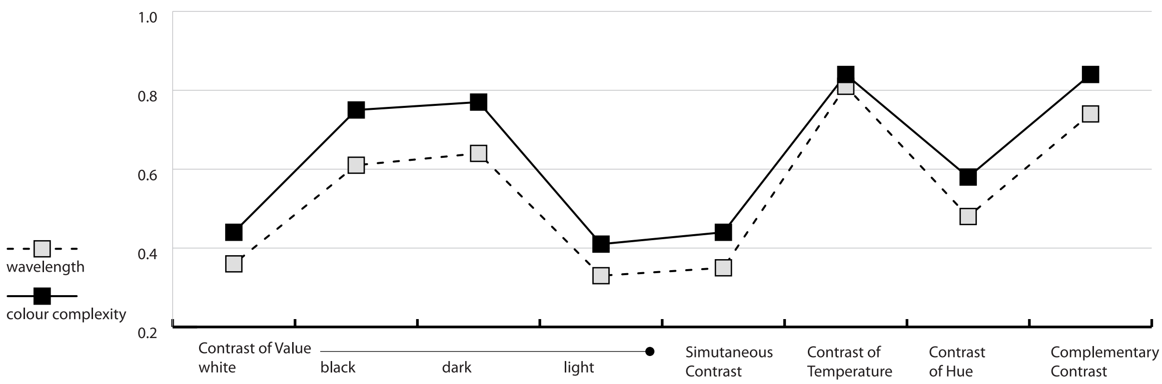
Figure 4.17 The colour wavelength mathematical formula used to calculate the energy of a controlled, two colour combination in a design.

(Table 4.8) provides the results for the mathematical formula employed by the research with regard to the colour wavelength of combined colour designs. It shows consistency for some combinations and for a number of colour schemes. The table divided each colour scheme into a number of contrasts, with the consideration to the different ration of each design, which presented with the high and low. In it shows the average from each contrast in each individual colour scheme. The data has been normalized, so 1= the most complex colour combination.

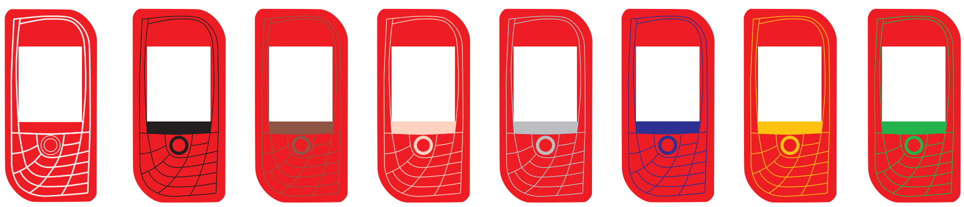
Colour scheme	**Colour contrast**							
Red	**White**	**Black**	**Dark**	**Light**	**Gray**	**Temp**	**Hue**	**Complementary**
high	0.5	0.63	0.6	0.34	0.34	0.84	0.5	0.83
low	0.22	0.6	0.68	0.33	0.37	0.78	0.46	0.65
Averege	0.36	0.615	0.64	0.33	0.35	0.81	0.48	0.74
Orange								
high	0.41	0.71	0.58	0.68	0.64	0.64	0.7	0.8
low	0.31	0.67	0.72	0.38	0.47	0.81	0.75	0.89
Averege	0.36	0.69	0.65	0.53	0.56	0.73	0.73	0.85
Yellow								
high	0.4	0.69	0.47	0.34	0.46	0.7	0.58	0.77
low	0.31	0.64	0.62	0.36	0.49	0.7	0.45	0.7
Averege	0.36	0.67	0.55	0.35	0.48	0.70	0.52	0.74
Green								
high	0.23	0.61	0.4	0.72	0.38	0.7	0.67	0.83
low	0.49	0.81	0.35	0.66	0.42	0.82	0.74	0.65
Averege	0.36	0.71	0.375	0.69	0.4	0.76	0.705	0.74
Blue								
high	0.4	1	0.84	0.32	0.38	0.61	0.77	0.89
low	0.33	0.88	0.68	0.43	0.36	0.66	0.93	0.8
Averege	0.37	0.94	0.76	0.38	0.37	0.64	0.85	0.85
Violet								
high	0.47	0.6	0.42	0.25	0.23	0.82	0.82	0.7
low	0.27	0.74	0.57	0.25	0.27	0.71	0.74	0.4
Averege	0.37	0.67	0.50	0.25	0.25	0.765	0.78	0.55

Table 4.8 The results of the mathematical formula employed in Study III.

Figures 4.18, 4.19, 4.20, 4.21, 4.22, and 4.23 provide comparison graphs between the complexity factor and the wavelength energy that result from the mathematical formula. Each graph shows the average figures of the effect of different colour contrast for each colour scheme. The graphs show how the two sets of data (the complexity factor and the results produced by the mathematical formula) are related. A detailed report on the graphs is provided in Appendix I.

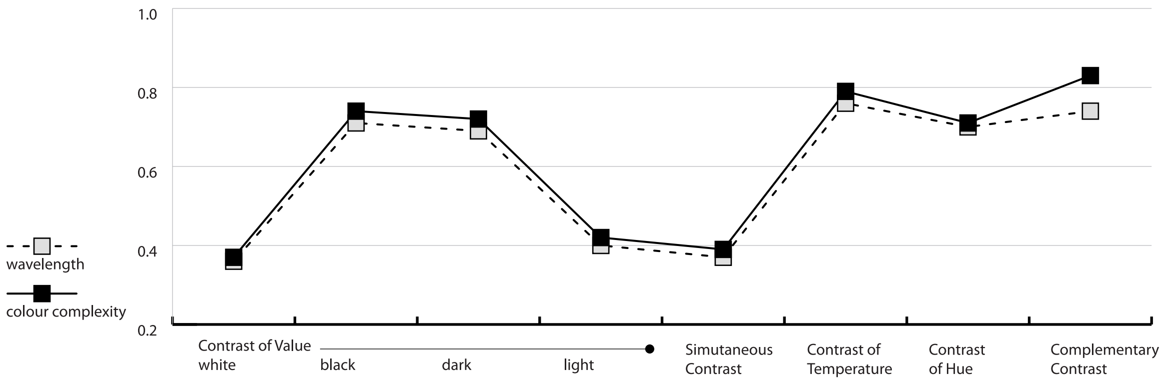


Design Application

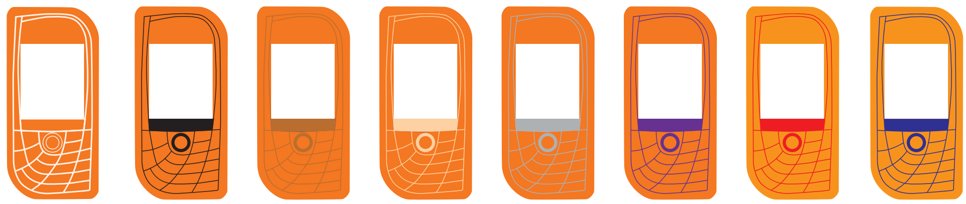


	Contrast of Value white	black	dark	light	Simutaneous Contrast	Contrast of Temperature	Contrast of Hue	Complementary Contrast
Complexity Factor								
	0.27	0.73	0.82	0.40	0.45	0.79	0.60	0.92
	0.61	0.77	0.73	0.42	0.42	0.89	0.56	0.75
Average	0.44	0.75	0.77	0.41	0.44	0.84	0.58	0.84
Combined Wavelength								
	0.50	0.63	0.60	0.34	0.34	0.84	0.50	0.83
	0.22	0.60	0.68	0.33	0.37	0.78	0.46	0.65
Average	0.36	0.61	0.64	0.33	0.35	0.81	0.48	0.74

Figure 4.18 The average figures for colour contrast comparing the complexity factor and the combined wavelength for the red scheme

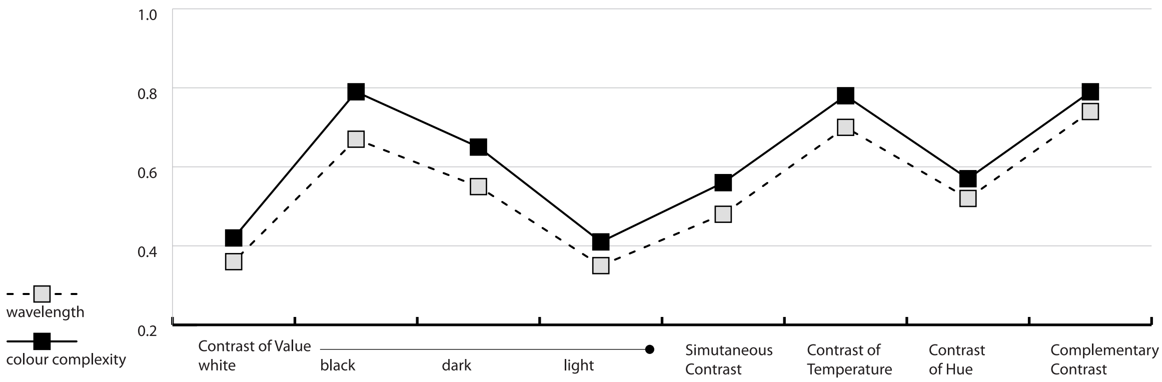


Design Application

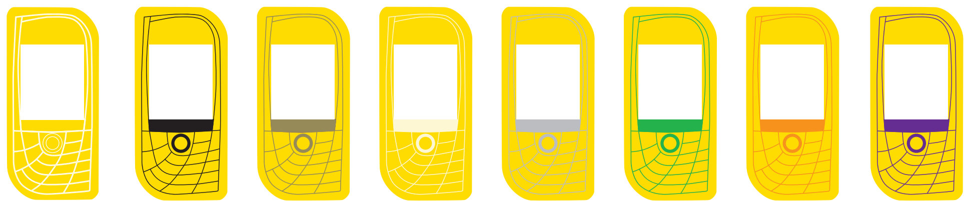


	Contrast of Value							
	white	black	dark	light	Simutaneous Contrast	Contrast of Temperature	Contrast of Hue	Complementary Contrast
Complexity Factor								
	0.32	0.69	0.74	0.39	0.48	0.63	0.81	0.79
	0.41	0.73	0.60	0.37	0.66	0.74	0.81	0.90
Average	0.37	0.71	0.67	0.38	0.57	0.69	0.81	0.85
Combined Wavelength								
	0.41	0.71	0.58	0.68	0.64	0.64	0.70	0.80
	0.31	0.67	0.72	0.38	0.47	0.81	0.75	0.89
Average	0.36	0.69	0.65	0.53	0.56	0.73	0.73	0.85

Figure 4.19 The average figures for colour contrast comparing the complexity factor and the combined wavelength for the orange scheme.

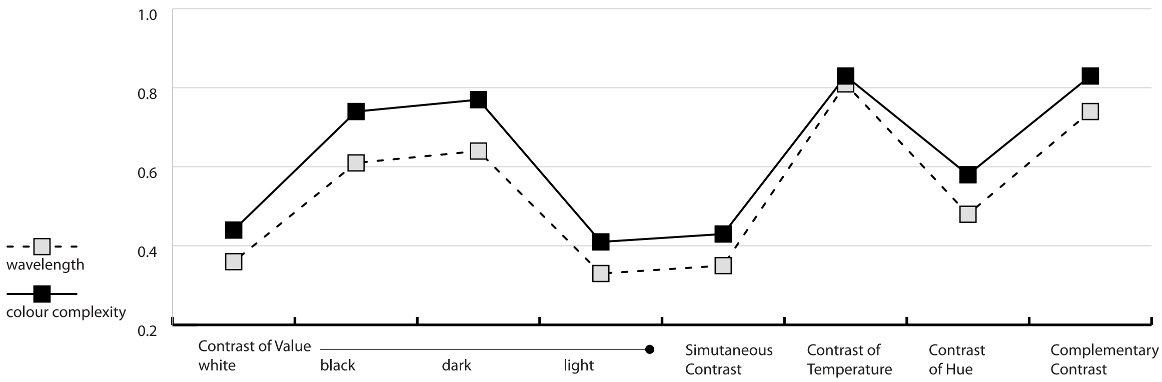


Design Application

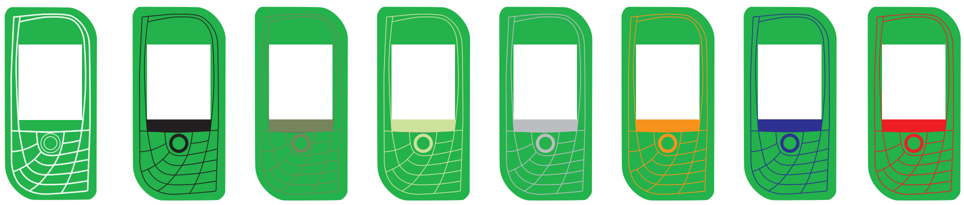


	Contrast of Value white	black	dark	light	Simutaneous Contrast	Contrast of Temperature	Contrast of Hue	Complementary Contrast
Complexity Factor								
	0.48	0.82	0.56	0.40	0.55	0.76	0.48	0.73
	0.37	0.75	0.74	0.44	0.58	0.81	0.66	0.87
Average	0.42	0.79	0.65	0.42	0.56	0.78	0.57	0.80
Combined Wavelength								
	0.40	0.69	0.47	0.34	0.46	0.70	0.58	0.77
	0.31	0.64	0.62	0.36	0.49	0.70	0.45	0.70
Average	0.36	0.67	0.55	0.35	0.48	0.70	0.52	0.74

Figure 4.20 The average figures for colour contrast comparing the complexity factor and the combined wavelength for the yellow scheme.

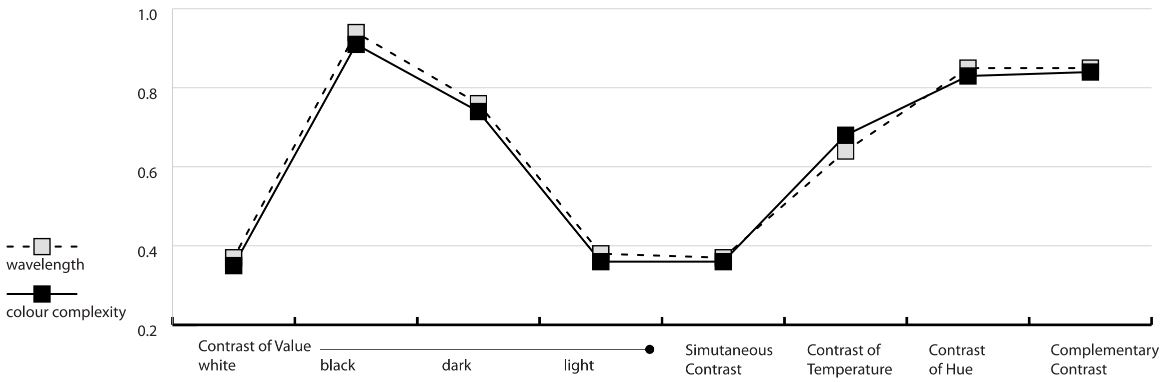


Design Application

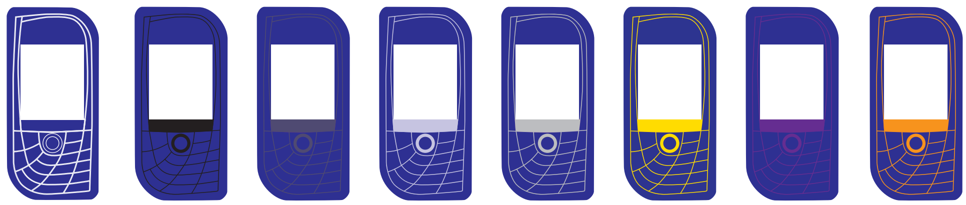


	Contrast of Value				Simutaneous Contrast	Contrast of Temperature	Contrast of Hue	Complementary Contrast
	white	black	dark	light				
Complexity Factor								
	0.24	0.64	0.76	0.40	0.42	0.85	0.74	0.76
	0.52	0.85	0.69	0.45	0.37	0.73	0.69	0.92
Average	0.38	0.75	0.73	0.43	0.40	0.79	0.72	0.84
Combined Wavelength								
	0.23	0.61	0.40	0.72	0.38	0.70	0.67	0.83
	0.49	0.81	0.35	0.66	0.42	0.82	0.74	0.65
Average	0.36	0.71	0.37	0.69	0.4	0.76	0.70	0.74

Figure 4.21 The average figures for colour contrast comparing the complexity factor and the combined wavelength for the green scheme.

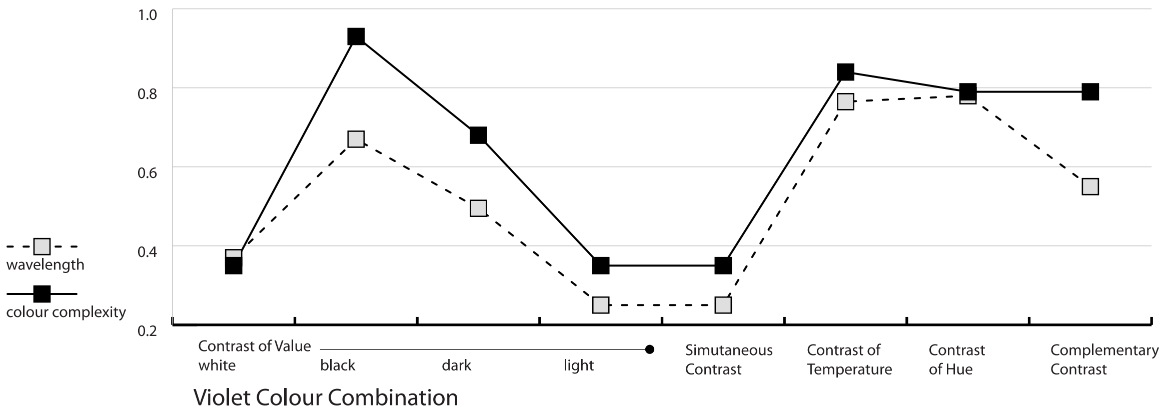


Design Application

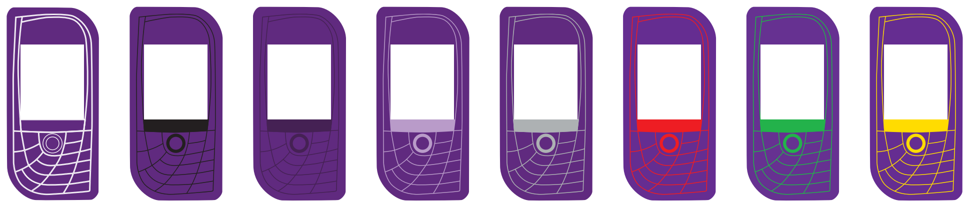


	Contrast of Value white	black	dark	light	Simutaneous Contrast	Contrast of Temperature	Contrast of Hue	Complementary Contrast
Complexity Factor								
	0.32	0.85	0.66	0.42	0.35	0.69	0.76	0.90
	0.38	0.97	0.82	0.31	0.37	0.68	0.90	0.79
Average	0.35	0.91	0.74	0.36	0.36	0.69	0.83	0.85
Combined Wavelength								
	0.4	1	0.84	0.32	0.38	0.61	0.77	0.89
	0.33	0.88	0.68	0.43	0.36	0.66	0.93	0.8
Average	0.37	0.94	0.76	0.38	0.37	0.64	0.85	0.85

Figure 4.22 The average figures for colour contrast comparing the complexity factor and the combined wavelength for the blue scheme.



Design Application



	Contrast of Value white	black	dark	light	Simutaneous Contrast	Contrast of Temperature	Contrast of Hue	Complementary Contrast
Complexity Factor								
	0.26	0.87	0.68	0.42	0.32	0.82	0.76	0.87
	0.45	1	0.69	0.29	0.39	0.87	0.82	0.73
Average	0.35	0.94	0.69	0.35	0.35	0.85	0.79	0.80
Combined Wavelength								
	0.47	0.60	0.42	0.25	0.23	0.82	0.82	0.70
	0.27	0.74	0.57	0.25	0.27	0.71	0.74	0.40
Average	0.37	0.67	0.50	0.25	0.25	0.76	0.78	0.55

Figure 4.23 The average figures for colour contrast comparing the complexity factor and the combined wavelength for the violet scheme.

Figures 4.18, 4.19, 4.20, 4.21, 4.22, and 4.23 show an interesting trend; the data values regarding the complexity factor and wavelength move in the same way for different colour contrasts. Considering that the data was kept the same in terms of colour combinations, this result leads to the conclusion that the complexity factor is not only affected by colour contrast, but also that the colour used affects the level of complexity. The wavelength of each colour affects the complexity of the colour scheme, and it is related to the colour energy. Low frequency and high energy in the colour red makes it the most complex hue, while high frequency and low energy makes violet the simplest colour scheme.

Accordingly, it can be said that colour contrast has the ability to make a simple design appear complex. In addition, the energy of individual colour elevates the complexity of the designs; the relationship between a simple and complex design is associated directly to the colour wavelength, as presented in (Figure 4.24). Each colour contrast has a complexity factor, however each colour scheme can either increase or decrease the magnitude of the same.

(Figure 4.25) presents the complexity factor of each colour contrast. Showing the increasing of the complexity factor toward the effect of colour contrast on the design appearance approve the effect of different colour combinations of the designs appearance. These findings fulfil the aims and the objectives of the research and establish the need for a design tool which informs designers of the size of the complexity factor of different colour combinations. A summary of the proven colour contrast results is given in (Table 4.9). This information is the basis of the data used in the design tool.

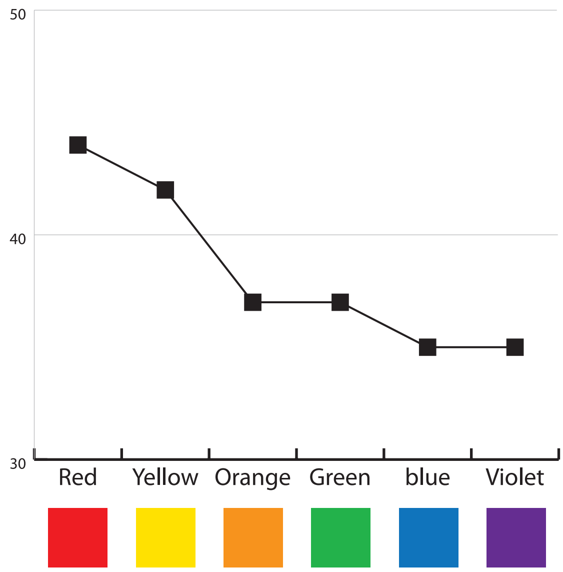


Figure 4.24 An illustration of the complexity factor of colour based on Study III

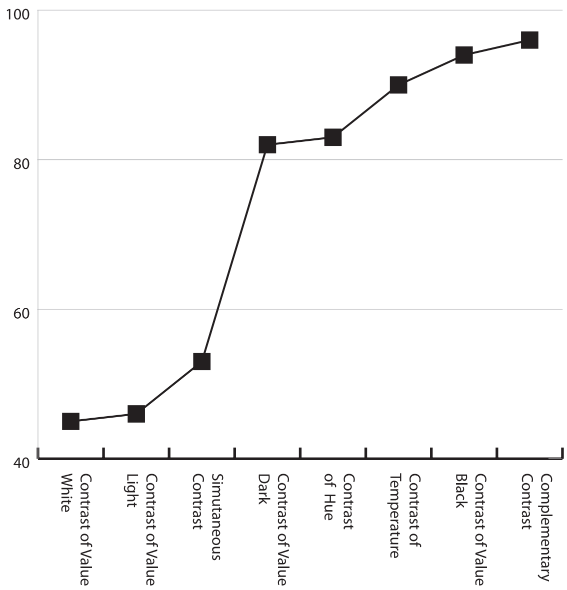


Figure 4.25 An illustration of the complexity factor presented in colour contrast average order

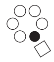
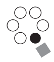
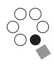
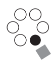
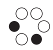
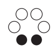
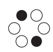
	Contrast name	Contrast code	Contrast position	Weighted average	Complexity order
1	Contrast of Value (White)	WDBA		45	1
2	Contrast of Value (Black)	CBBA		94	7
3	Contrast of Value (Dark)	DABA		82	4
4	Contrast of Value (Light)	LIBA		46	2
5	Simultaneous Contrast	SIBA		53	3
6	Contrast of Temperature	CWBA		90	6
7	Contrast of Hue	HLBA/HRBA		83	5
8	Complementary Contrast	COBA		96	8

Table 4.9 A key to presentation for the colour contrasts of the study (*1=simple)

4.4.3 Summary

The collected results met the aim of Study III, which defined the complexity factors of colour combinations and identified the effect of colour contrasts in relation to colour wavelength. It was determined that different colour contrasts affect the appearance of the design form, as do the colour combinations used. The results of Study III can be listed as follows:

- Different colour contrasts need to be considered, and they affect the appearance of the design form in a range from simple to complex.
- Different colour schemes affect the complexity factor in the same colour contrast.
- Each colour scheme has a different complexity factor which is related to the energy of the wavelength; high energy equates to complex colour and low energy equates to a simple colour scheme.
- Perception is affected by the presentation of the design based on the colour combination.
- Colour complexity can be analyzed and measured.

4.5 Chapter summary

The combined findings of the three studies suggest the importance of contrast, colour, and colour contrast in design. (Table 4.10) provides a summary of the key findings from the three studies. Clearly, contrast, colour contrast, and colour combinations with colour contrast show an increasing depth of influence with regard to perceived simplicity/complexity.

	Effect on design form appearance	Perceived as Simple Design	Perceived as Complex Design	Increased Time to Evaluate Design
Chromatic	yes	Black on white	White on black	yes
Colour Contrast	yes	Solo colour with white; simultaneous contrast; contrast of saturation and contrast of value.	Contrast of temperature (cold and warm); contrast of hue; and solo colour with black.	yes
Colour Contrast with different Colour Combination	yes	Low energy colours (Violet)	High energy colours (Red)	yes

Table 4.10. Summary of key findings from Preliminary Studies I, II, and III

The findings shown in (Table 4.10) support Eves (2002) who suggests that because of the complexity of colour itself, in terms of wave structure and the wide range of colours and combinations, colour choice in design is a significant consideration. This study agrees with the theory that colour wave structure is an element related to complexity. Shapiro, in 2008, minimized the importance of contrast in describing colour vision, however, the results of this study show that contrast and colour contrast are significant in how simplicity and complexity are differentiated. What is important in Shapiro's work, however, was the finding that colour and contrast were processed separately.

One result of the study with regard to design form evaluation, time, and complexity differs somewhat from Norman's (2011) suggestion that complexity can be measured by the amount of time required to learn it. In this study, complex designs took less time to evaluate and recognize than simple designs. This may not, however, be a direct comparison since evaluating a design as complex is different to learning the elements or functionality of a designed product.

Not only has Study III shown the existence of the complexity factor and its effect on colour contrast, but it has also shown that there are differences in complexity between colour schemes. This indicates a need to analyze in more depth the individual colour schemes.

CHAPTER FIVE

Data verification study

5.1 Introduction

This chapter evaluates the objectivity of the research data and explains how the human aspects were controlled in the development of the research. The process of gathering data from the secondary data collection sources mentioned in chapter three involved the interpretations of a number of participants. Even though the sample consisted of an educational group involved in the field of design, this chapter explains how the research study was designed to refine the information gathered and minimize the subjective aspects of the sample.

5.2 Data definition study

5.2.1 Introduction

The data verification study was created to confirm the results of Study III. Its purpose was to improve the validity of the research data, which was used in the design-tool. The aim was to ensure that the data gathered was valid and not just a collection of opinions. Additionally, the study needed to check whether the data collected could be applied to different design applications and have the same effect as on the mobile phone designs. Based on the findings in the study, further research might be valuable to explore the processing differences, given the importance shown of contrast and colour contrast in product design.

A selection process was devised to choose the key colour combination, which would ultimately be used to gather the research data. The selected colour combination was the one that had been ranked consistently by 70% of the total participants from Study III. Thirty-six colour combinations were selected and divided into 12 sets of three colour contrasts each.

In order to ensure that the participants shared the same understanding of the subject, a question was asked which enabled the researcher to develop a verbal description for the terms simple and complex colour contrast.

5.2.2 Aims of the study

- Confirm the validity of the data collected in Study III to be used in the tool design.
- Analyze whether the results of the previous study had the same effect on different design applications or were related solely to mobile phone design.
- Define the terms simple and complex colour combination.

5.2.3 Evaluation process

The test was designed carefully to fulfil the aims of this study. It was presented electronically to ensure the consistency of the test environment for the participant. The sample technique was kept the same, but the participants were new to the project.

Moreover, it was designed to evaluate 36 colour combinations covering all of Itten's (1973) contrasts. Plus, it was planned to apply those colour combinations to two different design applications. The test was divided into four parts.

Part one

The first part included some introductory information on how to participate in this voluntary questionnaire, and presented the Ethical Code of Practice for Bournemouth University. Then questions were asked to ensure that the participants matched the sample criteria and did not have a colour vision problem.

Part two

This section was more involved with the study. It introduced a new electronic mechanical design application presented by different colour combinations. A *wristwatch* was selected as the application for part two because of its similarity to the old design application, the mobile phone device. Both the mobile phone and the wristwatch are everyday objects and, most importantly, they share the application aims mentioned in (Section 3.4.1). One of the aims of the study was to test the validity of the colour contrasts effect on the products. (Figure 5.1) presents the first application with selected colour combinations.

The new application was coloured in the selected colour combinations and grouped into six sets created of three different colour contrasts. The sets were grouped in such a way that they covered different carefully selected colour contrasts, presented together in a suitable size. The order of the contrast and the different level of complexity in each set was shuffled. The participants were asked two questions which were repeated each time a set of three images appeared. The first question was: "which image is the simpler one for telling the time?" The second question with the same set of images was: "which image is the most complex one for telling the time?" The participants were asked to select one image for each question. (Figure 5.2) presents questions one and two and a set of images.

Figure 5.1 A product design application (wristwatch) using the selected colour combinations

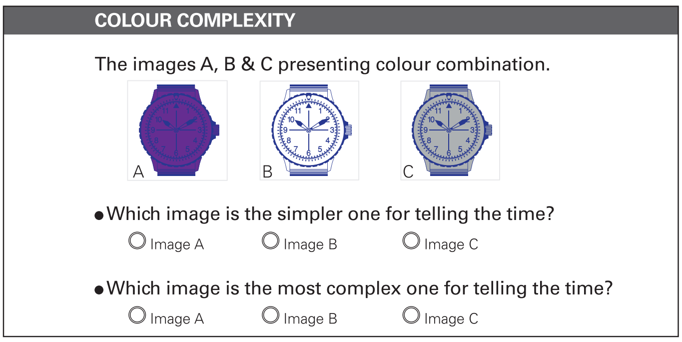


Figure 5.2 A sample of how the questionnaire presented a set of three images and two questions

Part three

Part three had the same purpose as part two, but with different colour combinations applied to a new design application. An abstract solution was carefully illustrated to communicate a non-verbal message with the use of design principles (Section 2.4). It was employed as a design application for part three, and served to determine the effect of colour contrast, simple or complex, on an abstract design solution. The aim was to check whether the data collected previously had the same value on any design solution, or whether it was limited to an electronic mechanical device (a mobile device). (Figure 5.3) presents the abstract application with different colour combinations.

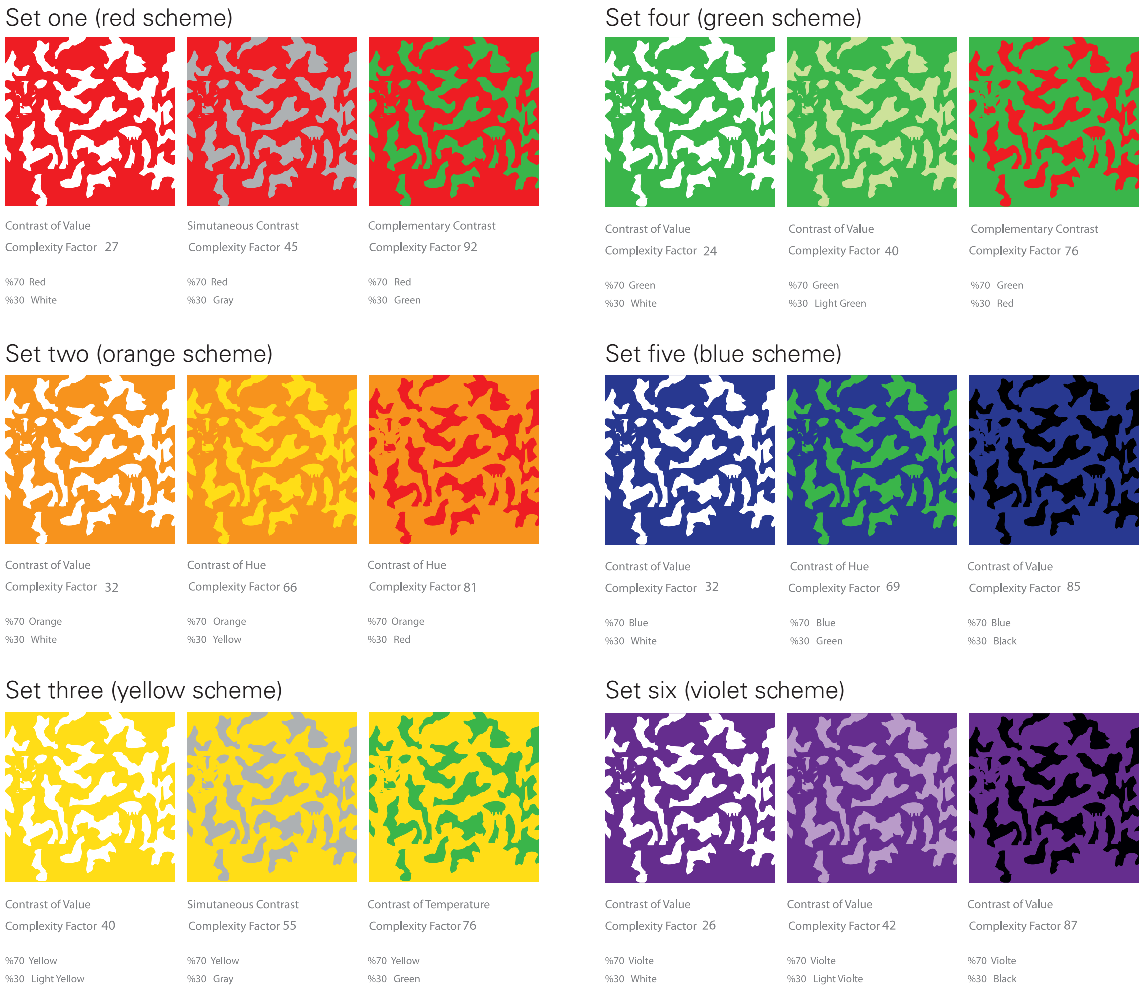


Figure 5.3 The new application (abstract design) using the selected colour combinations

Part four

Finally, it comes to the definition of the words simple and complex in relation to colour combination. Selecting the simplest or the most complex colour combination was straightforward; however, describing a simple or complex colour combination verbally was a big dilemma. No clear line could be drawn when describing such contrasts. Consequently, definitions were explored and analyzed. A list of adjectives describing the words was cautiously put together, such that each adjective can be moved to fit either or both words, as shown in (Table 5.1). The definitions and sources, which helped to logically produce the list, are provided in Appendix J.

Simple adjective	**Complex adjective**	**Control adjective**
balanced	unbalanced	coherence
basic	complicated	harmony
clear	confused	interesting
easy	difficult	poor
effortless	challenging	rich
focused	unfocused	pleasing
low contrast	high contrast	powerful
quite	loud	powerless
trust	noisy	quality

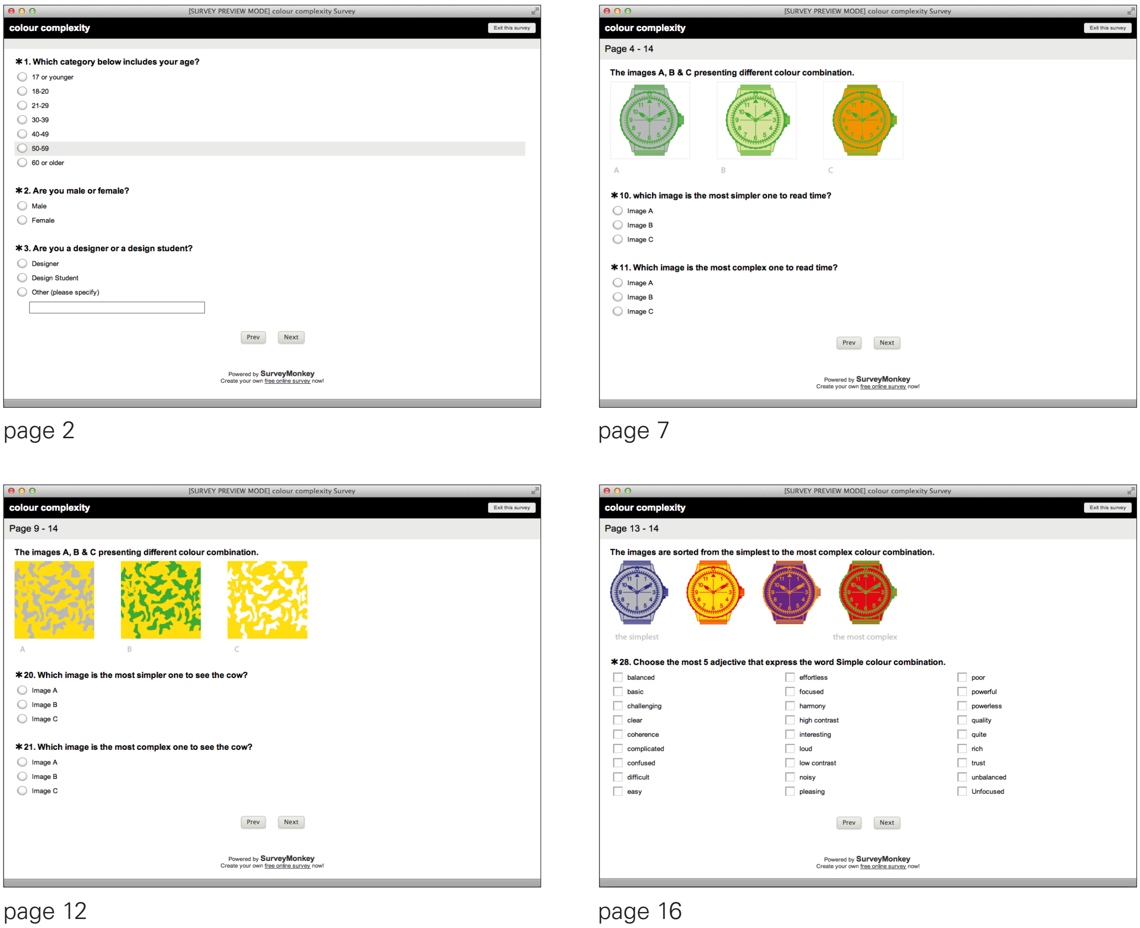
Table 5.1 A list of adjectives describing the words simple, complex and controlled

The lists were presented in alphabetical order and the participants were asked to select the five adjectives that best expressed the word simple with regard to colour combination, then they were asked to do the same for the adjectives related to the word complex. This process helped to define the terms simple and complex colour combination. The consistency of their interpretation confirms that the terms simple and complex colour combination are objectively applied. Check (Section 3.5.1) where details are provided toward defining new domains in research process.

In order to help the participants visualize the simple and complex colour combination, a set of four colour combinations were carefully selected and employed on the wristwatch illustration. Each combination presents a different contrast with a different value of the complexity factor. The selection process was spread over the total combinations used in the research.

5.2.4 Questionnaire

In order to achieve the aims of this study, and to ensure the objectivity of the results, the participants were asked to answer all the questions voluntarily. A soft copy questionnaire was carefully designed and conducted using the online questionnaire design tool www.surveymonkey.com. The aim was to make the questionnaire simple, user friendly and available online as shown in (Figure 5.4). A sample of the online questionnaire in large format is provided in Appendix K.



page 2 page 7

page 12 page 16

Figure 5.4 The online questionnaire used to verify the research data

5.2.5 Challenges and limitations

Firstly, selecting the colour combination. It was not easy to find a systematic method to choose a limited number of colour combinations out of the 90 which were available, and at the same time they had to encompass the majority of the research data. A large number of the colour combinations would work against the study rather than help it. To manage this, it was decided that the research would select the high ranked combinations to mimic the total available combinations. Twenty-four colour combinations were able to meet the needed criteria, and 12 combinations were carefully added to create the key colour combinations. Each group was carefully divided and placed in sets of three to create different colour contrasts. The aim was to help the participants select the simpler and the most complex colour combinations for each set. Moreover, the chosen combination in each set was picked from the spread of the colour scheme across all the degrees of complexity. (Figure 5.5) provides further clarification of the selection process.

Figure 5.5 An illustration of the selected colour combination across the spread of the complexity factor in each colour scheme. ○ total colour combinations ● the selected colour combination

Secondly, choosing design applications that have the same design features as the old design application (mobile phone) which could be employed to achieve the study aims. The dilemma was finding new applications that not only had similar design features but also had the same specifications (for further information see Section 3.4.1). Additionally, the current application (the mobile phone) has certain design aesthetics; mainly the form aspect with the negative positive space. The pixels of the mobile phone image were carefully counted using a programme (Adobe Photoshop) in order to create new applications (figure 5.6). Both solutions, the wristwatch and the abstract design, were carefully illustrated to match the same colour ratio (30%-70%) of negative positive space as the mobile phone. They had to carry the same ratio so that the effect of the colour combination was consistent.

Figure 5.6The different applications, mobile phone, wristwatch and abstract design, coloured in the same ratio

Thirdly, introducing the abstract shape as a new application was challenging. In order to prove that the results of the research were transferable, and could be applied to any type of design solution, an abstract application was needed. The issue for the abstract design was that it should somehow communicate a non-verbal message to the viewer, and it should do this without the use of text or numbers. Also, the abstract application had to be designed to make use of negative positive space. Thus, the result was a design solution that mimics the designs of Uwe Loesch (1986). Uwe Loesch is a German graphic designer and university lecturer, who designed a poster against radioactive contamination after Chernobyl (1986). He is considered to be one of the world's leading poster artists (Gerber and Lutz, 2006). His design was chosen because it conveyed Gestalt Principles (Section 2.4.3), and it has an interesting appearance in that different colour combinations affect the simplicity or the complexity for the message to come through.

Asking the right questions for each part of the process was the most challenging aspect. It was clear that the chosen question could either help elevate the understanding of the participants toward an objective result, or could make them confused. The language of the question had to convey the aim of the test. By considering the nature of each application, the wristwatch and the abstract design, the questions had to convey the aim of the test and the nature of each application.

Finally, defining the terms simple and complex colour combination. Identifying the adjectives that could be used to convey the meaning of these terms was a major task. The words simple and complex colour combinations were vague in terms of vocabulary. Thus, a list of different definitions by many respected designers and philosophers in the field of art and design were checked and analyzed to derive a number of adjectives that could describe the terms simple and complex colour combination. The definitions and the list of adjectives are provided in Appendix J.

5.3 Analysing the study results

Since the study was designed to refine the objectivity of the research data, there were a number of aims and goals which it needed to consider, and indeed achieve. The main aim was to analyze whether the data collected and the information gleaned could be applied to any design solution with the same effect, or was its effect limited to the current design application, the mobile phone? The test dealt with 36 colour combinations and covered all the colour contrasts mentioned in the research in Appendix H. The results collected achieved the objectives of the study and helped to develop the research further.

5.3.1 Test results

Part one

Sixty-five participants completed the test. Eighty-one percent of them were male, 19% were female. The majority of the participants were undergraduate design students while 20% were professional designers; 15% were categorised as other, specifically photographers. The ages varied between 18 and 49 years. The majority of the 65 respondents were between the ages of 21 and 29 (Figure 5.7).

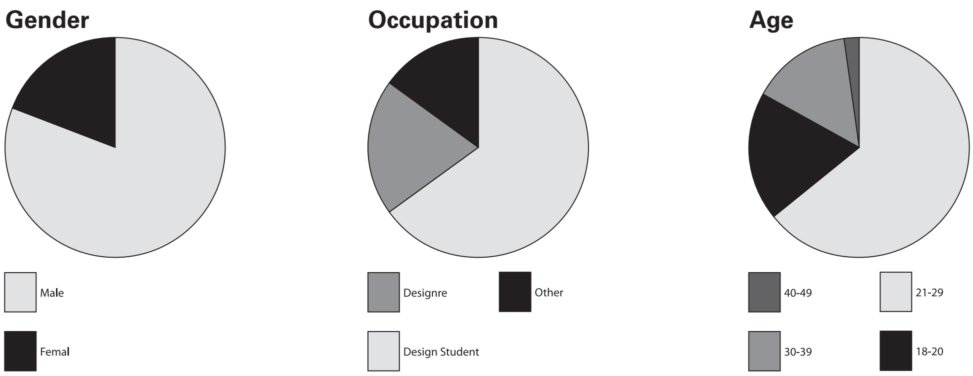


Figure 5.7 Analysis of the demographic data collected from the respondents

Since this study was undertaken to verify the significance of the research data and since it deals with colours, it was important to ensure that the participants were free from colour blindness, and that they met the sampling criteria of being either design students or designers. Accordingly, the feedback of 11 respondents who did not match the requirements was withdrawn from the results analysis. A detailed report on the data as well as a sample of an answer sheet is provided in Appendix M.

Part two (product design application)

As mentioned previously, the test divided the colour combinations into two main groups. Each group dealt with different sets of combinations and a different application. Part one presented a new design application (wristwatch, product design) in six sets created from three different colour combinations and different contrasts in the same colour scheme. Each set was shown with different questions, once asking the participant to select the simplest colour combination and the second time asking them to select the most complex colour combination. This process ensured that the participant did not select the same colour combination twice for the simple and again for the complex combination.

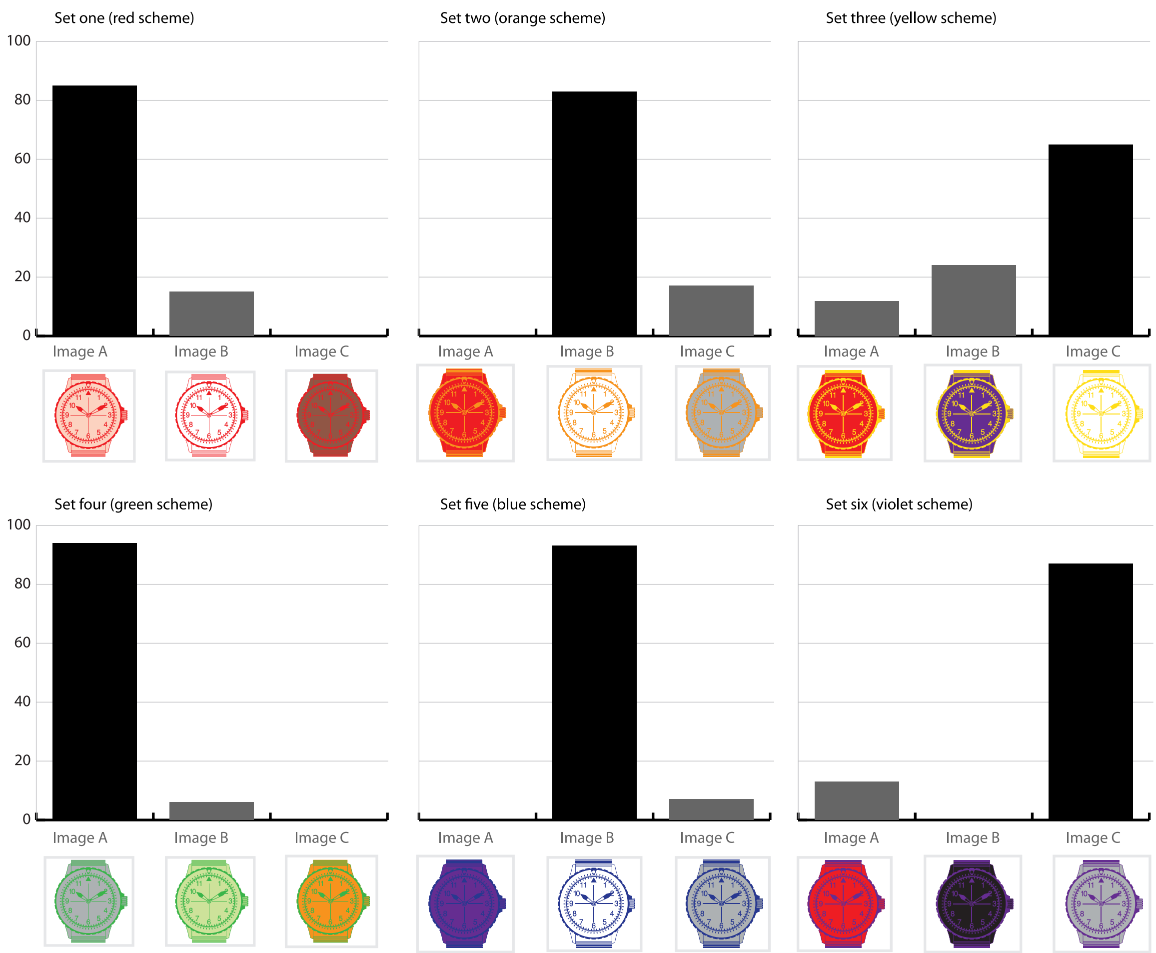


Figure 5.8 An illustration of the first design application (electronic mechanical device) presenting the most simple colour combination. ■ Shows the simplest combination based on Study III

The graph shows consistency in certain colour combinations, which are meant to be the most simple. Apart from the yellow colour scheme, the responses to a request to find the most simple colour combinations are almost identical. The new participants were able to select the most simple colour combination with 100% agreement with the data of Study III.

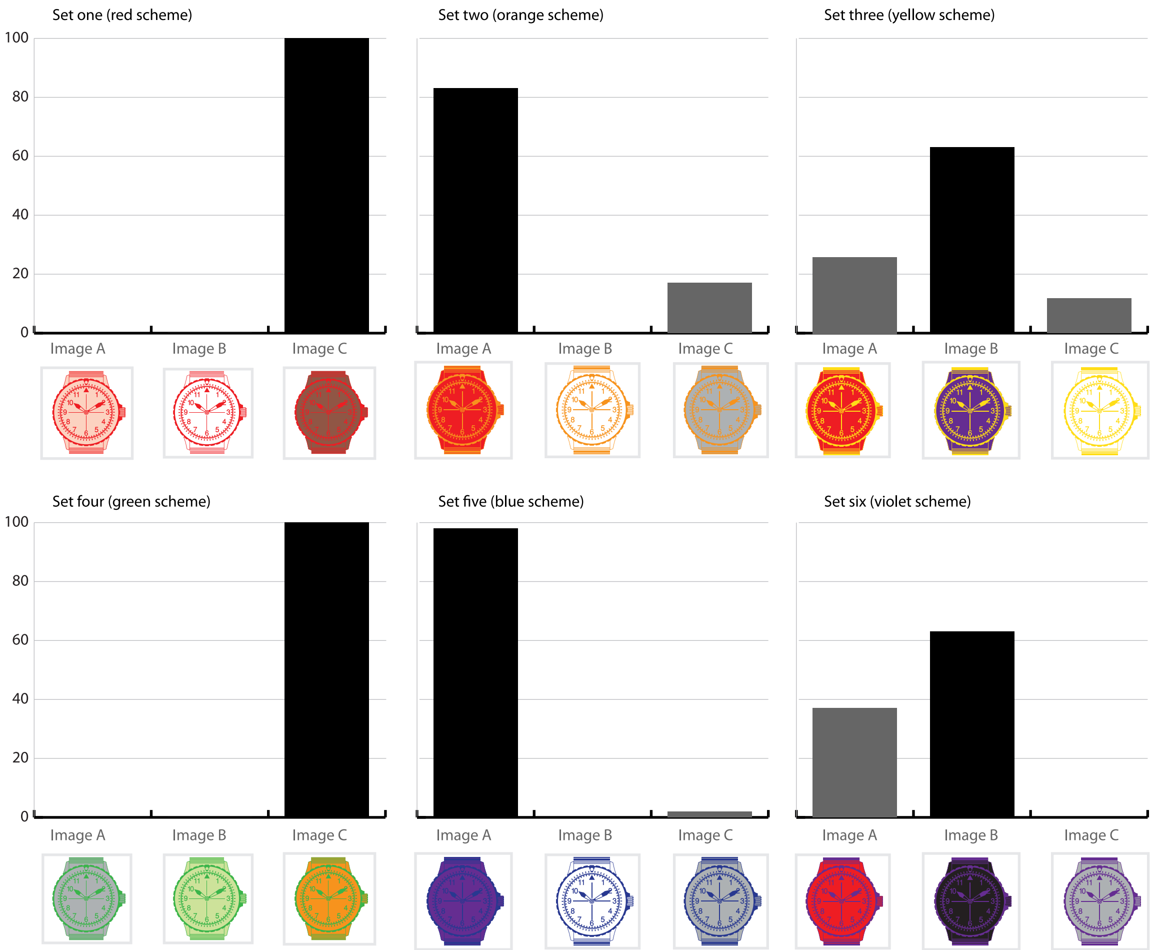


Figure 5.9 An illustration of the first design application (electronic mechanical device) presenting the most complex colour combination. ■ Shows the simplest combination based on Study III

As expected, in the case of selecting the complex combinations, the graph shows a greater degree of consistency. The responses are similar, if not identical, for some colour combinations. This is because participant responses are much more straightforward and reliable when selecting the complex image. See Study I in (Section 3.5) for further information.

Both (Figures 5.9 and 5.10) match the outcomes of Study III and indicate that the simplest and the most complex colour combinations have the same effect on all tested design applications that could be described as a product design. The results of part two are in complete agreement with the data from Study III with 84.5% consistency. The 84.5% presents the unchanging achievement and effect of the colour combination on the new design application (wristwatch) for different participants. (Table 5.2) presents the consistency of the effect of the colour combinations on the product design applications.

Colour combination	**Response percentage**	**Total response**
Simple colour combinations	84.5%	274
Complex colour combinations	84.5%	274
Data matching consistency	84.5%	548

Table 5.2 Consistency of the study data (in percentages); the results match those of Study III

Even though there was some noise in the third set of images (the yellow scheme) the results complement those of Study III. This noise was always present for the yellow scheme combinations because of the brightness and the accessibility of the physical colour, as mentioned in (Section 4.3.2).

Part three (abstract application)

Part three presented an abstract shape that communicated a non-verbal message to the viewer. As with the first application, part three was also divided into six sets created from three different colour combinations and different contrasts but with the same colour scheme. Each set was shown but with two different questions, once asking the participant to select the simplest colour combination and the second asking them to select the most complex. Introducing the second application (abstract shape) was critical to the research. If this test succeeded, it would elevate the research to a different level. Finding out whether the data had the same effect on different designs would be of positive benefit to designers and design students (Figure 5.10).

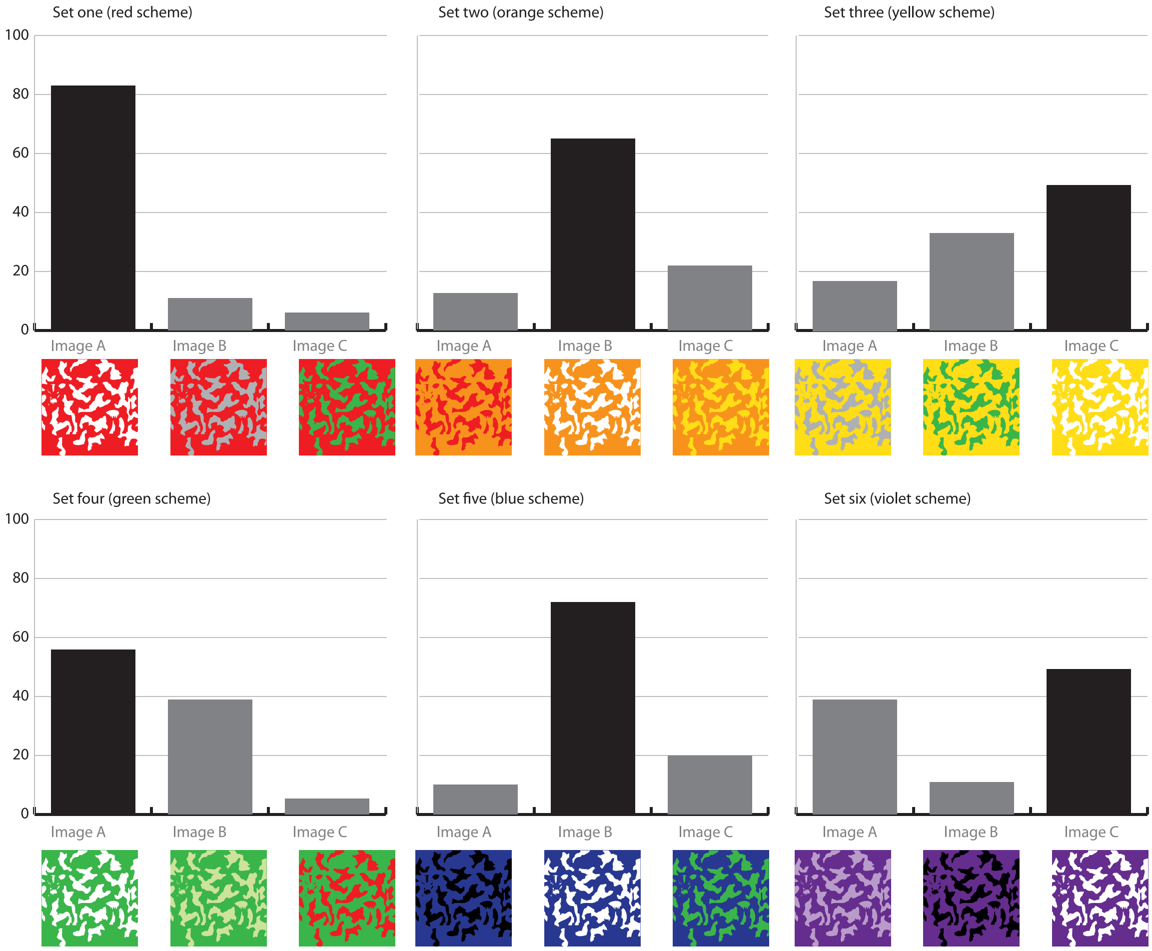


Figure 5.10 An illustration of the second design application (abstract application) presenting the most simple colour combination. ■ Shows the simplest combination based on Study III

The graphs on (Figure 5.10) show some consistency in certain combinations, which are meant to be the most simple. Apart from the yellow, green, and violet colour schemes, the responses are toward the most simple colour combinations. The results were 100% agreed with the data of study III.

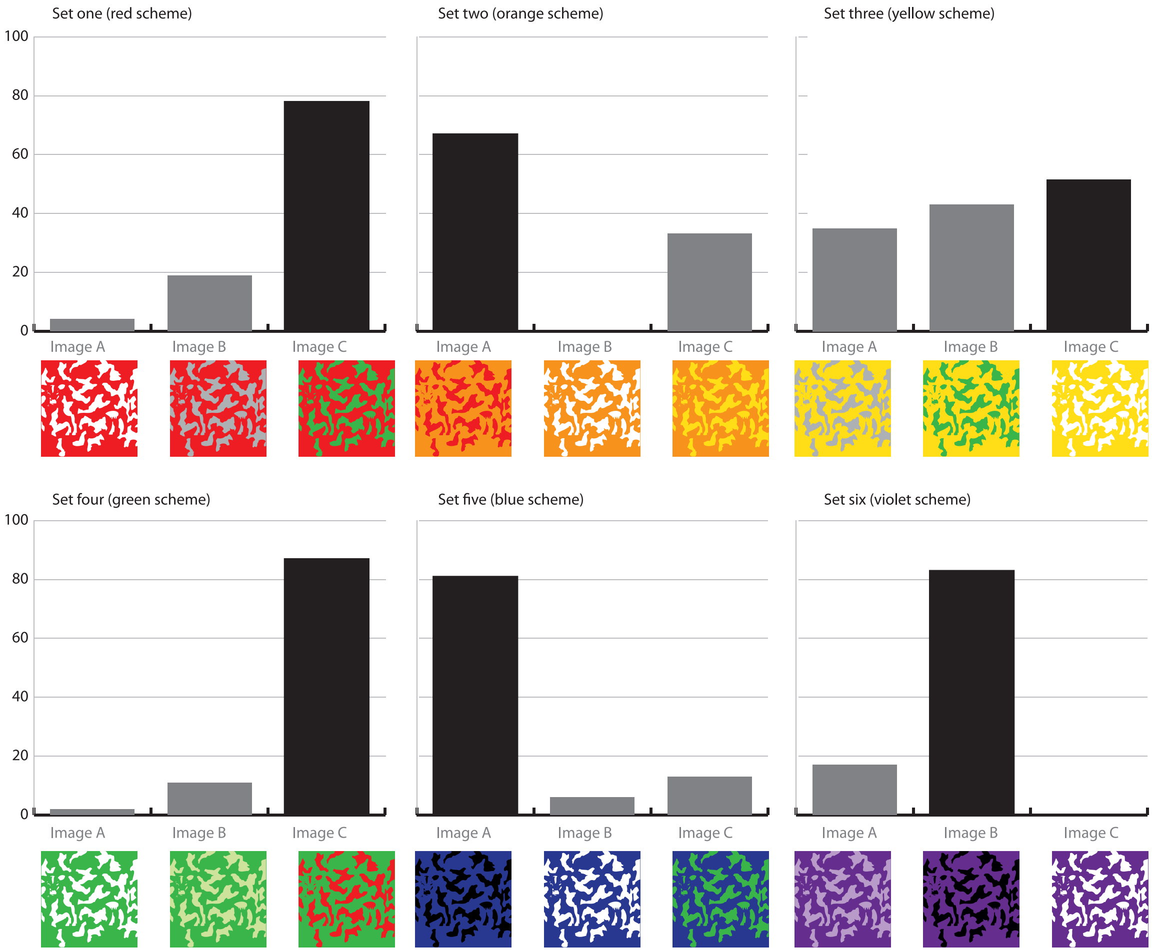


Figure 5.11 An illustration of the second design application (abstract application) presenting the most complex colour combination. ■ Shows the simplest combination based on Study III

As stated previously, participants found it easier to select the most complex colour combination; (Figure 5.11) shows more consistency in selecting this combination. The responses are more focused toward the complex colour combinations than the simple one.

The consistency of this study's data in comparison with Study III results is presented in (Table 5.3). Even though the total percentage of the consistency of the data matching is only 67%, this number only presents the unchanging achievement and effect of the colour combination on the new design application (abstract shape) for different participants.

Part three results match the data from Study III in the selected combination. The highest percentage in every set always represents either the simple or, on the other hand, the most complex combination of the research data.

Colour combination	Response percentage	Total response
Simple colour combinations	63%	203
Complex colour combinations	71%	231
Data matching consistency	67%	434

Table 5.3 Consistency of the study data (in percentages); the results match those of Study III

Part three results matched the findings of Study III, and indicate that the simplest and most complex colour combinations have the same effect on any design application. Even though there was some noise in the third set of images (the yellow scheme) the results complement Study III. This noise was always present for the yellow scheme combination because of the brightness and the accessibility of the physical colour.

Part four (defining the terms simple and complex colour combination)

Thirty-seven adjectives were carefully selected and presented to the participants in alphabetical order. This list appeared twice, each time with a different task. The first time they were asked to select the five adjectives that best expressed the term simple colour combination, and the second time they were asked to select the five which best represented complex colour combination. This activity not only helped to define the two terms, but also defines in words the agreement between the participants regarding the subjects simple and complex colour combination (Figure 5.12).

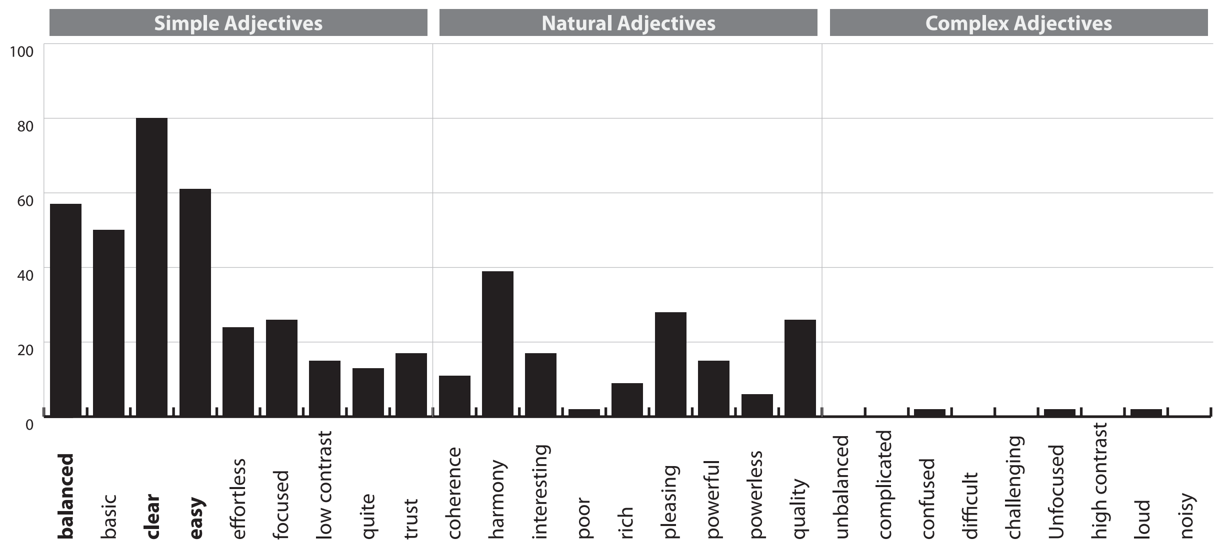


Figure 5.12 An illustration of the consistency for the term simple colour combination

(Figure 5.12) shows positive consistency in the adjectives that describe the simplest colour combination. Eighty percent of the participants selected the word *clear*, 61% the word *easy*, and 57% of them chose the word *balanced* aligned with different adjectives such as, basic, harmony, and pleasing. This helped to verbally define the term simple colour combination, and ensure that the participants were consistent in their responses and so their understanding.

As a result, simple colour combination is a clear, easily balanced combination. This definition can be adopted and will present no difficulty when composing a colour combination to be applied in a design.

(Figure 5.13) shows positive consistency in the adjectives that describe the term complex colour combination. The words *noisy* and *difficult* have equal evaluation, they share 70% of the participants' choice. Fifty-seven percent of the participants chose the word *unbalanced*. The words *confused*, *high contrast*, and *loud* also share a high volume of responses. This helped to ensure that the participants were consistent in their understanding of the term complex colour combination.

Thus, complex colour combinations consist of many different and connected contrasts. They are noisy and cannot easily balance a visual message.

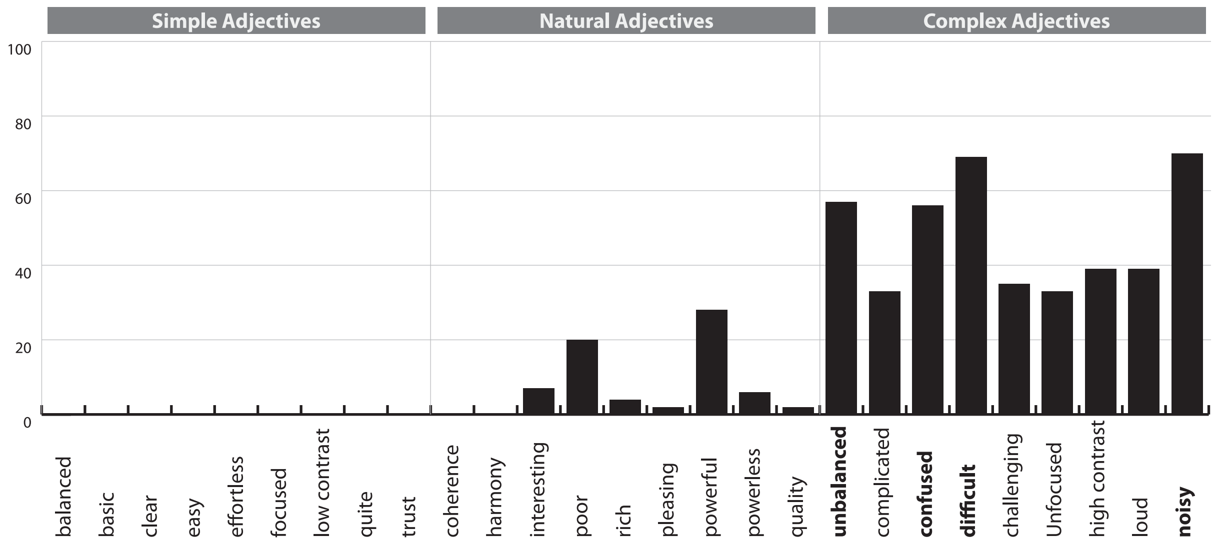


Figure 5.13 An illustration of the consistency for the term complex colour combination

5.4 Summary

The collected results met the aim of the study. It defines the simplest and most complex colour combinations based on colour contrasts, and has shown that colour combinations have an effect on any design application, and that this effect corresponds 100% with the research data. Moreover, it is consistent to a certain degree. The results can be listed as follows:

- The results of the study verify that the data of Study III are valid and represent a consistent response.
- The participants of this study are in 100% agreement with the data of Study III.
- The effect of the simplicity or the complexity of the colour contrast is applicable to any product design, with 84.5% consistency.
- The effect of the simplicity or the complexity of the colour contrast is applicable to any design solutions, with 69% consistency.
- The colour contrast has the same effect on any design solution with different degrees of consistency.
- There is a need to ensure that the concept of functionality is embodied in simple and complex colour combination considerations.
- Colour combination in design can affect the design appearance.
- The participants were able to understand and acknowledge the differences between the simple and complex colour combinations.
- Simple colour combination is a clear, easily balanced combination.
- Complex colour combinations consist of many different and connected contrasts. They are noisy and cannot easily balance a visual message.

CHAPTER SIX

The colour complexity tool

6.1 Introduction

Colour has a major impact on the design process. The colour choice can elevate the design solution to a different level, and either make or break it. In a world filled with designs and visual images, it is difficult to create an effective design message. This research aids both student and professional designers because it offers an understanding on colour contrasts' role as a design aspect, which affects the simplicity and complexity of a design's appearance. Having this understanding makes it easier to avoid problems, such as complex design devices, and to meet the established goals of the message. In addition, knowing and applying the most effective level of complexity for optimum perception could contribute to the improvement of designers' outcomes and therefore, to an improvement in people's lives.

This chapter covers multiple areas of data configuration. First, it explains the generation of conceptual solutions and preparation of a range of preliminary design approaches toward a colour complexity tool. The colour complexity tool is a needed vehicle for the findings and the raw data collected in this research project. Then, the chapter presents the results of the tool evaluation, where testing strategies were used to judge its efficacy, and the resulting selection of possible design solutions. Finally, it presents a retrospective evaluation of the final tool to determine strengths and weaknesses and to evaluate how future versions might be improved.

This chapter, which deals with data configuration, offers a way to control the relationship between the design form and the applied colour combination so that the final design solution meets the viewer's needs. The process of selecting the right colour contrast combination for any design is based on many things, one of them being the knowledge of the designer. However, the colour complexity tool offers a different side to the selection of an appropriate colour contrast combination. It provides designers and design students with an opportunity to select a colour then combined it with either a choice of colour contrast or the level of complexity needed. In other words, it offers the right colour combination to either increase or decrease the perceived complexity of a design.

6.2 The tool design

This section applies the research data and the synthesis of the findings of this study to the design of a tool which communicates aspects of colour. Consideration was initially given to the application direction, to determine how the tool could best be made to demonstrate the findings of the study (Section 4.5), by improving the design process. The tool is the interface between the valid data generated in this research and the designers and the design students.

6.2.1 Aims of the tool design

- The tool created for this research should be for use by designers and design students with a decent knowledge of colour theory.
- The tool should be easily accessible and provide a user-friendly interface.
- The tool should provide information on the simplicity and complexity of colour contrast combinations.
- The tool should provide experience of the effect of colour combinations on different design forms.

6.2.2 Ideation

Because of the study type and the research data, the potential application had to be an informative design tool that delivered the research findings to the target audience; that is, designers and design students.

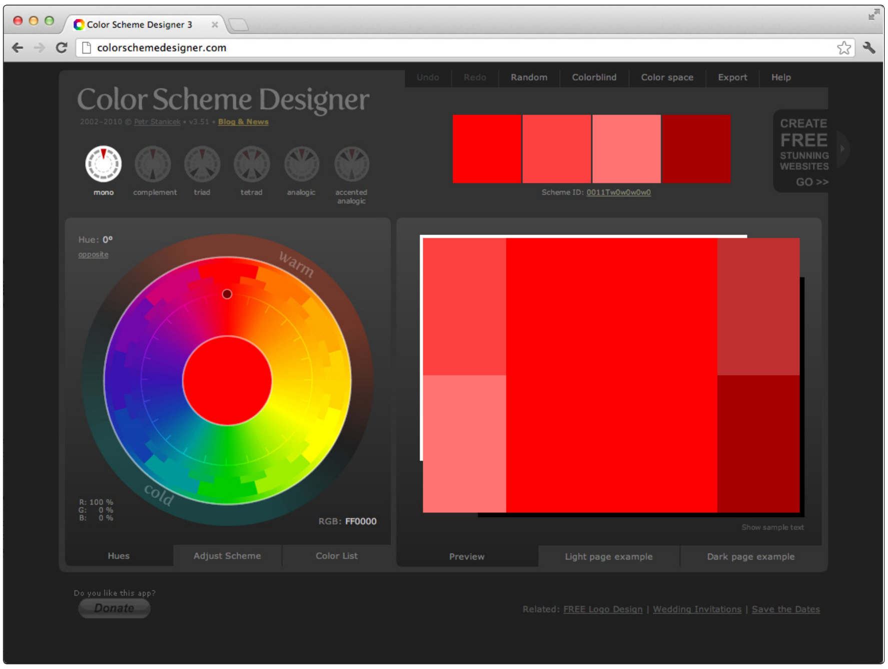
To inform creation of a new design tool related to colour complexity factors, an implementation matrix was built of similar colour tools in order to understand the pros and cons of each. The matrix (Figure 6.1) cross-references a number of current colour tools available online. Additionally, it shows the design elements available in each tool, including the target audience, the users of the tool, tool clarity, design decisions used in the tool, its functionality, the kind of information provided in the tool, and the experience that the user gains by using it.

The selection process used to produce the matrix was based on certain criteria. The tools needed to: be available online; provide free access to the visitor; have received good reviews from a number of designers and design websites; and deal with the concept of colour combination or colour scheme generation. The matrix helped identify the target form of the research tool, thus optimizing its chances of success.

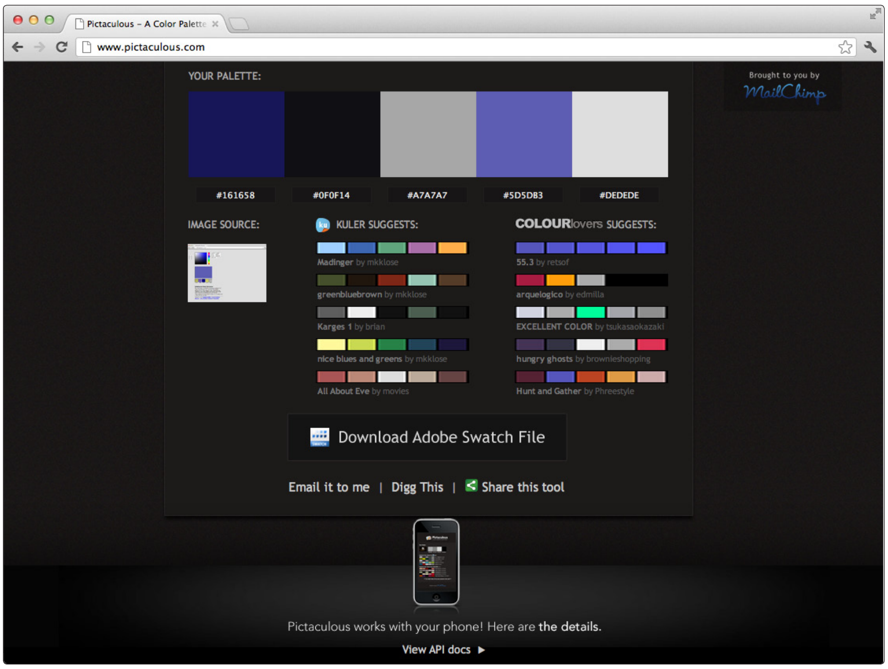
The matrix helped crystallise the process of designing the layout of colour tools, as well as our understanding of the navigation and functionality of a good colour tool. Moreover, it improved the ideation process involved in creating an informative design tool related to the data collected in this research.

Figure 6.1. A matrix of the current colour tools available online, and of their design elements

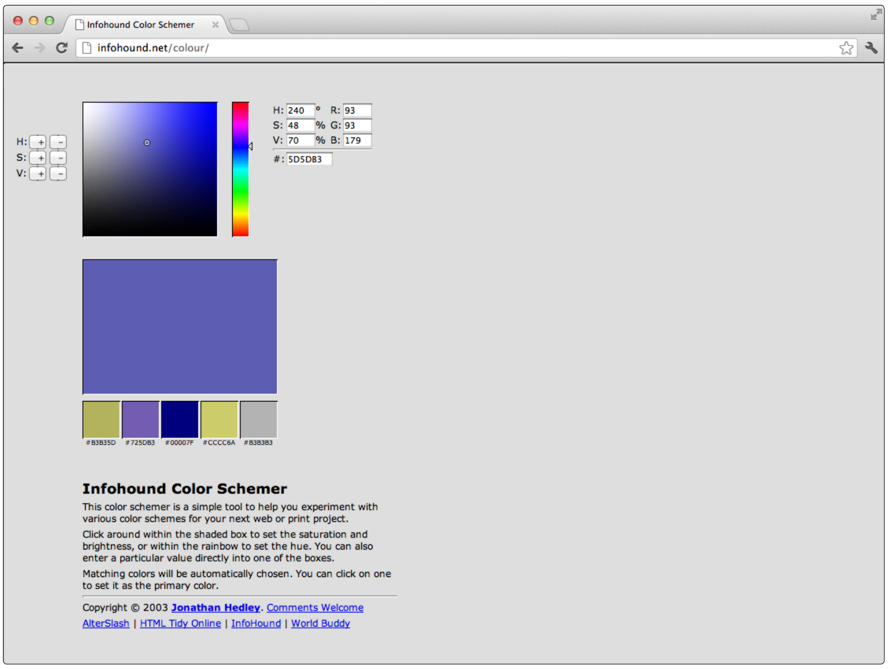
1	**Colour scheme designer**
Website	www. colorschemedesigner.com



Description	Colour Scheme Designer helps create beautiful colour schemes in seconds. Colour blind simulation is built in so user can ensure usability will be optimized for all users.
Users	Professional web designers.
Clarity and design	Has many elements but overall produces good design decisions.
Functionality	Easy navigation can create a colour scheme with minimum effort.
Information	Generative colour scheme for website designers. Colour theory used and transformed into algorithms to combine colours that go best together.
Experience	A complex tool. Provides a great deal of information as well as examples of websites which carry the selected colour scheme.

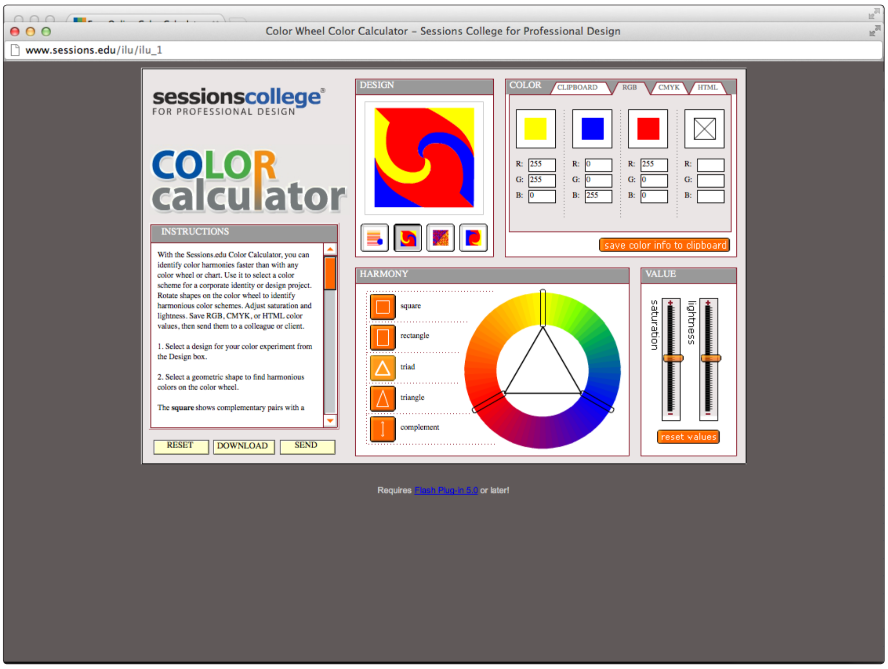
2	**Pictaculous**
Website	www. pictaculous.com
	
Description	Simply upload a picture and automatically get a colour scheme that matches. Plus, it provides suggestions from Kuler and Colour Lovers websites.
Users	Any user.
Clarity and design	Simple, minimal elements.
Functionality	One click does the whole job.
Information	Scanning an uploaded image to generate a related colour palette.
Experience	Easy but no information related to colour theory provided.

3	**Infohound Color Schemer**
Website	www.infohound.net



Description	This colour schemer is a simple tool to help the user experiment with various colour schemes for the next web or print project. Click around within the shaded box to set the saturation and brightness, or within the rainbow to set the hue. The user can also enter a particular value directly into one of the boxes. Matching colours will be auto matically chosen.
Users	This is meant for designers and design students but is really easy and straight forward to use.
Clarity and design	Many design elements and hidden windows.
Functionality	One click does the whole job.
Information	Gives the user complement and contrast combinations for any chosen colour, but no information related to colour theory provided
Experience	Many options to navigate.

4	**Color Calculator**
Website	www.sessions.edu/for-students/career-center/tools-quizzes/color-calculator



Description	Basically an electronic colour wheel that provides designers with all the necessary information regarding contrasts, values, and harmony. It also provides users with the colour codes for different formulae such as, RGB, CMYK, and HTML. The tool gives the user the option to choose from four different design applications and to apply the colour combination to it.
Users	Designers and design students.
Clarity and design	Although it has many options it is clear and nicely designed.
Functionality	Complex. There are many icons and scales which need to be adjusted to obtain the results.
Information	Gives the user complement and contrast combinations for any chosen colour.
Experience	Provides a huge amount of information and could be the designer's best friend.

6.2.3 Design process

The tool was designed carefully to address the aim of this research: to inform its users (designers and design students in the field of industrial and graphic design) about the concept of colour complexity. It was created in a website format to ensure easy availability and to offer a consistent environment in terms of the users' colour perception as indicated in (Section 2.5.2). In addition, the design style used in the tool was an information design style; a visual representation where the meaning is more clearly expressed to the viewer. The layout considered each design element, including line, texture, colour, text, white space, and context. It was taken into consideration that the final tool should be compatible with both PCs and MACs so its functionality remains accurate for both sets of users. With the aid of a professional programmer; Mr. Yousuf Salim at Kuwait University, the tool was programmed using JavaScript, which is a language often used to create polls and quizzes online because of its universal platform and interactivity. This language was selected to ensure the interactivity of the tool with the user when selecting a target colour combination.

After reviewing the results of research Study III, all of the colour combinations used in the study were grouped by colour scheme and sorted based on the value of the complexity factor. A total of 120 colour combinations were sorted and are presented in (Figure 6.2).

To make the names of the contrasts better suited to the tool and easier for the user to understand, they were renamed and attached to an icon that indicated the location of the colour contrast, as presented in (Table 6.1).

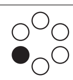
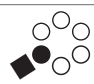
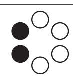
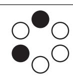
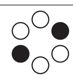
Study III Colour Contrast	Contrast Code	Name used in the Tool	Icon Design
Contrast of Value (White)	WDBA	Mono	
Contrast of Value (Black) Contrast of Value (Dark) Contrast of Value (Light) Simultaneous Contrast	CBBA DABA LIBA SIBA	Value	
Contrast of Temperature Contrast of Hue	CWBA HLBA/HRBA	Adjacent*	
Contrast of Temperature Contrast of Hue	CWBA HLBA/HRBA	Primary Secondary*	
Complementary Contrast	COBA	Complement	

Table 6.1 An explanation of the naming standards used by the tool for colour contrasts
* Adjacent and Primary share the same colour contrast, but in different colour combinations

The tool had mainly to deal with the complexity factor of the colour combinations. To achieve that, the combinations of each colour were sorted in two ways: in terms of colour contrast; and of the complexity factor, in the range 20, 30, 40, 50, 60, 70, 80 or 90. (Figure 6.2) presents the different degrees of complexity on the colour combinations displayed. The figure shows that certain colour schemes are missing a degree of complexity, which means that there are no available values for those particular degrees. For example, the combinations of the red scheme do not have a combination colour that fits into the 30 degree complexity. A large format version is provided in Appendix N.

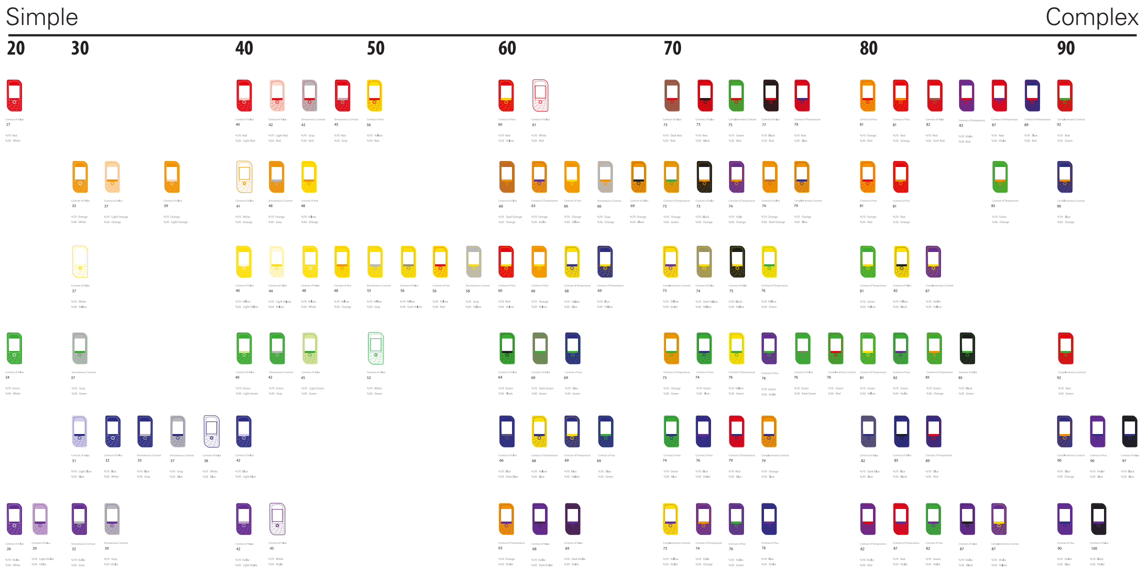


Figure 6.2 a presentation the different degree of complexity of the colour combination.

The tool was designed as an informative and interactive structure to provide the users with information regarding 120 colour combinations presented in three different design forms. This activity offers the user the opportunity to experience the effect of different colour combinations on different design forms. Each design form, out of the three, was selected carefully to represent a different level of complexity within the design aesthetic. The users are able to select the colour combination needed and apply that combination to different design forms to investigate and experience the effect of colour contrast on the appearance of the design application.

Moreover, the navigation of the tool was carefully designed to make the information clear to the visitor. (Figure 6.3) present a flow chart that shows the logic and the functionality of the tool. In addition, the screen layout was divided into three main areas: upper screen, middle of the screen, and the bottom of the screen. Each section dealt with different issues and led smoothly to the other sections. The aim was to give the user a coherent experience through the information provided in each section. (Figure 6.4) is an illustration of the screen layout and the process of navigation.

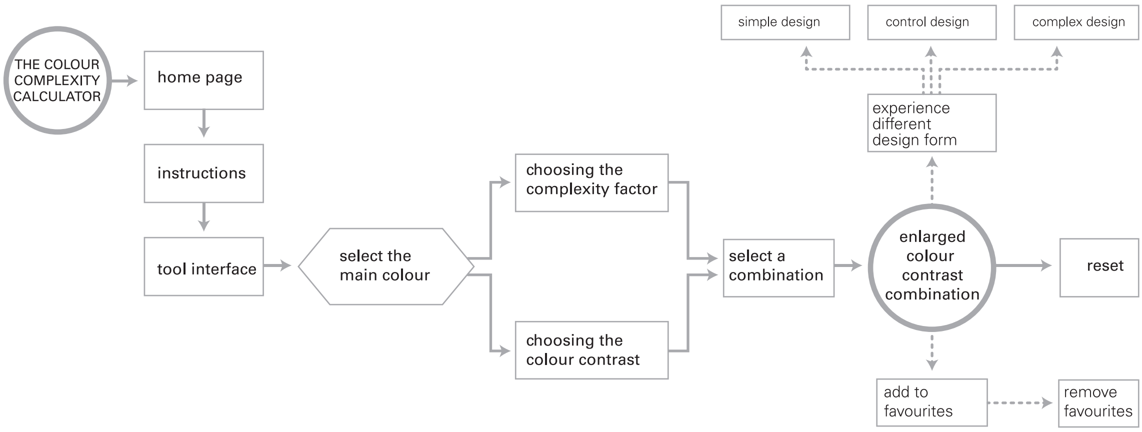
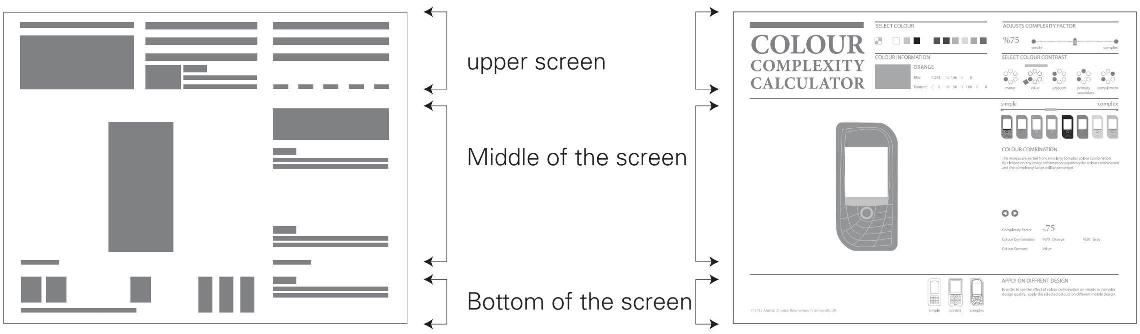


Figure 6.3 A flow chart shows the logic and the functionality of the colour complexity tool



process of navigation

tool screen layout

Figure 6.4 An illustration of the process of navigation and the tool screen layout design

Upper screen

The upper part of the screen is the area where the user provides input. The user is required to select the main colour, and the combined colour option. To choose the combined colour, the tool offers two different methods. Each method offers a different experience and provides different kinds of information. First, the user can select the complexity factor that they are aiming toward by adjusting the complexity scale. This method gives the user a fixed colour combination based on their entry within a ten-point range, plus the tool will inform them if there is no match. For example, by selecting the colour orange and adjusting the complexity scale bar to 80%, a list of different combinations such as, orange and red or orange and green will appear with full contrast information. This method is only effective if the user knows exactly the complexity factor that is suitable for their final design. In the second method, the way to select a combined colour is by choosing a colour contrast. This method gives the user the opportunity to choose a combined colour from a list of the same contrasts irrespective of the level of complexity. For example, the user could know that he/she wants the colour red as a dominant colour with a contrast of value, but he/she does not know which value (white, grey, black, darker shade or lighter shade) is best suited for the complexity factor that they require. This second method is more effective if the user knows the contrast needed but does not know which colour is best suited.

Middle of the screen

This part of the screen is more involved with the data. It presents the results of the user's input in an information design. Moreover, it shows a group of thumbnail images, either of the colour combinations that have a matching complexity factor degree chosen by adjusting the complexity factor scale bar, or a group of thumbnails for colour combinations that share the same kind of colour contrast based on option two of the input on the upper part of the screen. The user can select the thumbnails that he/she is interested in and can enlarge them, along with all details regarding the combination such as, the degree of the complexity factor, the ratio and the names of the colour combinations, and the kind of contrast. In addition, the user can create a favourite list of colour combinations. This option gives the user the opportunity to compare the colour combination and the complexity factor of the same. The information in this part of the screen represents the culmination of the work done in this research to produce the tool. The tool summarizes the findings of this research and presents an interactive informative webpage that allows easy access by designers and design students. It helps them solve their design process problems by selecting the right colour combination suitable to their design form and provides information about the precise complexity appearance of their design.

Bottom of the screen

This part of the interface gives the user the opportunity to check the validity of the tool and experience the complexity factor. It provides the ultimate experience by showing the effect of colour on how the user will perceive the design. After selecting the colour combination and knowing the information regarding that selection, it is time to experiment with the colour combination by applying it to different design forms. A number of design forms with different levels of complexity (simple, control and complex) are provided and the user observes the effects that different colour combinations can have on the appearance of those forms. So he/she is able to experience the effect of simple or complex colour combinations on different design forms in order to choose the one they require.

Also, the website provided the visitor with PDF files containing the summary of the research, the aims of the study, and the final conclusion. In addition, a list of the colour combinations sorted by complexity factor was provided. The aim of these PDF files was to give the user extra information on the project to enrich their knowledge in terms of simple and complex colour contrast combination.

The website had a number of pages:
1 A home page, which had a link to the tool.
2 An instruction page, which provided the user with the directions needed to navigate the tool.
3 The tool itself, where the use interacts with the information provided, and chooses the colour combination needed.

In order to achieve the aims of the tool, and to ensure the consistency of the information provided and the functionality of the software, it was designed to be available online and accessible to both PC and Mac users. In order to ensure that the tool was compatible with both PCs and Macs, the JavaScript programming language was used, making sure that the information and the design of the tool were consistent. The layout of the tool was carefully designed to help enhance its interactivity. The aim was to make it simple, user friendly and understandable, as shown in (Figure 6.5).

Figure 6.5 The layout design of the tool.

6.2.4 Challenges and limitations

First, several problems arose during the design process. The most challenging problem was programming and designing the tool. It was not easy entering all the data and the colour combinations and making sure that all the data was correct. The data was gathered from the results of Study III and these results were presented in a certain way to aid programming of the tool. A number of design phases were necessary to achieve the aims of the tool; that it would be functional, easily accessible, and informative.

Second, the presentation of the colour contrasts was a big issue. It was essential to present the colour combination in a context, however choosing the application on which to demonstrate that combination was not simple. After reviewing the pros and cons of each application used throughout this research, it was decided to adopt the mobile phone design as an application for the tool. It was not an option to present the colour combinations in colour swatches because of the concept of simple and complex communication with regard to the appearance of the design. As previously stated, the terms simple and complex colour combination need a context in which to deliver the message to the viewer, even those viewers who use their imagination. It was crucial that the designers and design students see the concepts displayed within a specific context so they could be sure that they were relating to the end-user experience.

A final challenge lay in providing the user (designer and design students) with the complexity experience. The aim was to provide the user with the option of testing the selected colour combination on an uploaded image of the device they were designing; however, because of limited programming skills, it was decided to replace this option and incorporate it later into phase two. Consequently, the users were given the facility to apply the selected colour combination to three different design forms built into the tool.

6.3 Tool evaluation

The aim of evaluating the tool was to confirm that it had achieved the intended goals and delivered the intended message. The primary aim was to check whether the research data used in the tool informed the users about the concept of simple and complex colour combinations, provided knowledge of the simple and complex colour combinations delivered, and afforded an experience of the complexity factor achieved. There were five sections to the test: general information, layout and design, functionality of the tool, agreement of the information, and tool experience. Designers and design students participated in the evaluation. Since the tool was presented in soft copy it was easier for the participants to contribute and complete a hard copy questionnaire. The questionnaire consisted of six A4 pages with 26 questions and an introduction on how to use the tool. A sample of the questionnaire is provided in Appendix O.

6.3.1 Tool test results

Twenty participants took part in the test. Fifty percent of them were undergraduate design students while 50% were professional designers. The ages varied between 21 and 39 years. The majority of the respondents were between the ages of 21 and 29. A detailed report of the tool test results is provided in Appendix P.

As suggested by the survey results, the strengths and weaknesses of the tool are:

Tool strengths

- Ease of use
- Simplicity of design
- Adjustable complexity factor

The weaknesses

- Lack of options for printing, sharing, and saving favourites
- Inability to upload own design forms
- Inadequate instructions for the upper screen where users input data

6.3.2 Summary of the test results

Participants expressed an overwhelmingly positive attitude towards the Colour Complexity Calculator and the results showed no responses in the 'Slightly Agree' or 'Not at All Agree' categories. The majority of all responses to all questions indicated that respondents ticked either the 'Extremely Agree' or 'Strongly Agree' category with just a few responses for 'Moderately Agree'. Although the response to the tool was very positive, the question that received the highest percentage in the 'Moderately Agree' category was whether they would continue to use the tool in the future. Twenty percent of the participants only 'Moderately Agreed' that they would use the tool in the future. Higher response percentages in the 'Moderately Agree' category were found when participants were asked about the functionality of the tool, with 15% of respondents only 'Moderately Agreeing' that the tool functionality was good. The comments provided in response to Question 26 suggested improvements to functionality. Participants wanted to be able to upload their own designs and to print and share the results. They also wanted larger text on the user interface and better instructions on the top portion of the screen where user input was required. Comments also suggested that the ease of use, simple design, and adjustable complexity factor were especially liked by participants. The positive response to the Colour Complexity Calculator tool encourages continued testing and further implementation of the features desired by the participants in this study.

6.4 Implementation of future refinements

Based on the feedback gathered during the evaluation phase (Section 6.3) by relevant evaluators, the tool (the Colour Complexity Calculator) could be revised in several ways to enhance its clarity and communication with the users. This section discusses major alterations that could be incorporated into the new tool.

Layout and design aesthetics

Enlarge the size of the text in general and make the illustration sharper.

Functionality

Adding an introduction will help the user understand what they are going to experience. An introduction should give the user a summary about the effect of colour combinations on the appearance of the design. In addition, it should present the complexity factor in detail.

Tool experience

Probably the most important improvement to the tool would be to give the user the option to choose the form of the application from a list of different alternatives, or to give him/her the ability to upload their own design form image. This is important because it would not only help the user to understand the effect of colour combination on their design, but would also allow them to check the impact of colour combinations on the complexity factor.

6.5 Summary

Chapter six describes the conceptual foundation for the Colour Complexity Calculator and also the important challenges that arose in the development of the tool. A summary of the survey results in tabular and narrative format was provided together with an appreciation of the strengths and weaknesses of the tool as revealed in the survey responses. Finally, the implementation of future refinements based on survey results was discussed with an emphasis on improvements in the areas of design, functionality, and tool experience. The aim was to provide designers and design students with information on the complexity factor of colour contrasts.

CHAPTER SEVEN

Conclusion and Future Research

7.1 Introduction

This chapter is a summary of the research and is based upon the studies made and their analyzed results. The conclusions of the research are provided together with a number of recommendations for further development.

7.2 Conclusion

Design delivers an intentional message from the sender to the intended receivers and can be simple, straightforward, and easy to understand or intricate, complex, and layered in detail. Colour, as a factor of design, has the power to alter the design intention, either adding complexity or simplifying complex designs appearance. The aim of this study was to understand the relationship between colour combination and colour contrast, and the interplay between these two with regard to design complexity.

This study adds to the body of knowledge on colour and design form by determining the effect of colour contrast on the latter. The study consisted of a series of analyses on both colour contrast and colour combination samples in order to find an effective way to identify and measure the level of simplicity and complexity represented by a colour combination. Additionally, it established and tested a design tool that measured the degree of simple and complex colour combinations.

In this study, several themes emerged in the literature review regarding how design perception is influenced by colour, and these common themes guided this research. The themes included: 1) luminance contrast is more important than hue contrast; 2) colour perception is different for subtractively created colours as compared to additively created colours; 3) people perceive colour with consistency, in spite of great variance in the response of individual eye cones; and 4) colour combination has an effect on aesthetics, memory, trust, and readability.

7.3 Discussion of the findings

This study was completed in three parts, with each stage building on the results of the one before and solving a different set of problems. (Table 7.1) summarizes the three stages.

Preliminary Study 1	Preliminary Study II	Preliminary Study III
Achromatic (black and white only)	Itten's colour contrasts using one colour combination only	Itten's colour contrasts multiple colour combinations

Table 7.1 The three studies

In each stage there was a test which was designed to validate the suggested methods as well as to answer the research questions of the project:

1. What are simple and complex design and what are the differences between them?
2. How can simple and complex design be measured?
3. What are the design aspects that affect the simplicity and complexity of a design?
4. Does colour affect the simplicity or complexity of the appearance of a design form?
5. What are the simpler and more complex colour combinations?
6. Can the simplicity and complexity of a colour combination be measured?

The study found that differences in complex and simple design are determined by colour combination, and colour contrast with each adding a degree of complexity to a design form. In particular, colour contrast types were found to be related to complexity as shown in (Table 7.2).

Simple Colour Contrasts	Complex Colour Contrasts
Single colour with white	Temperature contrast
Saturation contrast	Single colour with black
Value contrast	Hue contrast
	Complementary contrast

Table 7.2 Simple and complex colour contrasts by contrast type

These findings lend support to Stone (2006) who demonstrated that value contrast plays a more important role in readability allowing content to appear in layers, and showing that hue contrast does not allow this separation into layers. It might be presumed that content that is more readable would be considered simple as opposed to complex. The study also supports Norman (2010) who suggests that time is a measurement of complexity. In this study, it is shown that both time and perception are influenced by the colour combination presented in the design form.

However, where Norman suggests that organization, modularization and structure, and training can remove complexity, the results of this study suggest otherwise. Colour contrast and colour combinations would not necessarily be removed through organization, modularization, and training and yet they contribute strongly to perceived complexity. The results of this study suggest that overlooking colour in evaluating complexity would be a mistake. Norman was dealing with the idea of features versus simplicity, while this study focused on the appearance of the design. Participants were able to distinguish the complex design appearance much faster than the simpler one.

The most important finding in this research was that the complexity factor for colour increases in the same order as colour wavelength. One conclusion of the study was that the complexity factor is affected by colour contrast, and that the wavelength of each colour affects the complexity factor, as it relates to the colour energy. An example in the results showed that a high energy and low frequency in the colour red makes this the most complex hue, while a low energy and high frequency in the colour violet makes this colour the simplest. This finding provides a scientific measurement for complexity based on wavelength information. Colour contrast can increase the complexity of a design form as can an increase in the colour energy. The relationship between a complex and simple design corresponds directly with the colour wavelength. While each colour contrast has a complexity factor, the related colour scheme will decrease or increase that complexity factor. For example a high ratio of red combined with temperature or a complementary contrast will produce the highest level of complexity. Clearly, based on the results of this study, colour complexity can be measured and subsequently analyzed.

It was also determined that for both black and white and colour combination, complex design forms are selected or recognized more quickly than simple design forms. Colour contrast was an important factor affecting the design form appearance across multiple colour combinations, and when colour contrast was added as a factor, the identification of complex design forms continues to occur more quickly than for simple design forms.

The results of the study provide insight for each of the research questions asked and provide guidance to designers in how to manipulate the perceived design complexity based on colour combination and colour contrast. Additionally, the study provides a tool for evaluating design complexity with regard to colour combination and colour contrast.

7.4 Recommendations for future research

Based on the results, there is a need to investigate the physical attributes and physiology of the various colours used in this research, and even those not included. Study III shows the existence and impact of the complexity factor on colour contrast, and shows that there are additive differences between colour schemes. This finding suggests a need to further research individual colour schemes and their relation to complexity. Additionally, future research is suggested to test these same concepts on devices other than a mobile phone to determine whether the influence of colour contrast and colour combination extends to different device designs.

Shapiro (2008) demonstrates that colour and contrast are processed separately and asks which colour signal dominates: chromatic or contrast information. Since the findings of this study show that colour combinations, colour contrast, and the combination of the two affect perceived complexity, future research might focus on which of these colour signals is predominant in complexity perception.

It will be important to perform further research on the influence of colour combination and colour contrast with colours created additively or subtractively, since it was revealed in the literature review that people perceive colour differently when it is created additively or subtractively. For example, will a colour-related interface design on a television screen have different results to the same colour-related design in the case of a hand-held mobile device with regard to colour contrast and colour combination?

Future research might focus on the limits of colour-related complexity to determine at what level it begins to obscure device comprehension because device designs often have a dual purpose of increasing interest in the device, and making the device immediately comprehensible. In other words, how much colour-related complexity is an end user willing to accept whilst still being able to understand how to use a device? An additional and related question might be: 'Do users tend to select colour combinations and colour contrasts that are in accord with favourite colours regardless of the complexity presented?'

7.5 Summary

Colour contrast, colour combination, and the relationship between the two have been definitively shown, in this study, to influence design complexity based on the colour's energy emission. By using a number of design application forms in a range of complexity levels, the effect of colour contrast was demonstrated on the appearance of the designs. An appropriate colour contrast, when applied to a simple or complex design application, can make it appear simpler than the same form in a different colour contrast. Additionally, the relationship between colour wavelength and complexity has been demonstrated and can be applied by designers in evaluating design complexity factors. Time is considered to be a measurement element of complexity. Complex colour contrasts are identified more quickly than simple colour contrasts. The study also provides a tool for measuring and evaluating design complexity, with the potential for further refinement to improve the tool's usability. The results of this study open the door to many new avenues of research, which can, in turn, lead to highly informed design decisions.

References

- Albers, J., 2006. *Introduction of colour*. 3rd edition. London: Yale University Press.
- Aloumi, A., 2008. *Timing considerations in visual communication*. Thesis (MFA). Rochester Institute of Technology.
- Anter, K., 2001. *What color is the red house: Perceived color of painted facades*. Unpublished doctoral dissertation, The Royal Institute of Technology, Department of Architecture, Stockholm.
- Apple Inc. 2013. *Itunes Application*. USA: Apple Inc. Available from: http://www.apple.com/itunes/whats-new/ [Accessed 17 February 2006].
- Apple Inc. 2013. 2007. IPhone UK (first-generation) review. London: Macworld. Available from: http://www.macworld.co.uk/digitallifestyle/reviews/?reviewid=2388 [Accessed 17 February 2006].
- ASA Analytics., 2012. *Color analysis*. Retrieved from http://www.asaanalytics.com/color-analysis.php
- Balasubramanian, R., Braun, K., Buckley, R. and Rollesto, R., 2001, June/July. *Color documents in the Internet era. The Industrial Physicist*. Retrieved from http://www.aip.org/tip/INPHFA/vol-7/iss-3/p16.pdf
- Bartleson, C. and Breneman, E., 1967-1. *Brightness perception in complex fields*. J. Opt. Soc. Am., 57, 952-957.
- Bartleson, C. and Breneman, E., 1967-2. *Brightness reproduction in the photographic process*, Phot. Sci. Eng. 11, 254-262.
- Bense, M., 1969. Einf ¨uhrung in die informationstheoretische¨ Asthetik. *Grundlegung und Anwendung in derTexttheorie*. Rowohlt Taschenbuch Verlag GmbH.
- Berlyne, D. E., 1971. *Aesthetics and psychobiology*. Appleton-Century-Crofts, Educational Division, Meredith Corporation, New York (1971).
- Berryman, G., 1984. *Notes on Graphic Design and Visual Communication*. Los Altos, California: William Kaufmann, Inc.
- Bierut, M., Drenttel, W., Heller, S. and Holland, D. K., 1997. Looking Closer: Bk. 2: *Critical Writings on Graphic Design*. 2nd edition. USA: Allworth Press.
- Birkhoff, G., 1933. *Aesthetic measure*. Harvard University Press.
- Birren, F., 1969. *Principles of Colour*. New York: Van Nostrand Reinhold Company.
- Brace, J., 2008. *The Power of Simplicity*. Available from: http://members.shaw.ca/jeff.brace/Simplicity.htm [24 May 2010].
- Breneman, E., 1962. *The effect of level of luminance and relative surround luminance on the appearance of black-and-white photographs*, Phot. Sci. Eng. 6, 172-179.

- Brusatin, M., 1991. *A History of Colours*. Translated by Robert H. Hopcke and Paul Schwartz. London: Shambhala Pubs Inc.
- Charles Eames. 2013. Evans Molded Plywood. USA: Eames Office. Available from: http://eamesdesigns.com/catalog-entry/lcw-1946/ [Accessed 17 February 2006].
- Chevreul, M. E., 1981. *The Principles of Harmony and Contrast of Colours*. London: Van Nostrand Reinhold.
- Coursaris, C., Swierenga, S. and Watrall, E., 2007. *Effects of color and gender on the perceived attractiveness of websites*. IRMA International Conference. Retrieved from http://www.irma-international.org/viewtitle/33359/
- Craig F. Bohren., 2006. *Fundamentals of Atmospheric Radiation: An Introduction with 400 Problems*. Wiley-VCH. ISBN 3527405038.
- Creswell, J. W., 2009. *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.).Thousand Oaks, CA: Sage.
- Davidoff, J., 1991. *Cognition through color*. Issues in the biology of language and cognition. Cambridge, MA: MIT Press.
- De Bono, E., 1998. *Simplicity*. Penguin Putnam: childrens Hc.
- Design Institute of Australia., 2012. *The voice of design*. Retrieved from http://www.dia.org.au/index.cfm?id=186
- Donderi, D. C.: *Visual complexity: A review*. Psychological Bulletin 132(1), 73–97 (2006)
- Eves, B. and Lefley, M., 2002., *The Colour Concept Generator: An adaptive fuzzy colour semiotic design tool*. Semiotica, 142 (4), 91-105.
- Eves, W. R., 1991. *The Development of a System to Produce Computer Graphical Art Representative of Musical Input*. Thesis, (MSc). Sheffield City Polytechnic.
- Eves, W. R., 1997. *The Colour Concept Generator: A Computer Tool To Propose Colour Concepts For Products*. Thesis, (PhD) Bournemouth University.
- Gerber, A., Lutz, A., 2006. *A lexicon of contemporary graphic design: Influences*. Gestalten Verlag, 2006, pp.288th.
- Goethe, J. W., 1970. *Theory of colours.* Translated by Charles Lock Eastlake. London: MIT Press.
- Gordon, J. and Shapley, R., 2005. *Brightness contrast inhibits colour induction*: Evidence for a new kind of colour theory.
- Gouras, P., 2009. *Color vision*. Webvision, University of Utah School of Medicine.
- Grady, D., 1993, June). *The vision thing: Mainly in the brain*. Discover. Retrieved from http://discovermagazine.com/1993/jun/thevisionthingma227

- Guiterrez, J., Camps-Valls, G., Luque, M. and Malo, J., 2012. *Contrast definition for perceptually based colour image coding*. Recent Patents on Signal Processing, 2.
- Hall, R. and Hanna, P., 2003. *The effect of webpage text-background color combinations on retention and perceived readability, aesthetics, and behavioral intention*. Ninth American Conference on Information Systems, 2149-2156.
- Harper, S., Michailidou, E. and Stevens, R., 2009. *Toward a definition of visual complexity as an implicit measure of cognitive load*. ACM Transactions on Applied Perception, 6(2), Article 10.
- Heaps, C. and Handel, C., 1999. *Similarity and features of natural textures*. J. Exper. Psych. Hum. Percept. Perform. 25, 299–320.
- Hembree, R., 2006. *The Complete Graphic Designer*. China: Rockport.
- Heylighen, F., 1997. *The Growth of Structural and Functional Complexity during Evolution*. Springer, New York.
- Hong S. and Shevell S., 2008. *The influence of chromatic context on binocular color rivalry: Preception and neural representation*. Vision Research, 48, 1074-1083.
- Hunt, R., 1987. *The reproduction of colour in photography*, printing, and television, Fountain Press, England, p.56.
- Hunter, S., Yohe J., Stella, F. and Dicke, T., 2006. Hans Hofmann. USA: Rizzoli.
- IEEE Std., 1998. *IEEE Computer Society*: Standard for Software Quality Metrics Methodology.
- Itten, J., 1973. *The art of colour: the subjective experience and objective rationale of colour*. Translated by Ernst van Haagen. New York: Van Nostrand Reinhold.
- Itten, J. and Birren, F., 1970. *The elements of colour: A treatise on the colour system of Johannes Itten*, based on his book The Art of Colour. John Wiley and Sons.
- Jain, A., 1989. *Fundamentals of Digital Image Processing*. New Jersey, United States of America: Prentice Hall. pp.68, 71, 73.
- Johnson, R. B., and Onwuegbuzie, A. J., 2004. *Mixed methods research: A research paradigm whose time has come*. Educational Researcher, 33(7), 14-26.
- Karim Rashid. 2013. Water bobble. North Carolina: Move Collective, LLC. Available from: http://www.waterbobble.com/all-products [Accessed 17 February 2006].
- Kelly, D., 1983. *Spatiotemporal variation of chromatic and achromatic contrast thresholds*. J. Opt. Soc. Am. A., 73(6), 742-749.
- Kerr, D., 2010. *The CIE XYZ and xyY Color Spaces*. Retrieved from http://graphics.stanford.edu/courses/cs148-10-summer/docs/2010--kerr--cie_xyz.pdf

- Klinger, A. and Salingaros, N., 2000. *A pattern measure. Environment and Planning B: Planning and Design*, 27, 537-547.
- Lidwell, W., Holden, K. and Butler, J., 2003. *Universal Principles of Design*. USA: Rockport Publishers.
- Lin, H., and Huang, K., 2009. *Effects of color combination and ambient illumination on visual perception time with TFT-LCD*. Perceptual and Motor Skills, 109, 607-625.
- Maeda, J., 2006. *The laws of simplicity*. Cambridge, Mass: MIT Press.
- Marcus, A., 1992. *Graphic design for electronic documents and user interfaces*. New York: Reading, Mass. McGraw-Hill.
- Mayer, R. E., 1992. *Thinking, Problem Solving, Cognition*. Second Edition. New York: WH Freeman.
- McConkie, G. and Currie C., 1996. *Visual stability across saccades while viewing complex pictures*. J. Exper. Psych. Hum. Percept. Perform. 22, 3, 563–581.
- McDougall, S., de Bruijn, O. & Curry, M., 2000. Exploring the effects of icon characteristics on user performance: The role of icon concreteness, complexity and distinctiveness. Journal of Experimental Psychology: Applied, 6, 291-306.
- Mihai, N., Zakia, R., 1994. *Creating Effective Advertising: Using Semiotics*. New York: Consultant Press.
- Muji Europe Holdings Ltd. 2012. Wall mounted CD player with radio and remote control White. London: Muji Europe Holdings Ltd. Available from: http://www.muji.eu/pages/online.asp?Sec=8&Sub=29&PID=5587 [Accessed 17 February 2006].
- Mullen, K., 1985. *The contrast sensitivity of human colour vision to red-green and yellow-blue chromatic gratings*. J. of Physiol, 359, 381-400.
- Mullet, K. and Sano, D., 1994. *Designing Visual Interfaces: Communication Oriented Techniques*. USA: Prentice Hall.
- Nielsen, J. and Loranger, H., 2006. *Prioritizing Web Usability*. USA: New Riders Press.
- Norman, D. A., 2011. *Living with Complexity*. Cambridge, MA: MIT Press.
- Norman, D. A., 2010. *Simplicity Is Not the Answer*. Don Norman's jnd website. Available from: http://www.jnd.org/dn.mss/simplicity_is_not_the_answer.html [9 April 2010].
- OED (Oxford English Dictionary)., 2012. *Perception*. Retrieved from http://oed.com/view/Entry/140560?redirectedFrom=perception#eid
- Okawa, Y., 1981. A *complexity measure for colored pictures in commercial design*. Computer Graphics and Image Processing, 17(4), 345-361.

- Oliva, A., Mack, M., Shrestha, M. and Peeper, A., 2004. *Identifying the perceptual dimensions of visual complexity of scenes*. In Proceedings of the 26th Annual Meeting of the Cognitive Science Society. Erlbaum, Mahwah, NJ.
- Padgham, C. A. and Saunders, J. E., 1975. *The Perception of Light and Colour*. London: Bell.
- Poggenpohl, S. H., 1993. *A Career Guide and Education Directory*. The American Institute of Graphic Arts. Available from: http://www.aiga.org/guide-whatisgraphicdesign/ [2 April 2010].
- Rayner, K.,1998. *Eye movements in reading and information processing: 20 years of research*. Psych. Bull. 124(3), 372–422.
- Russell, D., 1991. *Colour in industrial design*. London: Design Council.
- Shannon, C., 1948. *A mathematical theory of communication*. The Bell System Technical J. 27, 379-423 and 623-656.
- Shapiro, A., 2008. *Separating colour from colour contrast*. Journal of Vision, 8(1), article 8. Doi: 10.1167/8.1.8.
- Sinha, R., 2003. *Beyond Card sorting: Free-listing Methods to Explore User Categorizations*.
- Speranskaya, N. I., 1959. *Determination of spectrum color co-ordinates for twenty seven normal observers*. Optics and Spectroscopy 7, 424–428.
- Stickler, C., Ebner, M. and Holzinger, A., 2010. *The XAOS metric – Understanding visual complexity as a measure of usability*. In Proceedings of the 6th international conference on HCI in work and learning, life and leisure: workgroup human-computer interaction and usability engineering. Berlin: Springer-Verlag.
- Stiles, W. and Birch, J., 1958. N.P.L. *colour matching investigation: final report*. Optica Acta 6, 1–26.
- Stone, M., 2006. *Choosing colors for data visualization*. Retrieved from http://www.perceptualedge.com/articles/b-eye/choosing_colors.pdf
- Tannen, R., 2007. *Simplicity: The distribution of complexity*. Retrieved from http://www.boxesandarrows.com/view/simplicity-the
- Tawil, J., 2012. *Color theory*. Retrieved from http://www.gamonline.com/catalog/colortheory/language.php
- Transport for London. 2000. Design classics Introducing Harry Beck. London: Transport for London. Available from: http://www.tfl.gov.uk/assets/images/general/beckmap1.jpg [Accessed 17 February 2006].
- Tufte, E., 1997. *Visual Explanations: Images and Quantities, Evidence and Narrative*. Cheshire, CT: Graphics Press.

- University of Rochester (2005, October 26). *Color perception is not in the eye of the beholder: It's in the brain. Science Daily*. Retrieved from http://www.sciencedaily.com¬ / releases/2005/10/051026082313.htm
- Varley, H., 1983. *Colour*. second edition. London: Marshall Editions Limited.
- WebExhibits. , 2012. *Colortheory*. Retrieved from http://www.webexhibits.org/causesofcolor/1B.html
- Wroblewski, L., 2006. *The Complexity of Simplicity*. UXmatters. Available from: http://www.uxmatters.com/mt/archives/2006/12/the-complexity-of-simplicity.php [2 April 2010].
- Wodtke, M., 1993. *Mind Over Media; Creative Thinking Skills for Electronic Media*. USA:
- Zakia, R. D., 2002. *Perception and Imaging*. USA: Focal Press.
- Zeki, S. and Marini, L., 1998. *Three cortical stages of color processing in the human brain*. Brain, 121, 1669-1685.

Appendices

A

A sample of the preliminary study I questionnaire

Mobile phones Design Questionnaire

Ahmad Aloumi
PhD Candidate

Evaluator Background

Age ______ Sex (F) (M)
Occupation ______
Home Country ______

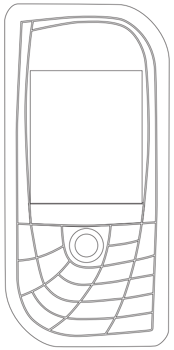
Are you a Designer? (Y) (N)
Are you exposed to design? (Y) (N)

Design Evaluation
Please fill in your responses to the following statements based on the Mobile designs you have reviewed.

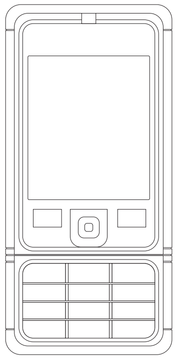
Your responses will be used in an academic research, knowing that your personal information will be anonymous.

Part One

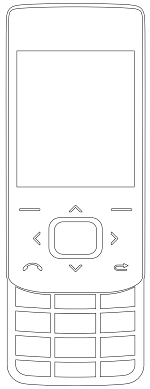
1



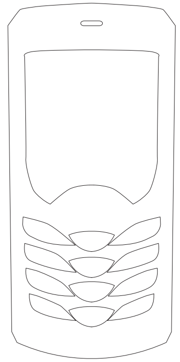
simple design ○—○—○—○—○ complex design



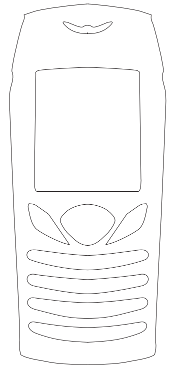
simple design ○—○—○—○—○ complex design



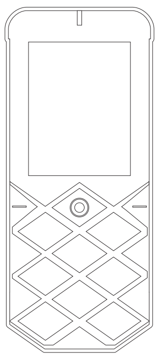
simple design ○—○—○—○—○ complex design



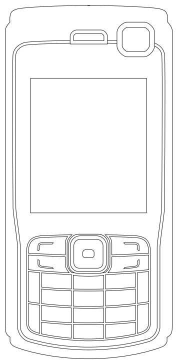
simple design ○—○—○—○—○ complex design



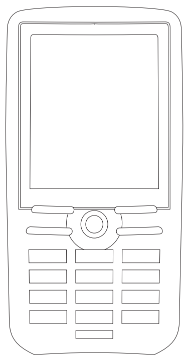
simple design ○—○—○—○—○ complex design



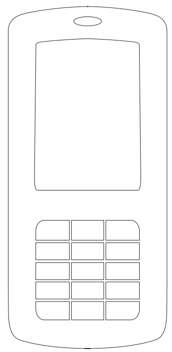
simple design ○—○—○—○—○ complex design



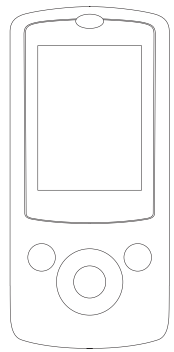
simple design ○—○—○—○—○ complex design



simple design ○—○—○—○—○ complex design



simple design ○—○—○—○—○ complex design

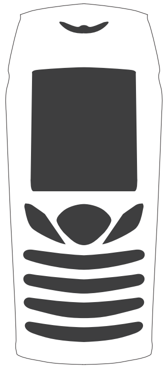


simple design ○—○—○—○—○ complex design

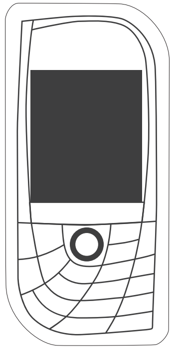
Mobile phones Design Questionnaire

Ahmad Aloumi
PhD Candidate

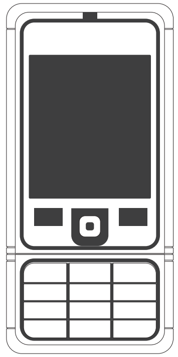
Part Two



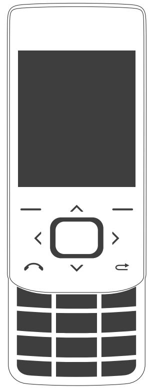
simple design ○—○—○—○—○ complex design



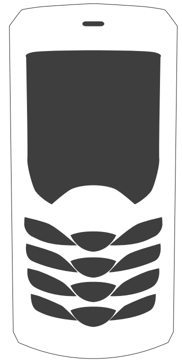
simple design ○—○—○—○—○ complex design



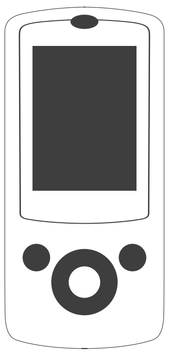
simple design ○—○—○—○—○ complex design



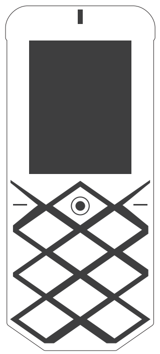
simple design ○—○—○—○—○ complex design



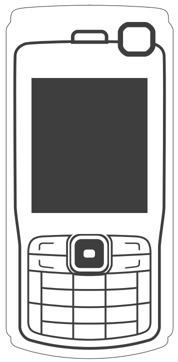
simple design ○—○—○—○—○ complex design



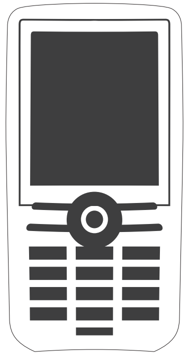
simple design ○—○—○—○—○ complex design



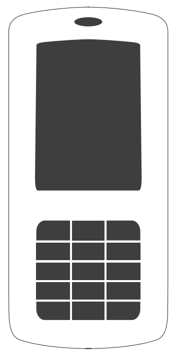
simple design ○—○—○—○—○ complex design



simple design ○—○—○—○—○ complex design



simple design ○—○—○—○—○ complex design

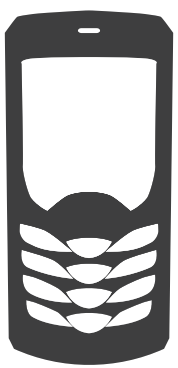


simple design ○—○—○—○—○ complex design

Mobile phones Design Questionnaire

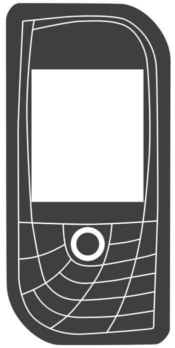
Ahmad Aloumi
PhD Candidate

Part Two **3**

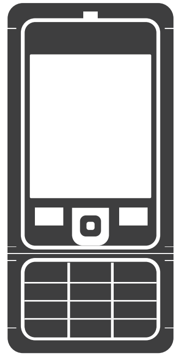


simple design ○—○—○—○—○ complex design

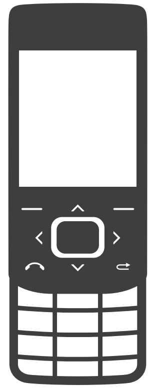
simple design ○—○—○—○—○ complex design



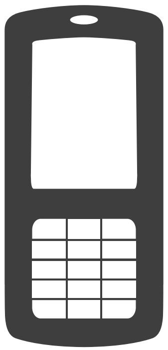
simple design ○—○—○—○—○ complex design



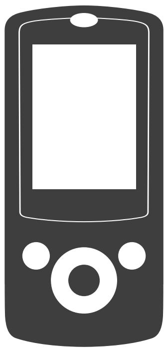
simple design ○—○—○—○—○ complex design



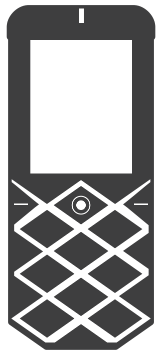
simple design ○—○—○—○—○ complex design



simple design ○—○—○—○—○ complex design

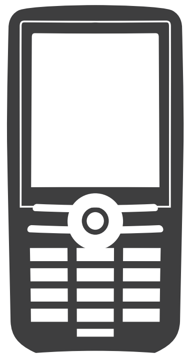


simple design ○—○—○—○—○ complex design



simple design ○—○—○—○—○ complex design

simple design ○—○—○—○—○ complex design



simple design ○—○—○—○—○ complex design

B

A full description of the study II questionnaire format

19 SEP 2010 | Ahmad Aloumi

Appendix B,

The Questionnaire Format

The Goals of the Questionnaire

- Check which colour contrast is the simplest and which is considered the most complex.
- Check whether the complex colour contrast has the power to make the simple design complex and increase the complexity of a complex design, and versa.
- Determine whether the colour contrast of the design require different amount of time to decide.

The questionnaire will be a web-based questionnaire in order to keep tracking of the time element. In addition, I will be around the applicants while they answering the questions.

Mutable stages will be created cover the aims and the goals of the research. Each stage helps define the answers of the research questions including which colour combination is simple and which is complex colour combination. The participant will be asked to answer all the questions while time is records.

The Focus group

Designers, design student
Male, Female
Educated
Kuwait & UK
Privet and Public school
Don't have a color vision problem
Understands the English language
Interested in design, visual arts, and communication
Knows how to operate a computer, mouse, and navigate through standard web sites

NOTE Before the applicants start the applicants, they will be reminded of what is needed to be answered, by saying: *simple design is not a design you like or don't like. The answers need to be based on the form and colour combination* (repeated the sentence three times or more).

Tracking the time and the duration needed to answer each question will be taking into a data file attached to each question asked of each participant. However, There will be two groups of participants. In group A they will be inform that they are tracking by time, while group B wont be informed; the time tracker will be invisible, but the data will be still collected.

Stages The questionnaire is divided into 5 stages. Each stage created to solve a problem or two, and formed differently.

19 SEP 2010 | Ahmad Aloumi

The Questionnaire Format

Stage 1 Personal Information

- *In this stage the participants will be asked some personal information to be insure that they fit into the selected focus group.*
- *Ethics code of practice. (a paragraph then, I accept. In order to start).*

"Your response will be used in an academic research and publications; however, they are anonymous and will be kept strictly combinational".

I Accept ☐

Age __ __ Sex M | F
Occupation ____________________________
What is your native language______________
Home Country ___________________________
Are you a Designer? Y | N
Do you have an educational degree? Y | N
If YES, from where?

Stage 2 Pretest Questions

- *In this stage, questions regarding the design background of the participants will be asked. These questions will help increase the depth of the research, and will create some extra understanding of the data collecting.*
- *Plus, this stage will define the colour vision of the participants.*

Are you colour-blind? Y | N
What would you call these colours? (list of the 6 colour swatch with space to write)
Do you have a favourite colour? Y | N
Please select your favourite colour. (6 colour swatch will be shown, radio button)
You have been asked to work with the colour BLUE, please pair it with a colour from the list. In order create a successful combination?
(6 colour swatch will be shown, radio button)
Why you paired Blue with _______? (Please leave a comment)

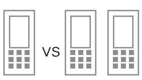
Stage 3 The Main Questionnaire Question.

- *In this stage the participants will be asked to rate* (radio button) *a cell phone design based on the different colour combination in relation to two different cell designs and colour combination selected randomly.*

This question will be repeated 30 times

- *These 30 times present the 10 colour combinations (Itten's) & 3 cell phones design selected from the pilot study, each one present different level of complexity.*
- *To avoid the sickness of the repetition, this stage will be divided to 3 units between each unit a question from stage 4 will come into use.*

Please fill in your responses to the following statements based on the Mobile designs you have reviewed.

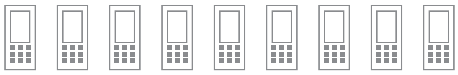


An assigned image, which present a selected colour combination will appear paired with 2 randomly selected different images.

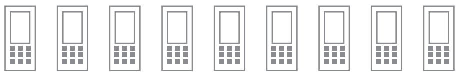
Stage 4 The Helper Stage

- *This stage created to serve two purposes, serve as a break for stage 3, and helps confirm the answers.*

Please select the simplest design from the rest. (a list from 9 different colour combinations with 6 different cell phone designs, radio button) this question will be repeated 2 times with 2 different set of images.



Please select the most complex design from the rest. (a list from 9 different colour combinations with 6 different cell phone designs, radio button) this question will be repeated 2 times with 2 different set of images.



(in total I will be creating 2 or 4 sets of images to be tested once to select the simplicity and other for the complexity).

Stage 5 Conformation and likeability

- *In this stage the participant is asked to answer a repeated question from Stage 2 but in different way.*

THE QUESTION IN STAGE 2

You have been asked to work with the colour BLUE, please pair it with a colour from the list. In order create a successful combination?

Please select a paired colour to work with the design shown.

(9 colour swatch will be shown, radio button)

Why you paired this colour with _______? (Please leave a comment)

Finally Thank you,

- *If you are willing to participate in further questionnaire in the field of Design Please leave your email.*

23 SEP 2010 | Ahmad Aloumi

Design & Colour Questionnaire

Instructions

- The questionnaire has multiple pages; each page consists of a question or more. You are required to answer each question before you hit NEXT button, leading you to the next page. This activity is voluntary and you can withdraw at any time.
- Your answers will be timed. You can answer as quickly or slowly as you want; it is only a way to keep track of your timing and your answers.
- Don't worry if you make a mistake; just move on. Using the back button on the browser will not get you back to the previous page, but it will corrupt the data and the questionnaire will reset itself.

  > Begin the questionnaire

- Before you start the questionnaire you have to be aware that your response will be used in an academic research and publications; however, they are anonymous and will be kept strictly confidential.

  > I Accept

Stage 1

1. Age __ __ Sex M | F
2. Occupation ____________________________
3. What is your native language______________
4. Home Country _________________________
5. Are you a Designer? Y | N
6. Do you have an educational degree? Y | N
7. If YES, from where?____________________

Stage 2

8. Are you colour-blind? Y | N
9. What would you call these colours? (list of the 6 colour swatch - space to write)
10. Do you have any favourite colour? Y | N
11. Please select your favourite colour from the list. (6 colour swatch will be shown)
12. Please pair the colour RED with another colour from the list to create a successful combination.
13. why do you think this is a successful colour combination?

Stage 3

14. Please fill in your responses to the following statements based on the mobile designs. to Q # 24..
24. Please select the simplest mobile design based on the based on the Colour. (setA)
25. Please select the simplest mobile design based on the based on the Colour. (setB)
26. Please select the simplest mobile design based on the based on the Colour. (setC)

27. Please fill in your responses to the following statements based on the mobile designs. to Q # 37
36. Please select the complexes mobile design based on the based on the Colour. (setA)
37. Please select the complexes mobile design based on the based on the Colour. (setB)
38. Please select the complexes mobile design based on the based on the Colour. (setC)

39 Please fill in your responses to the following statements based on the mobile designs. to Q # 49
48. Please select a paired colour to work with the design shown.

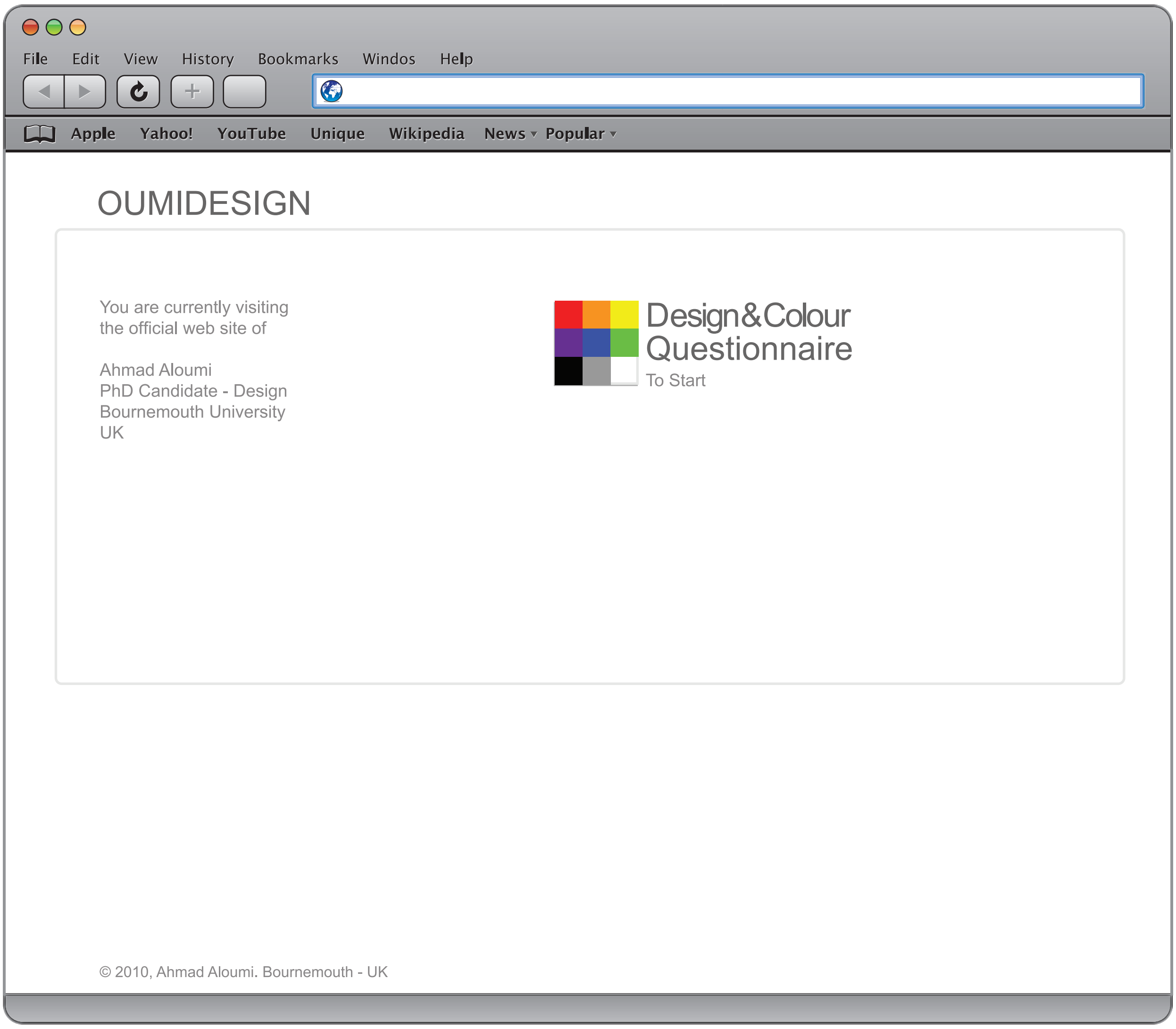
Thank you,

You are welcome to leave your email as long as you'd like or come back later to do more. Feel free to send the link to your friends so they can help too, but please do not collaborate on the same questionnaire session. We want to know your answers, not a consensus.

C

A screen shot of the online questionnaire for study II

Appendix C, secreen shoot of the online questionnaire.



OUMIDESIGN

You are currently visiting
the official web site of

Ahmad Aloumi
PhD Candidate - Design
Bournemouth University
UK

Design&Colour
Questionnaire
To Start

Design and Colour Questionnaire

Instructions

• The questionnaire has multiple pages; each page consists of a question or more. You are required to answer each question before you hit NEXT button, leading you to the next page. This activity is voluntary and you can withdraw at any time.

• Your answers will be timed. You can answer as quickly or slowly as you want; it is only a way to keep track of your timing and your answers.

• Don't worry if you make a mistake; just move on. Using the back button on the browser will not get you back to the previous page, but it will corrupt the data and the questionnaire will reset itself.

Begin the questionnaire

Next

Design and Colour Questionnaire

To Start

Before you start the questionnaire you have to be aware that your response will be used in an academic research and publications; however, they are anonymous and will be kept strictly confidential.

I Accept

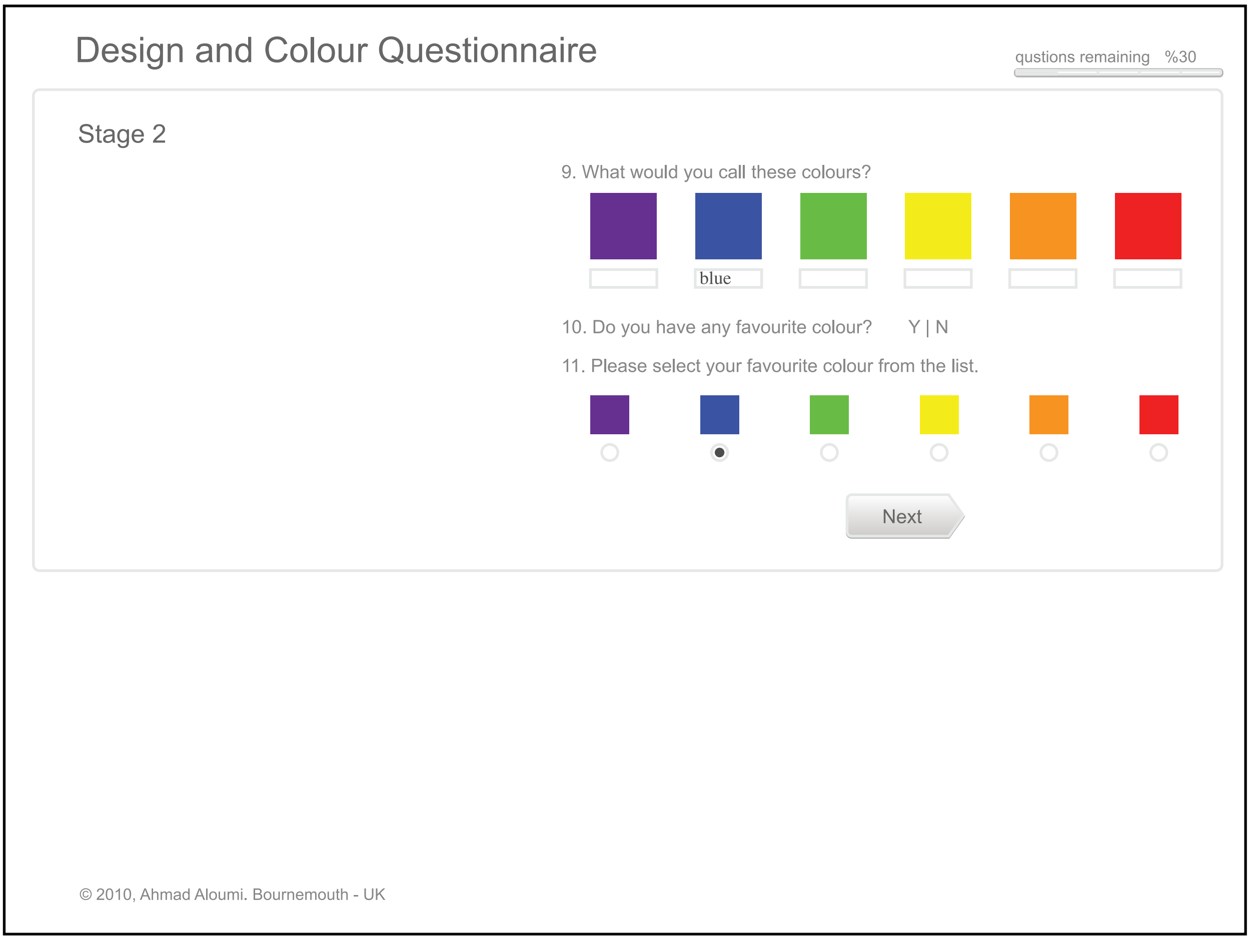
Design and Colour Questionnaire

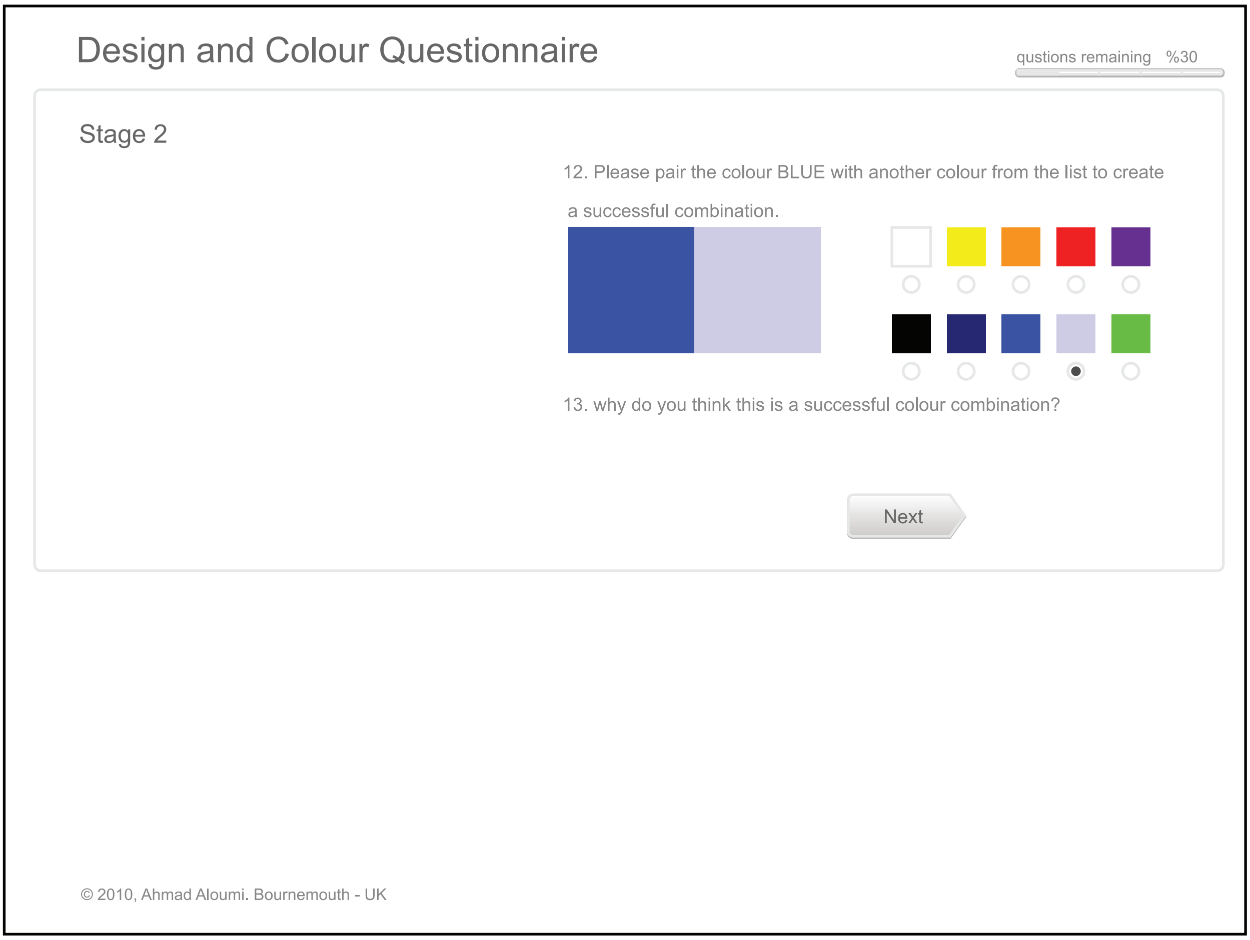
qustions remaining %30

Stage 1

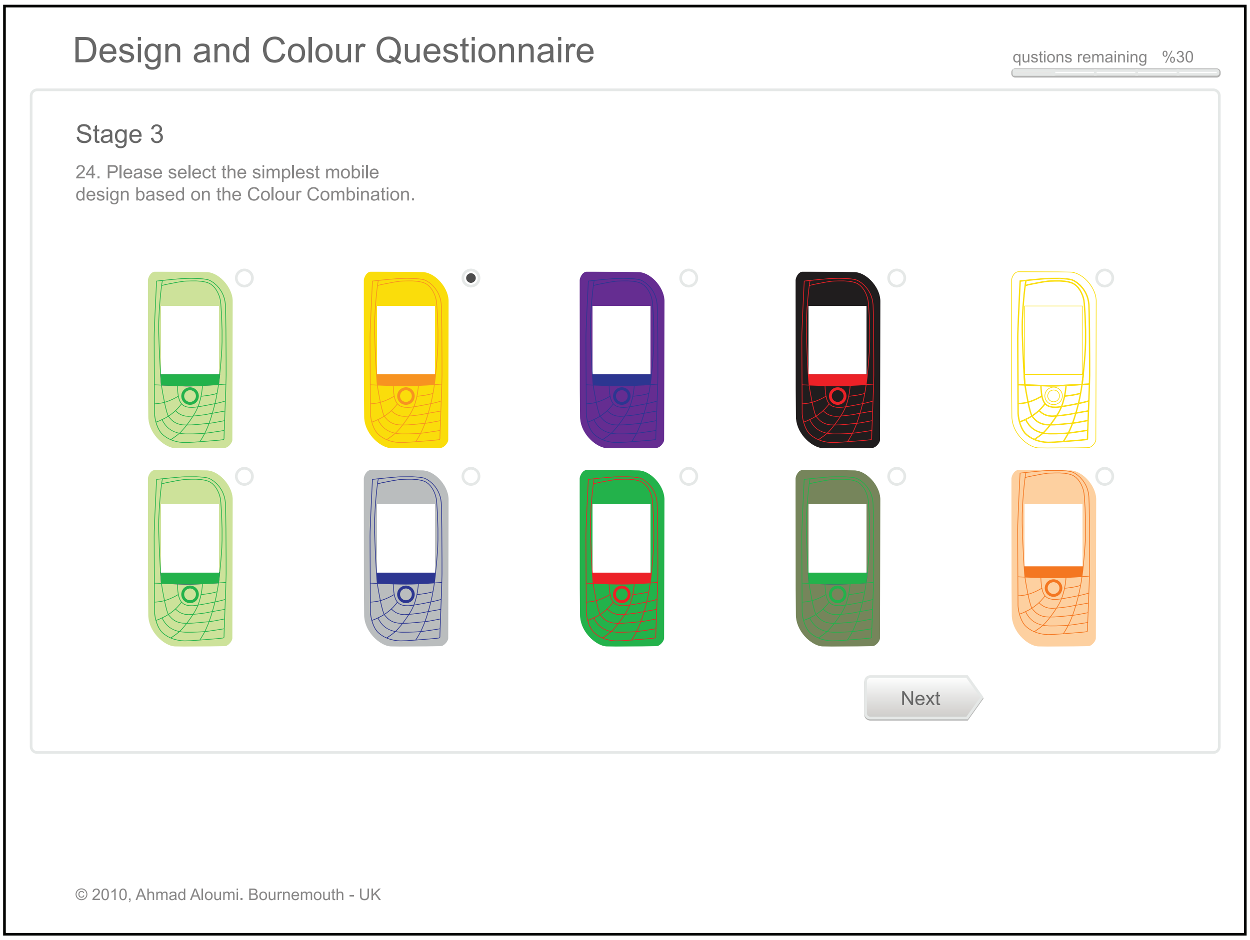
1. Age __ __ Sex M | F
2. Occupation ______________________________
3. What is your native language_______________
4. Home Country ___________________________
5. Are you a Designer? Y | N
6. Do you have an educational degree? Y | N
7. If YES, from where?______________________
8. Are you colour-blind? Y | N

Next


Design and Colour Questionnaire
qustions remaining %30
Stage 2
9. What would you call these colours?
blue
10. Do you have any favourite colour? Y | N
11. Please select your favourite colour from the list.
Next
© 2010, Ahmad Aloumi. Bournemouth - UK


Design and Colour Questionnaire
qustions remaining %30
Stage 2
12. Please pair the colour BLUE with another colour from the list to create
a successful combination.
13. why do you think this is a successful colour combination?
Next
© 2010, Ahmad Aloumi. Bournemouth - UK


Design and Colour Questionnaire
qustions remaining %30
Stage 3
14. Please fill in your responses to the following statements based on the mobile designs.
Simple Design
Complex Design
Next
© 2010, Ahmad Aloumi. Bournemouth - UK

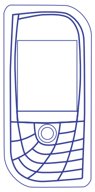

Design and Colour Questionnaire
qustions remaining %30
Stage 3
24. Please select the simplest mobile design based on the Colour Combination.
Next
© 2010, Ahmad Aloumi. Bournemouth - UK

Design and Colour Questionnaire

qustions remaining %30

Stage 3

48. Please select a paired colour
to work with the design shown.



Next

Design and Colour Questionnaire

Thank you,

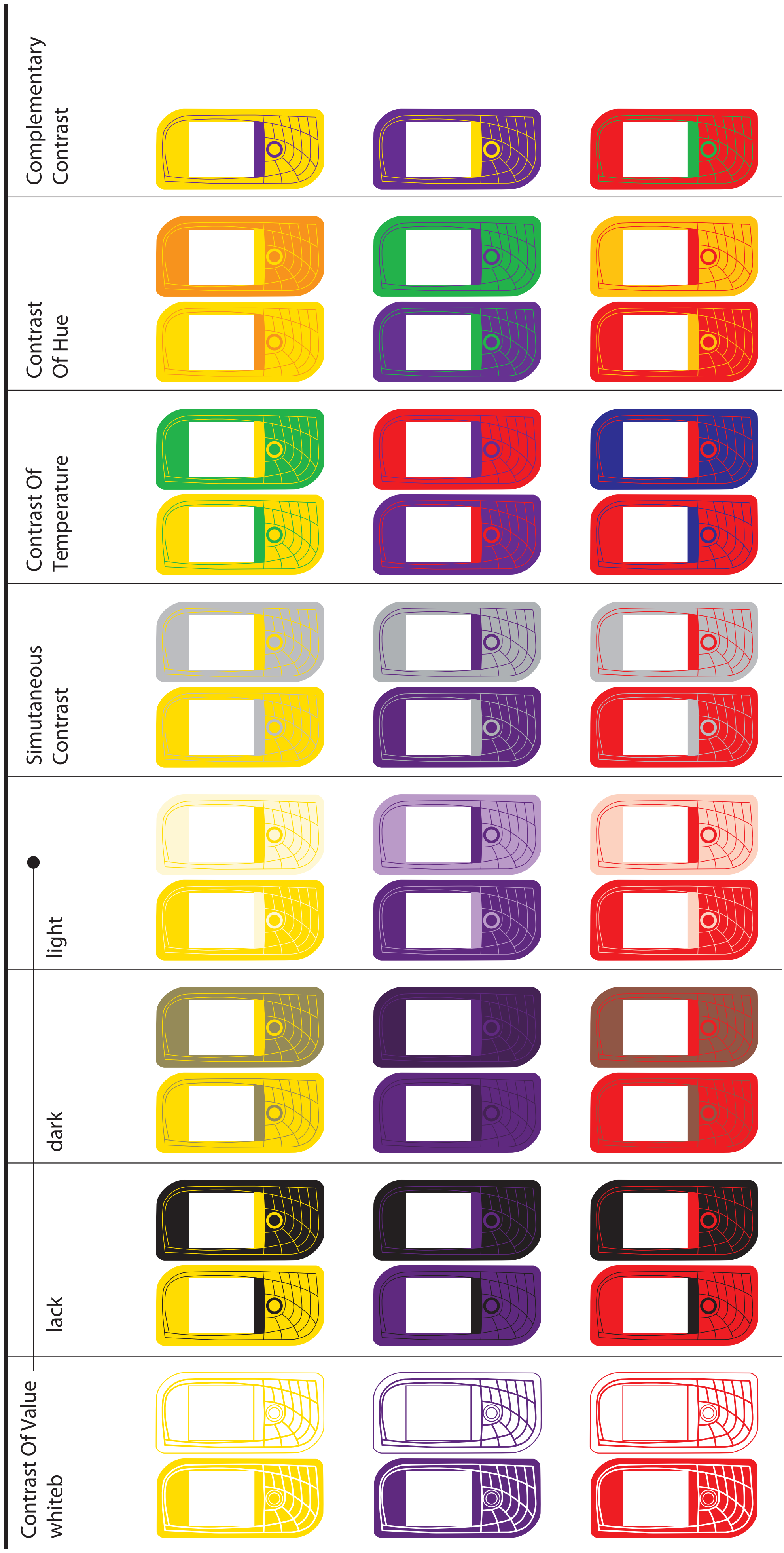
You are welcome to leave your email as long as you'd like
or come back later to do more.

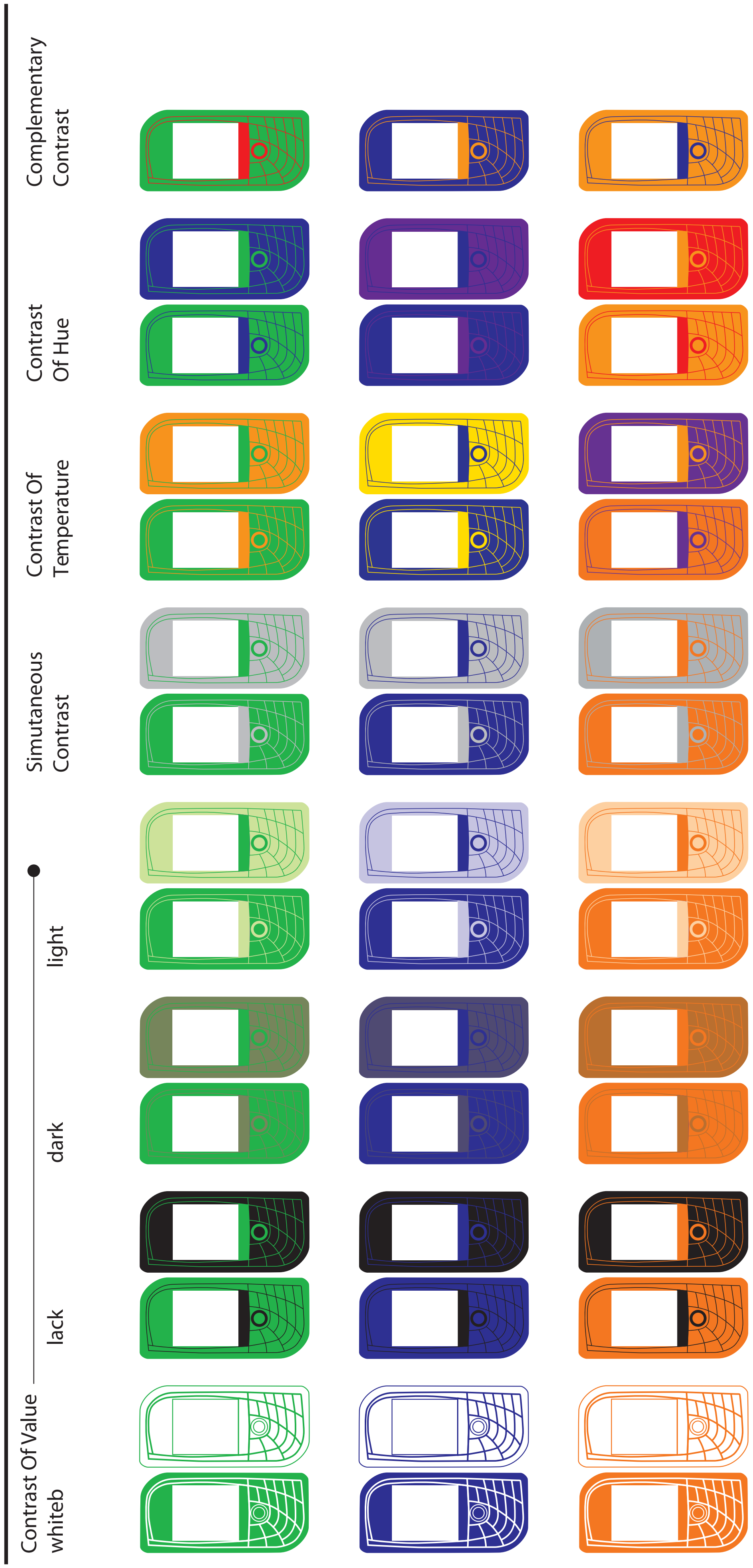
Feel free to send the link to your friends so they can help too,
but please do not collaborate on the same questionnaire session.
We want to know your answers, not a consensus.

Next

D

A large format version of the study III design application


Complementary Contrast
Contrast Of Hue
Contrast Of Temperature
Simutaneous Contrast
light
dark
lack
Contrast Of Value whiteb


Complementary
Contrast
Contrast
Of Hue
Contrast Of
Temperature
Simutaneous
Contrast
light
dark
lack
Contrast Of Value
whiteb

E

A screen shot of the online questionnaire for study III

OUMIDESIGN

Ahmad Aloumi
Bournemouth University
PhD Candidate - Design

Design&Colour Questionnaire

• This activity is voluntary and you can withdraw at any time.

• Don't worry if you make a mistake.

• Before you start the questionnaire, hide Edges (⌘ H) ,and hide bounding box (⇧⌘ B)

• Please be aware that your response will be used in an academic research and publications; however, they are anonymous and will be kept strictly confidential. By answering the questionnaire, you are accepting the terms and conditions of Bournemouth university.

Please sort the cell phones from simple to complex based on the mobile designs.

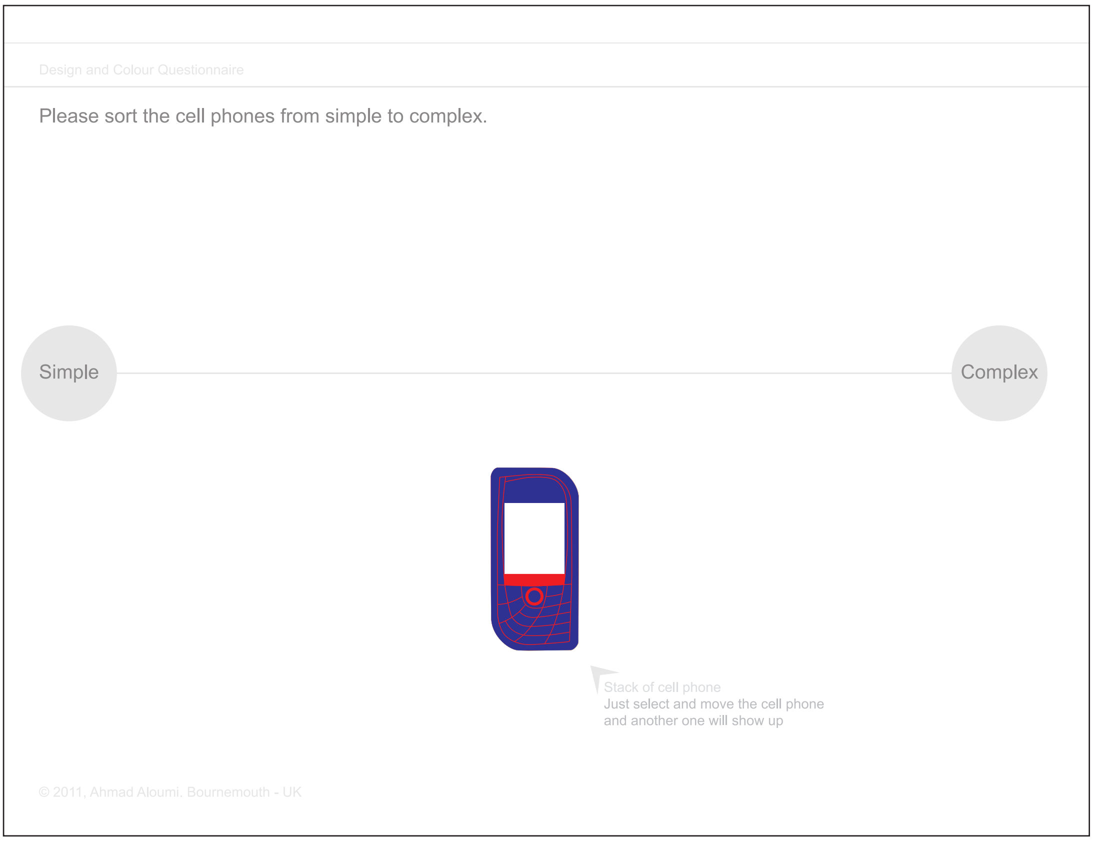
1. Age ☐ Sex ☐ M ☐ F
2. Home Country ☐
3. Do you understand English? ☐ Y ☐ N
4. Are you a Designer? ☐ Y ☐ N
5. Do you have design degree? ☐ Y ☐ N
6. Are you colour-blind? ☐ Y ☐ N

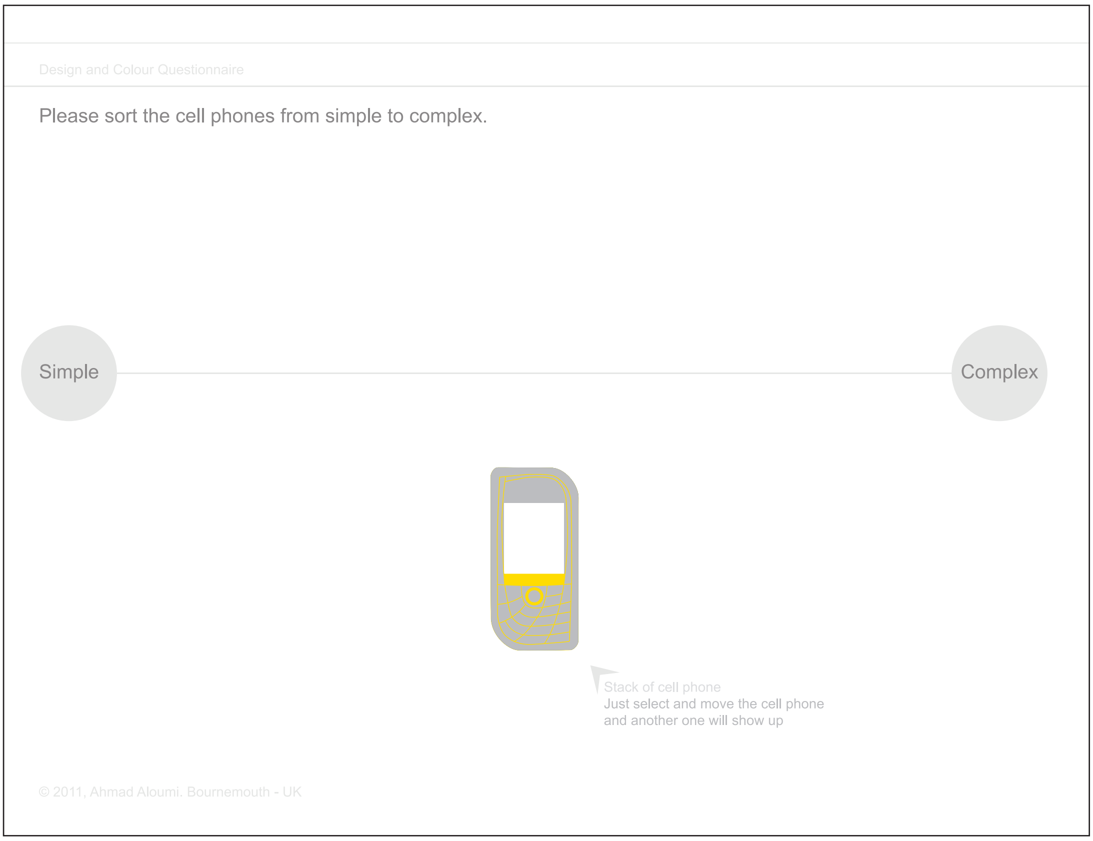
7. What would you call these colours?

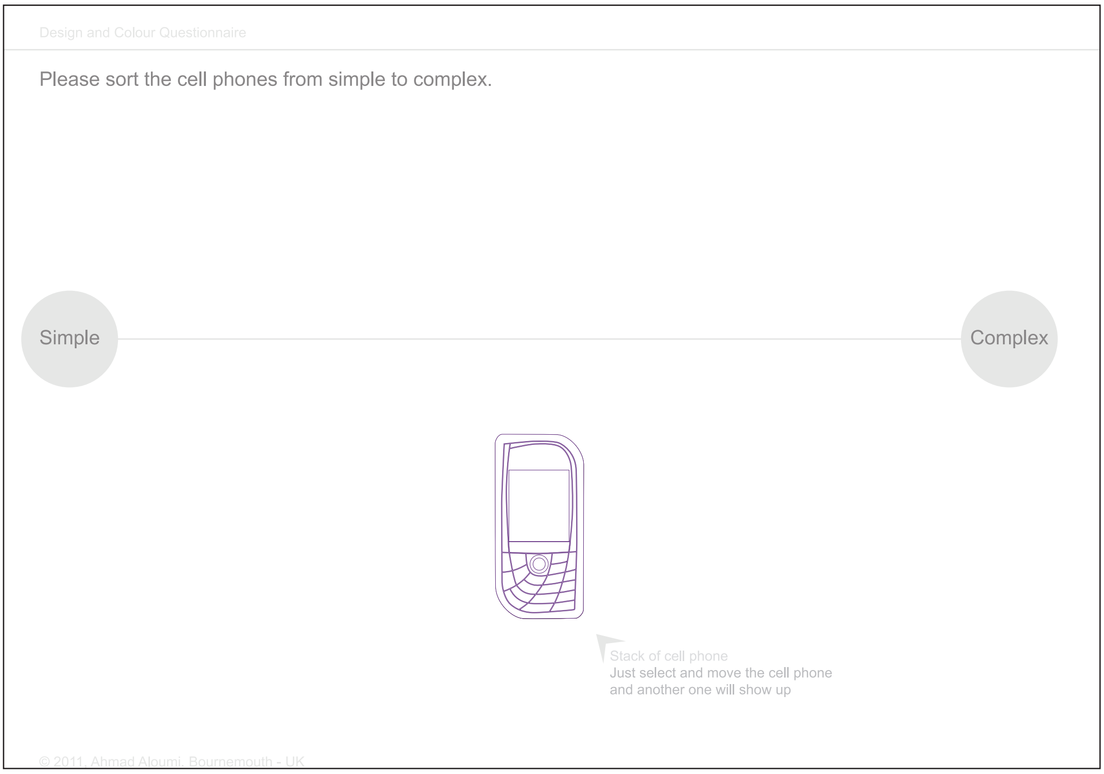
8. Do you have any favourite colour? ☐ Y ☐ N
9. Please select your favourite colour from the list.

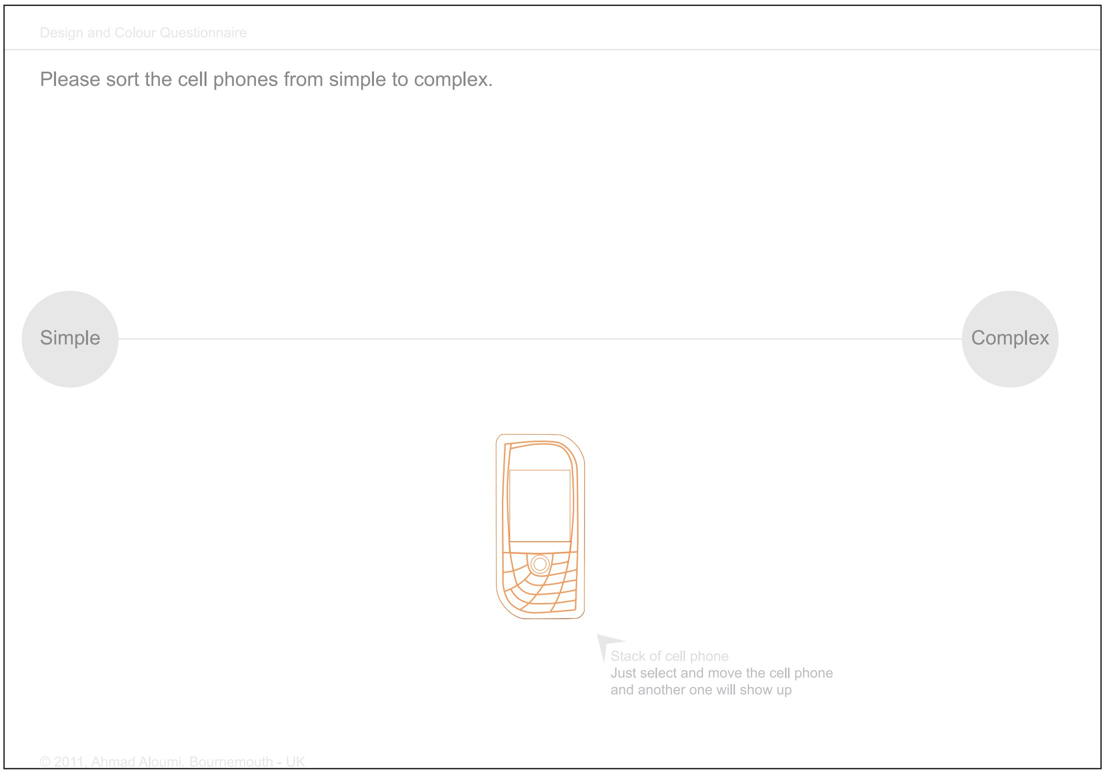

Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi. Bournemouth - UK

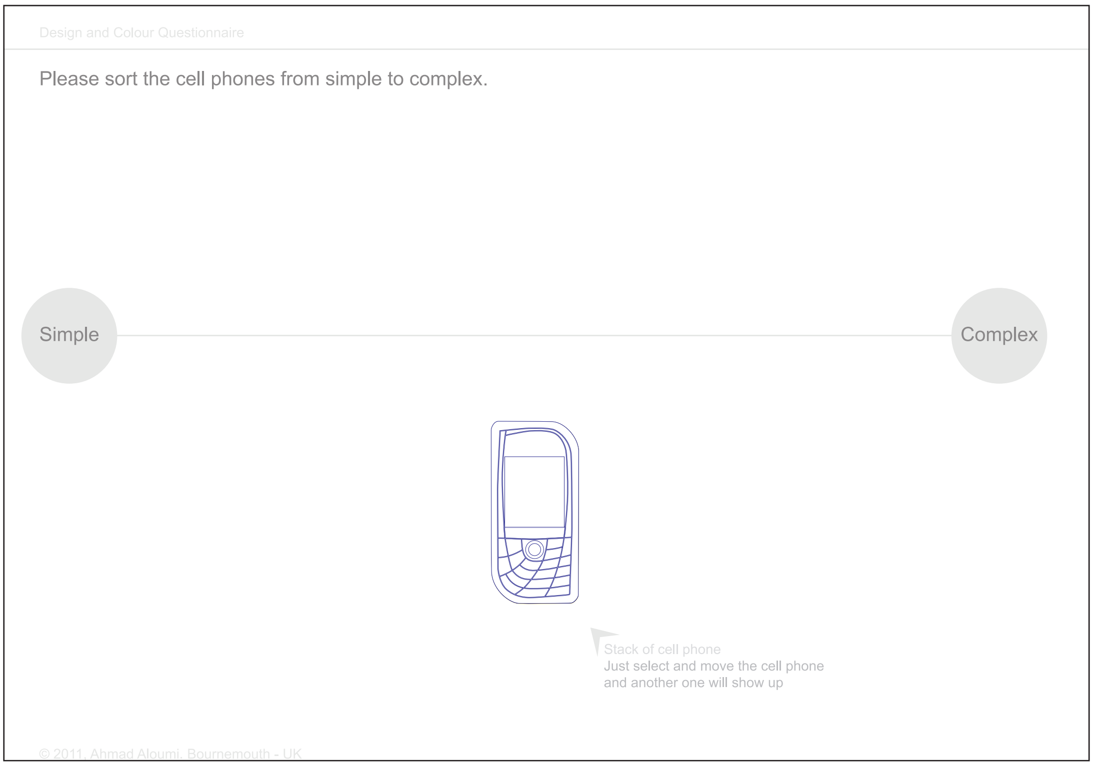

Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi. Bournemouth - UK

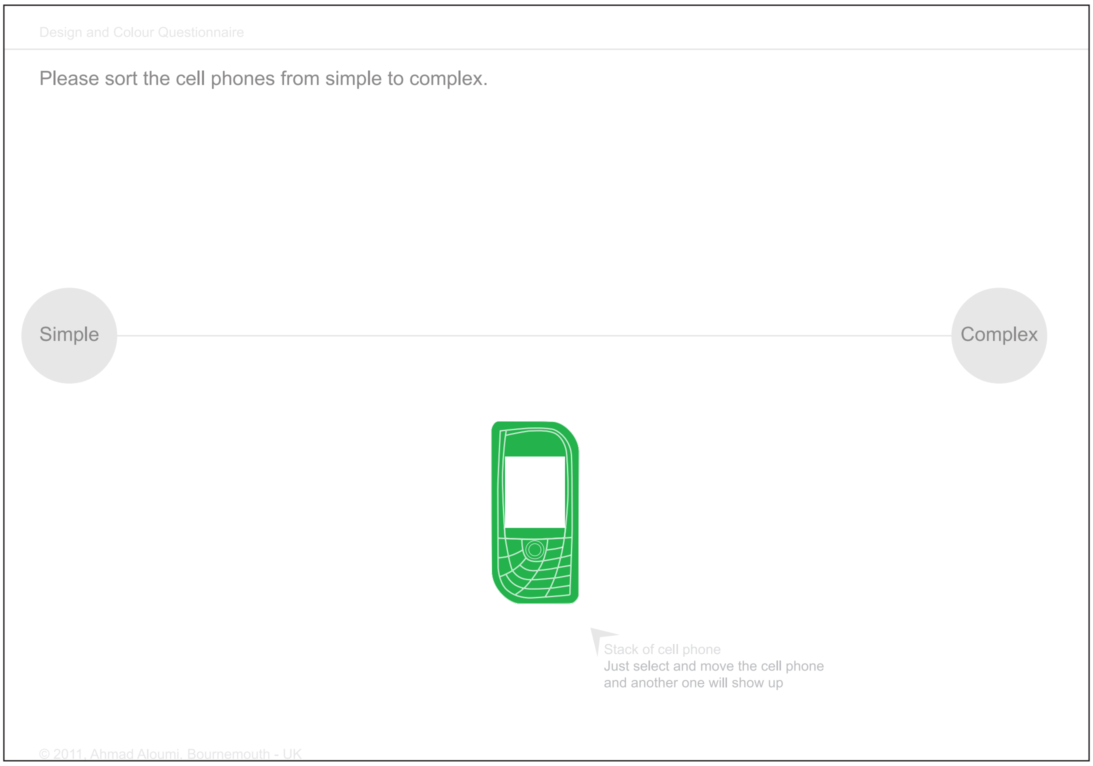

Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi, Bournemouth - UK

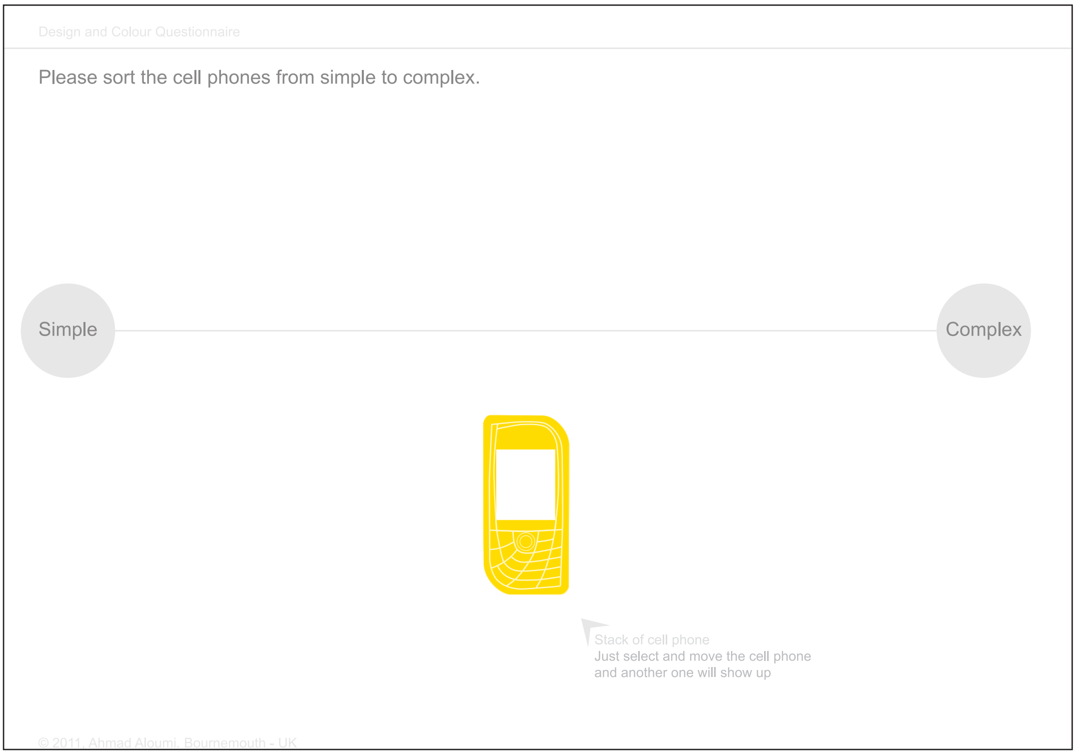

Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi, Bournemouth - UK

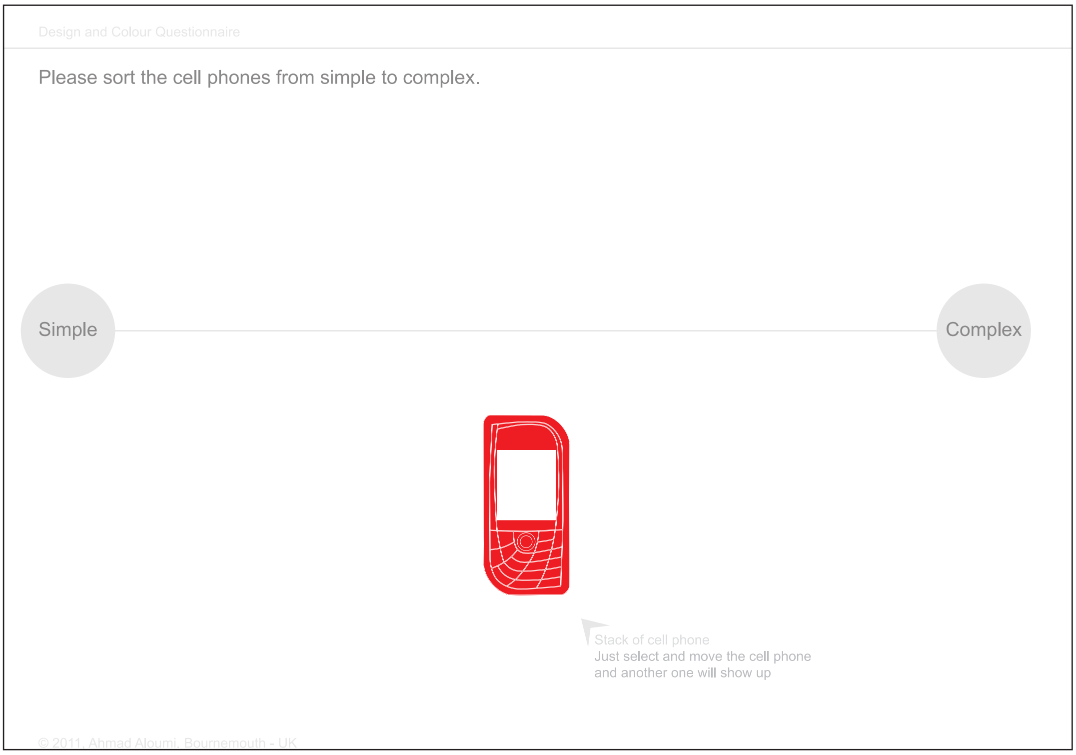

Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi, Bournemouth - UK

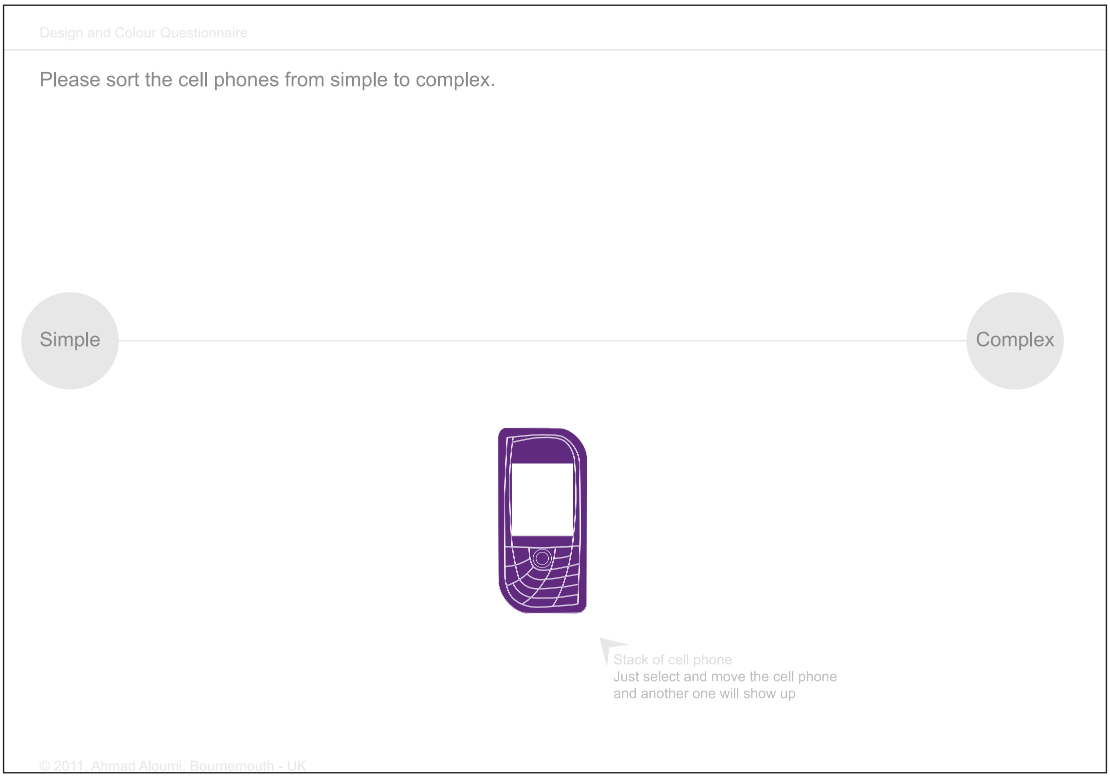

Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi, Bournemouth - UK

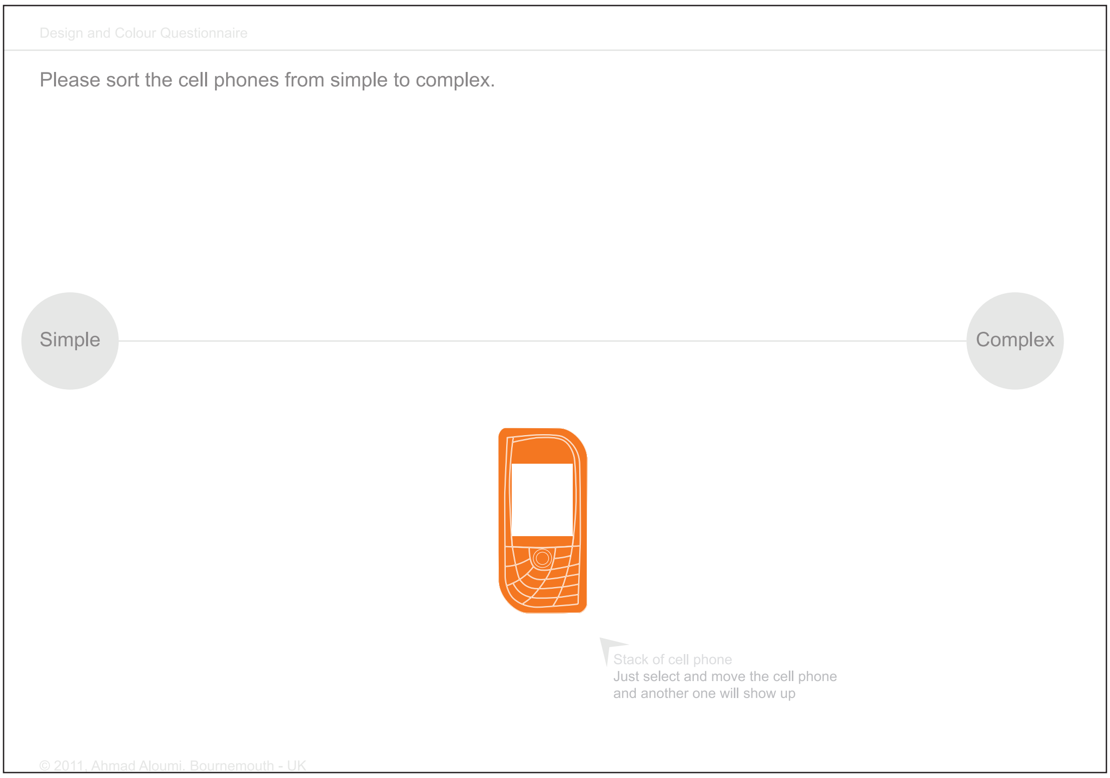

Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi, Bournemouth - UK


Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi, Bournemouth - UK


Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi, Bournemouth - UK


Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi, Bournemouth - UK


Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi, Bournemouth - UK


Design and Colour Questionnaire
Please sort the cell phones from simple to complex.
Simple
Complex
Stack of cell phone
Just select and move the cell phone
and another one will show up
© 2011, Ahmad Aloumi, Bournemouth - UK

Thank you,

• Please save the file and re-email it to me back.

• Feel free to send the link to your friends so they can help too, but please do not collaborate on the same questionnaire session. We want to know your answers, not a consensus.

F

A detailed report of the preliminary study II results

Data Report 20 Nov 10
Pilot Study II Ahmad Aloumi

Intro

Viewers are surrounded by visual stimuli on a daily basis. People do so many assumptions in a second, when they see a design solution. Am I interested or not? What it means? How it works? How well is it designed? These design solutions, which may have intriguing and/or exciting qualities, enable the current designers to deliver effective design solutions that could have heightened impact.
Design is a creative process that combines art and technology to communicate ideas. The designer works with a variety of communication tools; form, shape, texture, tone, weight, colour, and balance.

General Information

Table (1) Descriptive Statistics of the Age in years.

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Age of respondent	74	18	50	24.03	6.007
Valid N (listwise)	74				

The Average age of the respondents is around 24 years, with minimum age 18 years and maximum age 50 years.

Figure(1) The Distribution of the Age
As shown the distribution is skewed to right which implies that the majority of the sample were younger age.

Gender

Gender Gender of the respondent

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
1	Male	25	1.1	33.8	33.8
2	Female	49	2.2	66.2	100.0
	Total	74	3.4	100.0	

Regarding gender, 33.8% were male respondents, while 66.2% were females.

Language

Language Language

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
1	Arabic	59	2.7	80.9	79.5
2	Spanish	1	.0	1.4	80.8
3	English	9	.4	12.3	93.2
4	Farsi	2	.1	2.7	95.9
5	Romania	1	.0	1.4	98.6
6	Espa	1	.0	1.4	100.0
	Total	73	3.3	100.0	

80.9% of the respondents are Arabic speakers 12.3% are English speakers, 2.7% are Farsi, 1.4% are Spanish, 1.4% are both Arabic and English, 1.4% are Romanian, 1.4% are Espa.

Colour Blindness

Colour_Blind If the respondent is colour blind

		Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
1	Yes	2	.1	2.7	2.7
2	No	72	3.3	97.3	100.0
	Total	74	3.4	100.0	

Percentage of colour blind in the sample was2.7% and the remaining 97.3% don't have this problem Regarding the profession, 86.5% claims that they are designers, 13.5% are not.

Occupation

Table(2) The frequency Distribution of the Occupation

		Frequency	Percent	Valid Percent	Cumulative Percent
1	Student	54	2.4	79.5	77.9
2	Developer	1	.0	1.5	79.4
3	Designer	5	.1	7.5	82.4
12	Marketing Officer	1	.0	1.5	100.0
14	Faculty member	7	.0	10	97.1
	Total	68	3.1	100.0	

As shown in Table(2), 79.5% of the respondent were students, 7.5% were designers, 10% were Faculty members, and the rest are different other jobs related to designers.

Country

Country Country

		Frequency	Percent	Valid Percent	Cumulative Percent
1	Kuwait	61	2.8	83.6	83.6
2	Egypt	3	.1	4.1	87.7
3	Honduras	2	.1	2.7	90.4
4	England	1	.0	1.4	91.8
5	Jordan	1	.0	1.4	93.2
6	Iran	1	.0	1.4	94.5
7	Lebanon	1	.0	1.4	95.9
8	USA	1	.0	1.4	97.3
9	Qatar	1	.0	1.4	98.6
10	Romania	1	.0	1.4	100.0
	Total	73	3.3	100.0	

Regarding the country of origin, 83.6% are Kuwaitis 4.1% are Egyptians, 2.7% are Honduras, 1.4% are English, 1.4% are Jordanian, 1.4% are Iranian, 1.4% are Lebanese, 1.4% are Qataris, 1.4% are USA, 1.4% are Romanian.

Designer

Designer Designer

		Frequency	Percent	Valid Percent	Cumulative Percent
1	Yes	64	2.9	86.5	86.5
2	No	10	.5	13.5	100.0
	Total	74	3.4	100.0	

Regarding the profession, 86.5% claims that they are designers, 13.5% are not.

Degree

Degree

		Frequency	Percent	Valid Percent	Cumulative Percent
1	Yes	40	1.8	54.1	54.1
2	No	34	1.6	45.9	100.0
	Total	74	3.4	100.0	

54.1% of the respondents hold a degree, while 45.9% don't.

Degree Sourse

_Degree Country from which degree taken

		Frequency	Percent	Valid Percent	Cumulative Percent
1	Kuwait, CFW	8	.1	4.2	4.2
2	Kuwait, BHC	1	.0	1.4	63.9
3	Kuwait, AUK	17	.8	23.6	87.5
4	USA, RIT	3	.0	1.4	8.3
5	USA, USF	1	.0	1.4	12.5
6	USA, OHIO	1	.0	1.4	93.1
7	UK	1	.0	1.4	13.9
8	Egypt	2	.1	2.8	6.9
9	Iran	1	.0	1.4	88.9
10	Lebanon,AUL	1	.0	1.4	90.3
11	Auburn University	1	.0	1.4	91.7
12	Not Applicable	34	1.6	47.2	62.5
	Total	72	3.3	100.0	

Favorite Colour

Do you have any favorite colour

		Frequency	Percent	Valid Percent	Cumulative Percent
1	Yes	63	2.9	85.1	85.1
2	No	11	.5	14.9	100.0
	Total	74	3.4	100.0	

85.1% claimed that they have favorite colour, while 14.9% have no favorite colour.

favorite colour from the list

		Frequency	Percent	Valid Percent	Cumulative Percent
1	Violet	29	1.3	39.2	39.2
2	BLUE	14	.6	18.9	58.1
3	GREEN	6	.3	8.1	66.2
4	YELLOW	7	.3	9.5	75.7
5	ORANGE	6	.3	8.1	83.8
6	RED	12	.5	16.2	100.0
	Total	74	3.4	100.0	

39.2% chose Violet as their favorite colour, 18.9 chose the blue as their favorite colour, 18.9% chose green as their favorite colour, 9.5% chose yellow as their favorite colour, 8.1% chose orange as their favorite colour, and 16.2% chose red as their favorite colour.

Pairing colour with Blue

	Frequency	Percent	Valid Percent	Cumulative Percent
1 Violet	2	.1	2.7	2.7
2 BLUE	1	.0	1.4	4.1
3 GREEN	2	.1	2.7	6.8
4 YELLOW	13	.6	17.6	24.3
5 ORANGE	26	1.2	35.1	59.5
6 RED	7	.3	9.5	68.9
8 GREY	9	.4	12.2	81.1
9 BLACK	3	.1	4.1	85.1
10 Dark Blue	6	.3	8.1	93.2
11 WHITE	5	.2	6.8	100.0
Total	74	3.4	100.0	

Pair favorite colour came out as follows, 2.7% chose Violet, 1.4% chose, blue, 2.7% chose green, 17.6% chose yellow, 35.1% chose orange, 9.5% chose red, 12.2% chose gray, 4.1% chose black, 8.1% chose dark blue, and 6.8% chose white .

Colour Information

Violet

what would you call these colours

		Frequency	Percent	Valid Percent	Cumulative Percent
1	check	61	2.8	83.6	83.6
2	violet	10	.5	13.7	97.3
3	Mauve	1	.0	1.4	98.6
4	purple/violet	1	.0	1.4	100.0
	Total	73	3.3	100.0	

Regarding colour identification, 83.6% identified the Violet colour correctly, 13.7% identified the purple colour as violet, 1.7% identified the purple colour as Mauve colour and 1.4% identified the colour as either purple or violet.

Blue

what would you call these colours

	Frequency	Percent	Valid Percent	Cumulative Percent
Blue	69	3.2	94.5	94.5
Royal Blue	2	.1	2.7	97.3
Pepsi Blue	1	.0	1.4	98.6
Navy Blue	1	.0	1.4	100.0
Total	73	3.3	100.0	

94.5% identified the blue colour correctly, while 2.7% identified the blue as royal blue, 1.4% identified the blue colour as Pepsi blue, and 1.4% identified the blue colour as navy blue.

Green

what would you call these colours

		Frequency	Percent	Valid Percent	Cumulative Percent
1	Green	62	2.8	84.9	84.9
2	Light Green	3	.1	4.1	89.0
3	Lime Green	6	.3	8.2	97.3
4	Bright Green	1	.0	1.4	98.6
5	Neon Green	1	.0	1.4	100.0
	Total	73	3.3	100.0	

84.9% of the respondents identified the green colour correctly, while 4.1% identified the colour as light green, 8.2% have identified the green colour as lime green, 1.4% identified the green colour as bright green, and 1.4% identified the green colour as neon green.

Yellow

what would you call these colours

		Frequency	Percent	Valid Percent	Cumulative Percent
1	Yellow	72	3.3	98.6	98.6
2	Bright Yellow	1	.0	1.4	100.0
	Total	73	3.3	100.0	

98.6% have identified the yellow colour correctly, while 1.4% of respondents have identified the yellow colour as bright yellow.

Orange

what would you call these colours

		Frequency	Percent	Valid Percent	Cumulative Percent
1	Orange	70	3.2	95.9	95.9
3	ORANGE with a tint o	1	.0	1.4	97.3
4	Yellow- Orange	1	.0	1.4	98.6
5	Buff	1	.0	1.4	100.0
	Total	73	3.3	100.0	

95.9% of the respondents have identified the orange colour correctly, 1.4% have identified the colour as orange with a tint, 1.4% have identified the orange colour as yellow /orange, and 1.4 % have identified the orange colour as buff.

Red

what would you call these colours

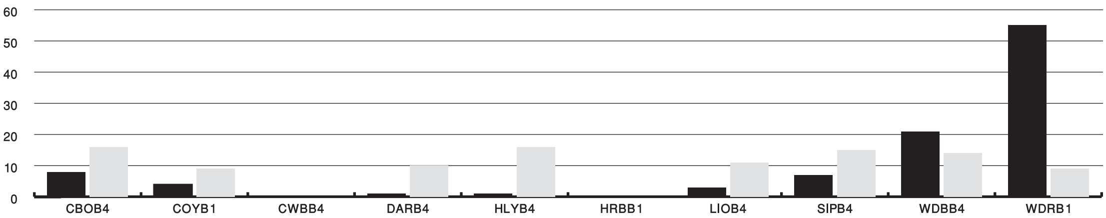
		Frequency	Percent	Valid Percent	Cumulative Percent
1	Red	71	3.3	97.3	97.3
2	Bright Red	1	.0	1.4	98.6
3	Red-Orange	1	.0	1.4	100.0
	Total	73	3.3	100.0	

97.3% have identified the red colour, while 1.4% have identified the colour as bright red, and 1.4% have identified the red colour as red/orange.

Simple Design vs Colour Combination

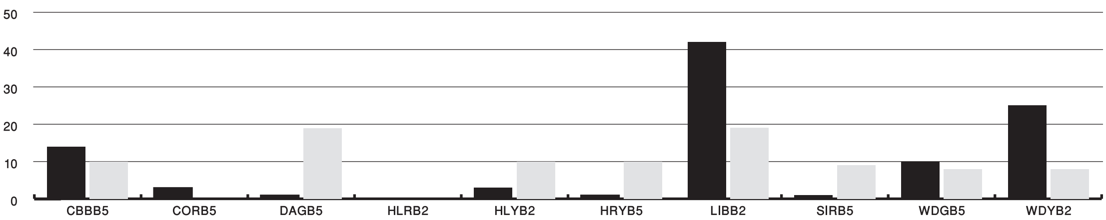
Set A

	Frequency	percent	Mean Time	Percent	Minimum	Maximum
CBOB4	6	8%	33.45	16%	18.90	42.70
COYB1	3	4%	18.20	9%	14.20	20.60
CWBB4	-	-	-	-		
DARB4	1	1%	19.40	10%	19.40	19.40
HLYB4	1	1%	31.80	16%	31.80	31.80
HRBB1	-	-	-	-		
LIOB4	2	3%	22.10	11%	21.50	22.70
SIPB4	5	7%	30.52	15%	8.00	65.70
WDBB4	15	21%	28.91	14%	13.20	77.40
WDRB1	40	55%	19.06	9%	8.00	54.40
Total	*73*	*100%*	*203.437*	*100%*	*135.000*	*334.70*



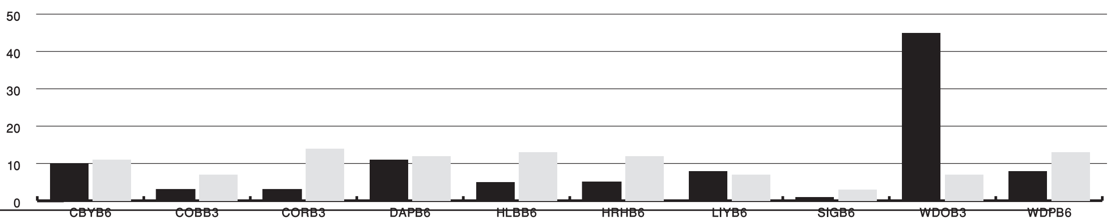
Set B

	Frequency	percent	Mean Time	Percent	Minimum	Maximum
CBBB5	10	14%	17.35	10%	10.10	27.30
CORB5	2	3%	13.15	8%	5.80	20.50
DAGB5	1	1%	31.90	19%	31.90	31.90
HLRB2	-	-		-		
HLYB2	2	3%	16.80	10%	15.40	18.20
HRYB5	1	1%	16.40	10%	16.40	16.40
LIBB2	31	42%	33.45	19%	33.45	33.45
SIRB5	1	1%	15.00	9%	15.00	15.00
WDGB5	7	10%	13.96	8%	9.60	21.30
WDYB2	18	25%	13.58	8%	7.80	27.50
Total	*73*	*100%*	*171.59*	*100%*	*145.45*	*211.55*



Set C

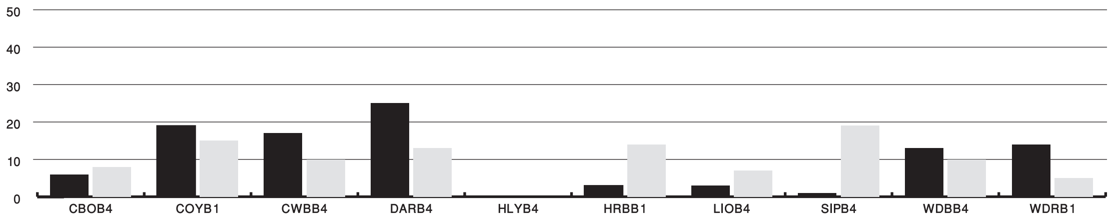
	Frequency	percent	Mean Time	Percent	Minimum	Maximum
CBYB6	7	10%	16.53	11%	6.20	46.50
COBB3	2	3%	10.50	7%	10.10	10.90
CORB3	2	3%	20.95	14%	16.50	25.40
DAPB6	8	11%	17.44	12%	7.80	31.10
HLBB6	4	5%	19.28	13%	11.20	29.20
HRHB6	4	5%	17.25	12%	10.60	28.40
LIYB6	6	8%	10.13	7%	3.80	16.10
SIGB6	1	1%	3.90	3%	3.90	3.90
WDOB3	33	45%	10.90	7%	4.00	23.50
WDPB6	6	8%	19.12	13%	9.60	35.50
Total	*73*	*100%*	*146.00*	*100%*	*83.70*	*250.50*



Complex Design vs Colour Combination

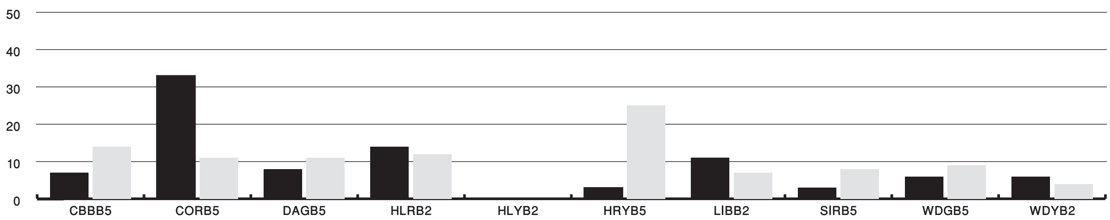
Set A

	Frequency	percent	Mean Time	Percent	Minimum	Maximum
CBOB4	4	6%	14.58	8%	7.80	20.80
COYB1	14	19%	25.76	15%	9.00	167.00
CWBB4	12	17%	16.73	10%	5.30	29.20
DARB4	18	25%	22.14	13%	9.00	60.00
HLYB4	-	-		-		
HRBB1	2	3%	23.45	14%	17.10	29.80
LIOB4	2	3%	11.35	7%	6.40	16.30
SIPB4	1	1%	32.60	19%	32.60	32.60
WDBB4	9	13%	16.78	10%	8.00	50.20
WDRB1	10	14%	9.10	5%	3.90	21.30
Total	*72*	*100%*	*172.47*	*100%*	*99.10*	*427.20*



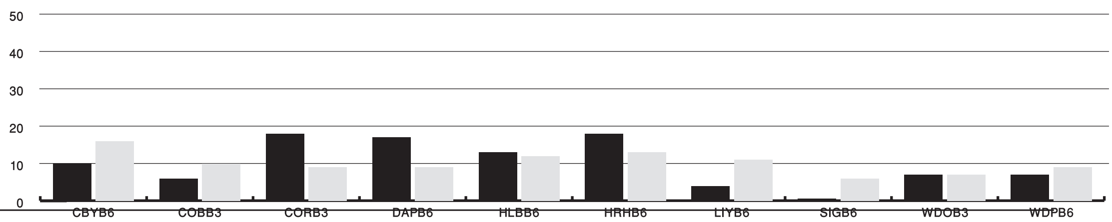
Set B

	Frequency	percent	Mean Time	Percent	Minimum	Maximum
CBBB5	5	7%	17.18	14%	6.50	24.20
CORB5	24	33%	13.18	11%	2.30	31.20
DAGB5	6	8%	13.42	11%	6.60	19.30
HLRB2	17	24%	14.07	12%	4.00	82.80
HLYB2	-	-	-		-	-
HRYB5	2	3%	29.90	25%	25.00	34.80
LIBB2	8	11%	8.10	7%	3.00	14.80
SIRB5	2	3%	9.45	8%	7.70	11.20
WDGB5	4	6%	11.15	9%	7.70	16.40
WDYB2	4	6%	4.30	4%	3.30	5.60
Total	72	100%	120.74	100%	66.10	240.30



Set C

	Frequency	percent	Mean Time	Percent	Minimum	Maximum
CBYB6	7	10%	19.13	16%	6.00	68.20
COBB3	4	6%	11.45	10%	4.30	18.90
CORB3	13	18%	10.18	9%	5.00	18.50
DAPB6	12	17%	11.17	9%	6.10	17.80
HLBB6	9	13%	13.64	12%	5.90	17.40
HRHB6	13	18%	14.98	13%	3.70	39.00
LIYB6	3	4%	12.43	11%	8.40	20.20
SIGB6	1	1%	7.20	6%	7.20	7.20
WDOB3	5	7%	7.94	7%	3.10	15.80
WDPB6	5	7%	10.18	9%	5.00	22.70
Total	*72*	*100%*	*118.30*	*100%*	*54.70*	*245.70*



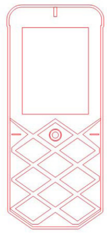
The table shows the different in time needed to make a decision
between Simple & Complex colour complication.

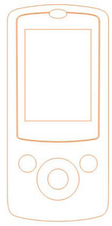
	simple Design	*Complex Design*	*diffence*	*Percent*
group A	25.430	19.164	6.266	25%
group B	19.065	13.416	5.649	30%
group C	14.600	11.830	2.770	19%
Total	*19.698*	*14.803*		*24%*

The participant took 24% move time to identify the simple design or colour combination than finding the most complex. However, they were more focus in finding the simplest that finding the complex design which means that people having difficulty fine the most complex design, and that could mean that they could be satisfied with the simpler designs.

The most simple design with the colour combination are:

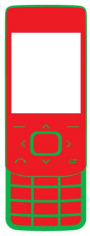
WDRB1 LIBB2 WDOB3

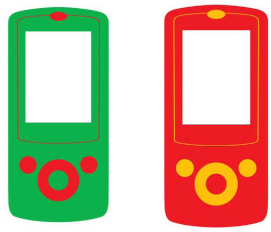




The most complex design with the colour combination are:

DARB4 CORB5 CORB3 & HRRB6





	Answer	1	2	3	4	5	Total
1 CBBA1	Count	7	10	21	21	15	74
	% within Picture	9.50%	13.50%	28.40%	28.40%	20.30%	
100.00%							
	% within Answer	1.70%	1.70%	3.50%	5.10%	7.60%	3.40%
	% of Total	0.30%	0.50%	1.00%	1.00%	0.70%	3.40%
	weight average	0.095	0.27	0.852	1.136	1.015	3.368
2 CBBA2	Count	7	24	19	22	2	74.000
	% within Picture	9.50%	32.40%	25.70%	29.70%	2.70%	1.000
	% within Answer	1.70%	4.20%	3.20%	5.40%	1.00%	0.034
	% of Total	0.30%	1.10%	0.90%	1.00%	0.10%	0.034
	weight average	0.095	0.648	0.771	1.188	0.135	2.837
3 CBBA3	Count	22	17	19	13	3	74.000
	% within Picture	29.70%	23.00%	25.70%	17.60%	4.10%	1.000
	% within Answer	5.40%	3.00%	3.20%	3.20%	1.50%	0.034
	% of Total	1.00%	0.80%	0.90%	0.60%	0.10%	0.034
	weight average	0.297	0.46	0.771	0.704	0.205	2.437
4 COBA1	Count	4	12	28	17	13	74.000
	% within Picture	5.40%	16.20%	37.80%	23.00%	17.60%	1.000
	% within Answer	1.00%	2.10%	4.70%	4.20%	6.60%	0.034
	% of Total	0.20%	0.50%	1.30%	0.80%	0.60%	0.034
	weight average	0.054	0.324	1.134	0.92	0.88	3.312
5 COBA2	Count	11	22	25	9	7	74.000
	% within Picture	14.90%	29.70%	33.80%	12.20%	9.50%	1.000
	% within Answer	2.70%	3.80%	4.20%	2.20%	3.60%	0.034
	% of Total	0.50%	1.00%	1.10%	0.40%	0.30%	0.034
	weight average	0.149	0.594	1.014	0.488	0.475	2.720
6 COBA3	Count	17	27	13	14	3	74.000
	% within Picture	23.00%	36.50%	17.60%	18.90%	4.10%	1.000
	% within Answer	4.10%	4.70%	2.20%	3.40%	1.50%	0.034
	% of Total	0.80%	1.20%	0.60%	0.60%	0.10%	0.034
	weight average	0.23	0.73	0.528	0.756	0.205	2.449
7 CWBA1	Count	4	10	21	24	15	74.000
	% within Picture	5.40%	13.50%	28.40%	32.40%	20.30%	1.000
	% within Answer	1.00%	1.70%	3.50%	5.90%	7.60%	0.034
	% of Total	0.20%	0.50%	1.00%	1.10%	0.70%	0.034
	weight average	0.054	0.27	0.852	1.296	1.015	3.487
8 CWBA2	Count	8	23	19	10	14	74.000
	% within Picture	10.80%	31.10%	25.70%	13.50%	18.90%	1.000
	% within Answer	1.90%	4.00%	3.20%	2.50%	7.10%	0.034
	% of Total	0.40%	1.10%	0.90%	0.50%	0.60%	0.034
	weight average	0.108	0.622	0.771	0.54	0.945	2.986
9 CWBA3	Count	18	20	13	14	8	73.000
	% within Picture	24.70%	27.40%	17.80%	19.20%	11.00%	1.000
	% within Answer	4.40%	3.50%	2.20%	3.40%	4.10%	0.033
	% of Total	0.80%	0.90%	0.60%	0.60%	0.40%	0.033
	weight average	0.247	0.548	0.534	0.768	0.55	2.647
10 DABA1	Count	3	16	18	26	10	73.000
	% within Picture	4.10%	21.90%	24.70%	35.60%	13.70%	1.000
	% within Answer	0.70%	2.80%	3.00%	6.40%	5.10%	0.033
	% of Total	0.10%	0.70%	0.80%	1.20%	0.50%	0.033

	weight average	0.041	0.438	0.741	1.424	0.685	3.329
11 DABA2	Count	12	19	27	11	4	73.000
	% within Picture	16.40%	26.00%	37.00%	15.10%	5.50%	1.000
	% within Answer	2.90%	3.30%	4.60%	2.70%	2.00%	0.033
	% of Total	0.50%	0.90%	1.20%	0.50%	0.20%	0.033
	weight average	0.23	0.73	0.528	0.756	0.205	2.449
12 DABA3	Count	22	16	18	14	3	73.000
	% within Picture	30.10%	21.90%	24.70%	19.20%	4.10%	1.000
	% within Answer	5.40%	2.80%	3.00%	3.40%	1.50%	0.033
	% of Total	1.00%	0.70%	0.80%	0.60%	0.10%	0.033
	weight average	0.301	0.438	0.741	0.768	0.205	2.453
13 HLBA1	Count	5	9	21	21	17	73.000
	% within Picture	6.80%	12.30%	28.80%	28.80%	23.30%	1.000
	% within Answer	1.20%	1.60%	3.50%	5.10%	8.60%	0.033
	% of Total	0.20%	0.40%	1.00%	1.00%	0.80%	0.033
	weight average	0.068	0.246	0.864	1.152	1.165	3.495
14 HLBA2	Count	8	23	18	15	9	73.000
	% within Picture	11.00%	31.50%	24.70%	20.50%	12.30%	1.000
	% within Answer	1.90%	4.00%	3.00%	3.70%	4.60%	0.033
	% of Total	0.40%	1.10%	0.80%	0.70%	0.40%	0.033
	weight average	0.11	0.63	0.741	0.82	0.615	2.916
15 HLBA3	Count	18	19	16	10	10	73.000
	% within Picture	24.70%	26.00%	21.90%	13.70%	13.70%	1.000
	% within Answer	4.40%	3.30%	2.70%	2.50%	5.10%	0.033
	% of Total	0.80%	0.90%	0.70%	0.50%	0.50%	0.033
	weight average	0.247	0.52	0.657	0.548	0.685	2.657
16 HRBA1	Count	4	12	23	24	10	73.000
	% within Picture	5.50%	16.40%	31.50%	32.90%	13.70%	1.000
	% within Answer	1.00%	2.10%	3.90%	5.90%	5.10%	0.033
	% of Total	0.20%	0.50%	1.10%	1.10%	0.50%	0.033
	weight average	0.055	0.328	0.945	1.316	0.685	3.329
17 HRBA2	Count	7	28	22	9	7	73.000
	% within Picture	9.60%	38.40%	30.10%	12.30%	9.60%	1.000
	% within Answer	1.70%	4.90%	3.70%	2.20%	3.60%	0.033
	% of Total	0.30%	1.30%	1.00%	0.40%	0.30%	0.033
	weight average	0.096	0.768	0.903	0.492	0.48	2.739
18 HRBA3	Count	19	23	17	10	4	73.000
	% within Picture	26.00%	31.50%	23.30%	13.70%	5.50%	1.000
	% within Answer	4.60%	4.00%	2.90%	2.50%	2.00%	0.033
	% of Total	0.90%	1.10%	0.80%	0.50%	0.20%	0.033
	weight average	0.26	0.63	0.699	0.548	0.275	2.412
19 LIBA1	Count	7	17	27	17	5	73.000
	% within Picture	9.60%	23.30%	37.00%	23.30%	6.80%	1.000
	% within Answer	1.70%	3.00%	4.60%	4.20%	2.50%	0.033
	% of Total	0.30%	0.80%	1.20%	0.80%	0.20%	0.033
	weight average	0.096	0.466	1.11	0.932	0.34	2.944
20 LIBA2	Count	13	27	22	8	2	72.000
	% within Picture	18.10%	37.50%	30.60%	11.10%	2.80%	1.000
	% within Answer	3.20%	4.70%	3.70%	2.00%	1.00%	0.033
	% of Total	0.60%	1.20%	1.00%	0.40%	0.10%	0.033
	weight average	0.181	0.75	0.918	0.444	0.14	2.433
21 LIBA3	Count	21	28	13	7	3	72.000
	% within Picture	29.20%	38.90%	18.10%	9.70%	4.20%	1.000
	% within Answer	5.10%	4.90%	2.20%	1.70%	1.50%	0.033
	% of Total	1.00%	1.30%	0.60%	0.30%	0.10%	0.033

	weight average	0.292	0.778	0.543	0.388	0.21	2.211
22 SIBA1	Count	11	18	18	19	6	72.000
	% within Picture	15.30%	25.00%	25.00%	26.40%	8.30%	1.000
	% within Answer	2.70%	3.10%	3.00%	4.70%	3.00%	0.033
	% of Total	0.50%	0.80%	0.80%	0.90%	0.30%	0.033
	weight average	0.153	0.5	0.75	1.056	0.415	2.874
23 SIBA2	Count	14	24	26	7	1	72.000
	% within Picture	19.40%	33.30%	36.10%	9.70%	1.40%	1.000
	% within Answer	3.40%	4.20%	4.40%	1.70%	0.50%	0.033
	% of Total	0.60%	1.10%	1.20%	0.30%	0.00%	0.033
	weight average	0.194	0.666	1.083	0.388	0.07	2.401
24 SIBA3	Count	29	22	14	4	3	72.000
	% within Picture	40.30%	30.60%	19.40%	5.60%	4.20%	1.000
	% within Answer	7.10%	3.80%	2.40%	1.00%	1.50%	0.033
	% of Total	1.30%	1.00%	0.60%	0.20%	0.10%	0.033
	weight average	0.403	0.612	0.582	0.224	0.21	2.031
25 WDBA1	Count	9	15	25	15	8	72.000
	% within Picture	12.50%	20.80%	34.70%	20.80%	11.10%	1.000
	% within Answer	2.20%	2.60%	4.20%	3.70%	4.10%	0.033
	% of Total	0.40%	0.70%	1.10%	0.70%	0.40%	0.033
	weight average	0.125	0.416	1.041	0.832	0.555	2.969
26 WDBA2	Count	27	19	15	8	2	71.000
	% within Picture	38.00%	26.80%	21.10%	11.30%	2.80%	1.000
	% within Answer	6.60%	3.30%	2.50%	2.00%	1.00%	0.033
	% of Total	1.20%	0.90%	0.70%	0.40%	0.10%	0.033
	weight average	0.38	0.536	0.633	0.452	0.14	2.141
27 WDBA3	Count	41	15	6	5	4	71.000
	% within Picture	57.70%	21.10%	8.50%	7.00%	5.60%	1.000
	% within Answer	10.00%	2.60%	1.00%	1.20%	2.00%	0.033
	% of Total	1.90%	0.70%	0.30%	0.20%	0.20%	0.033
	weight average	0.577	0.422	0.255	0.28	0.28	1.814
28 WDBA4	Count	5	11	26	22	7	71.000
	% within Picture	7.00%	15.50%	36.60%	31.00%	9.90%	1.000
	% within Answer	1.20%	1.90%	4.40%	5.40%	3.60%	0.033
	% of Total	0.20%	0.50%	1.20%	1.00%	0.30%	0.033
	weight average	0.07	0.31	1.098	1.24	0.495	3.213
29 WDBA5	Count	15	21	28	6	1	71.000
	% within Picture	21.10%	29.60%	39.40%	8.50%	1.40%	1.000
	% within Answer	3.60%	3.70%	4.70%	1.50%	0.50%	0.033
	% of Total	0.70%	1.00%	1.30%	0.30%	0.00%	0.033
	weight average	0.211	0.592	1.182	0.34	0.07	2.395
30 WDBA6	Count	23	26	15	6	1	71.000
	% within Picture	32.40%	36.60%	21.10%	8.50%	1.40%	1.000
	% within Answer	5.60%	4.50%	2.50%	1.50%	0.50%	0.033
	% of Total	1.10%	1.20%	0.70%	0.30%	0.00%	0.033
	weight average	0.324	0.732	0.633	0.34	0.07	2.099
	Count	411	573	593	408	197	2182
	% within Picture	18.80%	26.30%	27.20%	18.70%	9.00%	
100.00%							
	% within Answer	100.00%	100.00%	100.00%	100.00%	100.00%	
100.00%							
	% of Total	18.80%	26.30%	27.20%	18.70%	9.00%	
100.00%0							
Total	*72*	*100%*	*172.47*	*100%*	*99.10*	*427.20*	

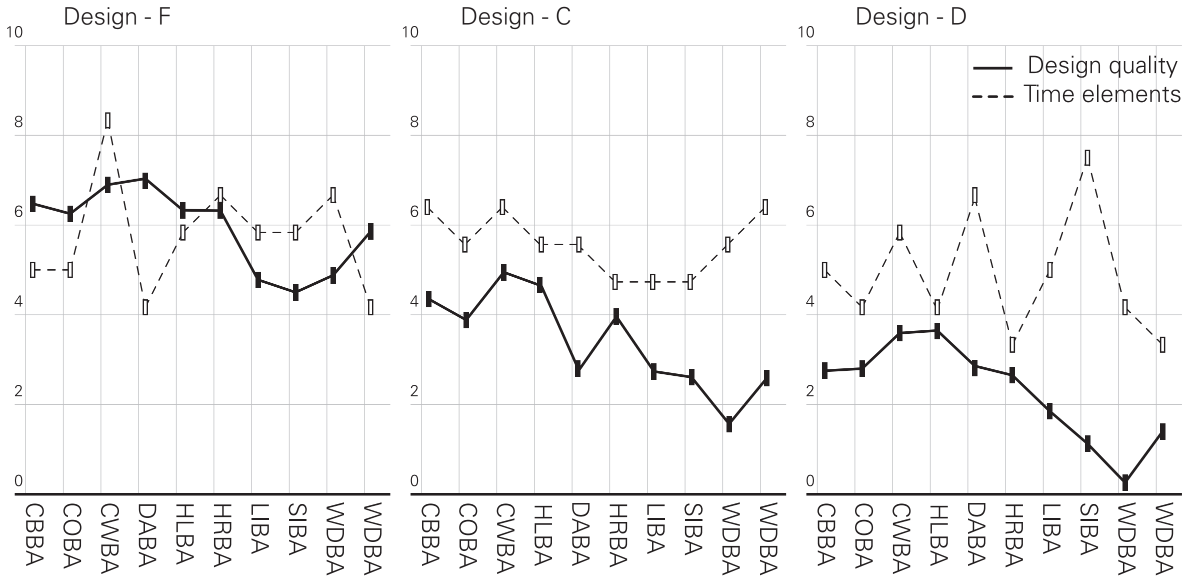
The weight average of the colour contrast affects on the design application quality.

Colour contrast	CBBA	COBA	CWBA	HLBA	DABA	HRBA	LIBA	SIBA	WDBA	WDBAx
Design - F	6.74	6.62	6.95	6.99	6.66	6.66	5.89	5.75	5.94	6.43
Design - C	5.67	5.44	5.97	5.83	4.90	5.48	4.87	4.80	4.28	4.79
Design - D	4.87	4.90	5.29	5.31	4.91	4.82	4.42	4.06	3.63	4.20
Weight average	5.76	5.65	6.07	6.05	5.49	5.65	5.06	4.87	4.62	5.14
Order	8	6	10	9	5	7	3	2	1	4

The weighted average of the colour contrast affects on the time elements.

Colour contrast	CBBA	COBA	CWBA	HLBA	DABA	HRBA	LIBA	SIBA	WDBA	WDBAx
Design - F	8.19	8.38	11.97	7.72	9.43	10.62	9.70	9.19	10.05	7.39
Design - C	9.66	8.62	9.11	8.10	8.49	7.80	7.98	7.92	8.03	8.90
Design - D	9.18	8.35	9.83	8.53	10.88	7.40	8.95	11.95	7.08	8.32
Weight average	9.01	8.45	10.30	8.12	9.60	8.61	8.88	9.69	8.39	8.21

The graph shows the design and time scale of each design tested.



G

A detailed report of the study III results

PS3-the results

	White	Black	Dark	Light	Gray	Temp	Hue	Contast
Red						**R+B**	**R+Y**	**R+G**
High	**1.89**	**5**	**5.67**	**2.78**	**3.11**	**5.44**	**4.11**	**6.33**
Low	**4.22**	**5.33**	**5**	**2.89**	**2.89**	**6.11**	**3.89**	**5.22**
Average	**3.06**	**5.17**	**5.34**	**2.84**	**3.00**	**5.78**	**4.00**	**5.78**
Orange						**B+V**	**O+R**	**O+B**
High	**2.22**	**4.78**	**5.11**	**2.67**	**3.33**	**4.33**	**5.56**	**5.44**
Low	**2.89**	**5**	**4.11**	**2.56**	**4.56**	**5.11**	**5.56**	**6.22**
Average	**2.56**	**4.89**	**4.61**	**2.62**	**3.95**	**4.72**	**5.56**	**5.83**
Yellow						**Y+G**	**Y+O**	**Y+V**
High	**3.33**	**5.67**	**3.89**	**2.78**	**3.78**	**5.22**	**3.33**	**5**
Low	**2.56**	**5.22**	**5.11**	**3**	**4**	**5.56**	**4.56**	**6**
Average	**2.95**	**5.45**	**4.50**	**2.89**	**3.89**	**5.39**	**3.95**	**5.50**
Green						**G+O**	**G+B**	**G+R**
High	**1.67**	**4.44**	**5.22**	**2.78**	**2.89**	**5.89**	**5.11**	**5.22**
Low	**3.56**	**5.89**	**4.78**	**3.11**	**2.56**	**5.00**	**4.78**	**6.33**
Average	**2.62**	**5.17**	**5.00**	**2.95**	**2.73**	**5.45**	**4.95**	**5.78**
Blue						**B+Y**	**B+V**	**B+O**
High	**2.22**	**5.89**	**4.56**	**2.89**	**2.44**	**4.78**	**5.22**	**6.22**
Low	**2.67**	**6.67**	**5.67**	**2.11**	**2.56**	**4.67**	**6.22**	**5.44**
Average	**2.45**	**6.28**	**5.12**	**2.50**	**2.50**	**4.73**	**5.72**	**5.83**
Violet						**V+R**	**V+G**	**V+Y**
High	**1.78**	**6**	**4.67**	**2.89**	**2.22**	**5.67**	**5.22**	**6**
Low	**3.11**	**6.89**	**4.78**	**2**	**2.67**	**6**	**5.67**	**5**
Average	**2.45**	**6.45**	**4.73**	**2.45**	**2.45**	**5.84**	**5.45**	**5.50**

Complexity Factor of the colour combination results of PS3.

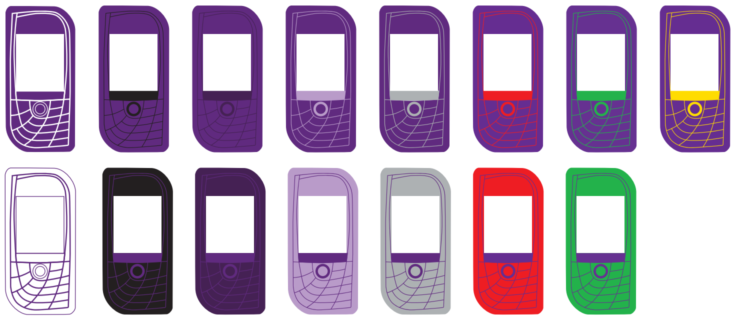
	White	Black	Dark	Light	Gray	Temp	Hue	Complementary
Red	3.06	5.17	5.34	2.84	3.00	5.78	4.00	5.78
Orange	2.56	4.89	4.61	2.62	3.95	4.72	5.56	5.83
Yellow	2.95	5.45	4.50	2.89	3.89	5.39	3.95	5.50
Green	2.62	5.17	5.00	2.95	2.73	5.45	4.95	5.78
Blue	2.45	6.28	5.12	2.50	2.50	4.73	5.72	5.83
Violet	2.45	6.45	4.73	2.45	2.45	5.84	5.45	5.50

PS3-the results

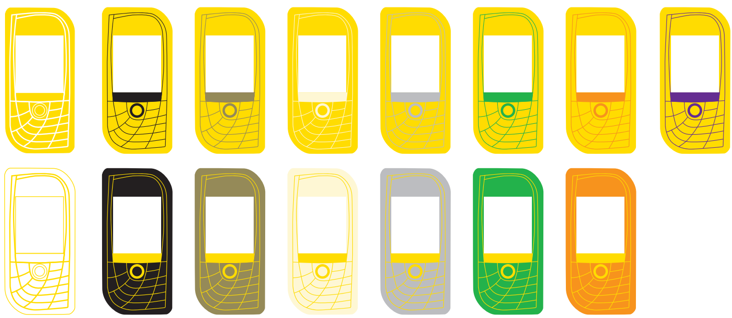
	White	Black	Dark	Light	Gray	Temp	Hue	Contast
Red						**R+B**	**R+Y**	**R+G**
High	**1.89**	**5**	**5.67**	**2.78**	**3.11**	**5.44**	**4.11**	**6.33**
Low	**4.22**	**5.33**	**5**	**2.89**	**2.89**	**6.11**	**3.89**	**5.22**
Average	**3.06**	**5.17**	**5.34**	**2.84**	**3.00**	**5.78**	**4.00**	**5.78**
Orange						**B+V**	**O+R**	**O+B**
High	**2.22**	**4.78**	**5.11**	**2.67**	**3.33**	**4.33**	**5.56**	**5.44**
Low	**2.89**	**5**	**4.11**	**2.56**	**4.56**	**5.11**	**5.56**	**6.22**
Average	**2.56**	**4.89**	**4.61**	**2.62**	**3.95**	**4.72**	**5.56**	**5.83**
Yellow						**Y+G**	**Y+O**	**Y+V**
High	**3.33**	**5.67**	**3.89**	**2.78**	**3.78**	**5.22**	**3.33**	**5**
Low	**2.56**	**5.22**	**5.11**	**3**	**4**	**5.56**	**4.56**	**6**
Average	**2.95**	**5.45**	**4.50**	**2.89**	**3.89**	**5.39**	**3.95**	**5.50**
Green						**G+O**	**G+B**	**G+R**
High	**1.67**	**4.44**	**5.22**	**2.78**	**2.89**	**5.89**	**5.11**	**5.22**
Low	**3.56**	**5.89**	**4.78**	**3.11**	**2.56**	**5.00**	**4.78**	**6.33**
Average	**2.62**	**5.17**	**5.00**	**2.95**	**2.73**	**5.45**	**4.95**	**5.78**
Blue						**B+Y**	**B+V**	**B+O**
High	**2.22**	**5.89**	**4.56**	**2.89**	**2.44**	**4.78**	**5.22**	**6.22**
Low	**2.67**	**6.67**	**5.67**	**2.11**	**2.56**	**4.67**	**6.22**	**5.44**
Average	**2.45**	**6.28**	**5.12**	**2.50**	**2.50**	**4.73**	**5.72**	**5.83**
Violet						**V+R**	**V+G**	**V+Y**
High	**1.78**	**6**	**4.67**	**2.89**	**2.22**	**5.67**	**5.22**	**6**
Low	**3.11**	**6.89**	**4.78**	**2**	**2.67**	**6**	**5.67**	**5**
Average	**2.45**	**6.45**	**4.73**	**2.45**	**2.45**	**5.84**	**5.45**	**5.50**

Complexity Factor of the colour combination results of PS3.

	White	Black	Dark	Light	Gray	Temp	Hue	Complementary
Red	3.06	5.17	5.34	2.84	3.00	5.78	4.00	5.78
Orange	2.56	4.89	4.61	2.62	3.95	4.72	5.56	5.83
Yellow	2.95	5.45	4.50	2.89	3.89	5.39	3.95	5.50
Green	2.62	5.17	5.00	2.95	2.73	5.45	4.95	5.78
Blue	2.45	6.28	5.12	2.50	2.50	4.73	5.72	5.83
Violet	2.45	6.45	4.73	2.45	2.45	5.84	5.45	5.50

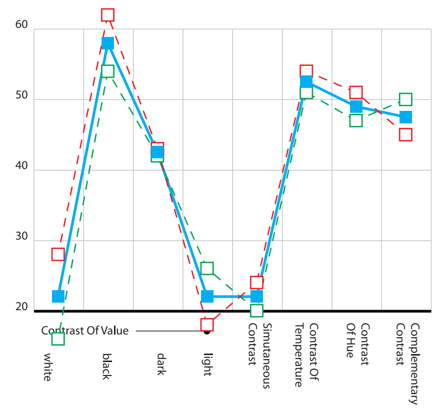


Contrast Of Value	white	black	dark	light	Simutaneous Contrast	Contrast Of Temperature	Contrast Of Hue	Complementary Contrast
	28	62	43	18	24	54	51	45
	16	54	42	26	20	51	47	50
Average	22	58	42.5	22	22	52.5	49	47.5
Order	1	8	4	2	3	7	6	5

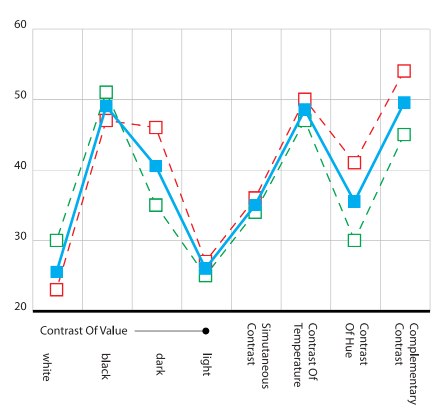


Contrast Of Value	white	black	dark	light	Simutaneous Contrast	Contrast Of Temperature	Contrast Of Hue	Complementary Contrast
	23	47	46	27	36	50	41	54
	30	51	35	25	34	47	30	45
Average	25.5	49	40.5	26	35	48.5	35.5	49.5
Order	1	7	5	2	3	6	4	8

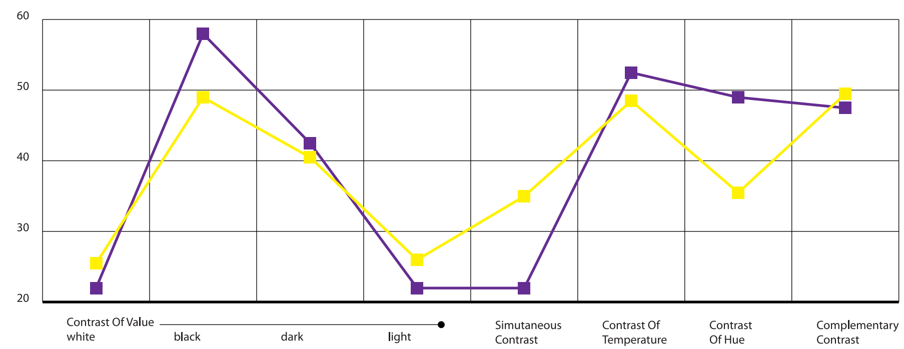
violet combination

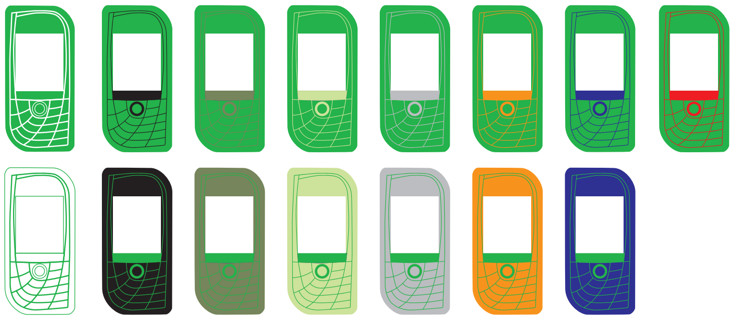


Yellow combination

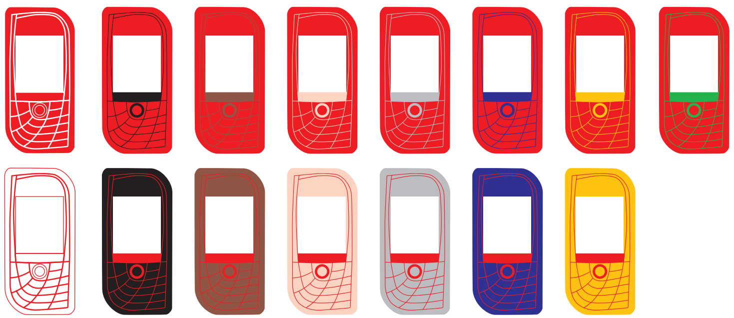


Yellow and violet combination



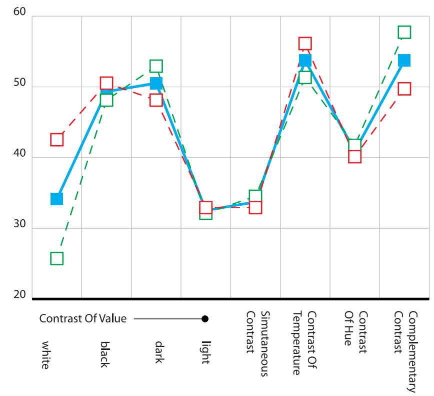


	Contrast Of Value							
	white	black	dark	light	Simutaneous Contrast	Contrast Of Temperature	Contrast Of Hue	Complementary Contrast
	32	53	43	28	23	45	43	57
	15	40	47	25	26	53	46	47
Average	24	46.5	45	26.5	24.5	49	44.5	52
Order	1	6	5	3	2	7	4	8

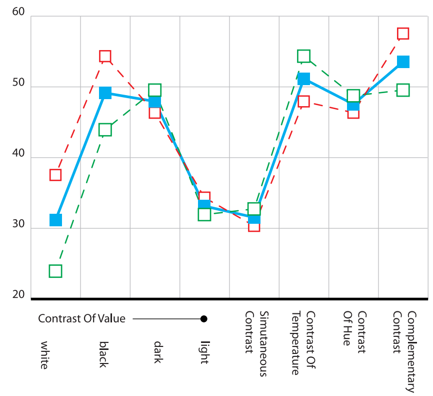


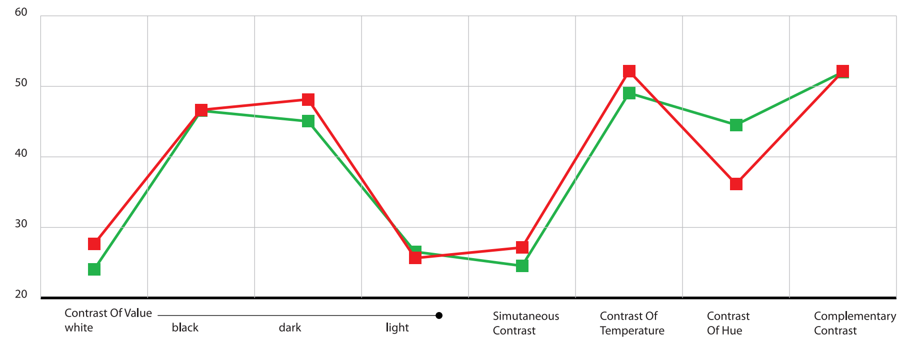
	Contrast Of Value							
	white	black	dark	light	Simutaneous Contrast	Contrast Of Temperature	Contrast Of Hue	Complementary Contrast
	38	48	45	26	26	55	35	47
	17	45	51	25	28	49	37	57
Average	27.5	46.5	48	25.5	27	52	36	52
Order	3	5	6	1	2	7	4	8

red combination

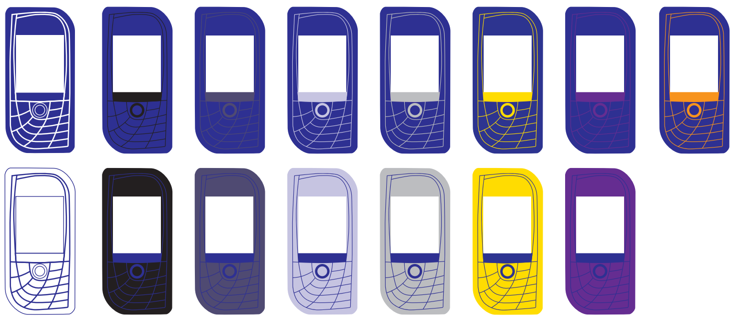


Green combination

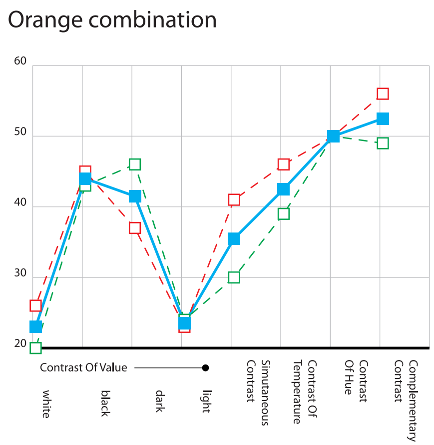


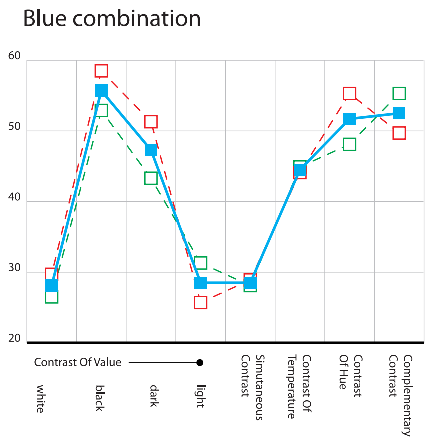


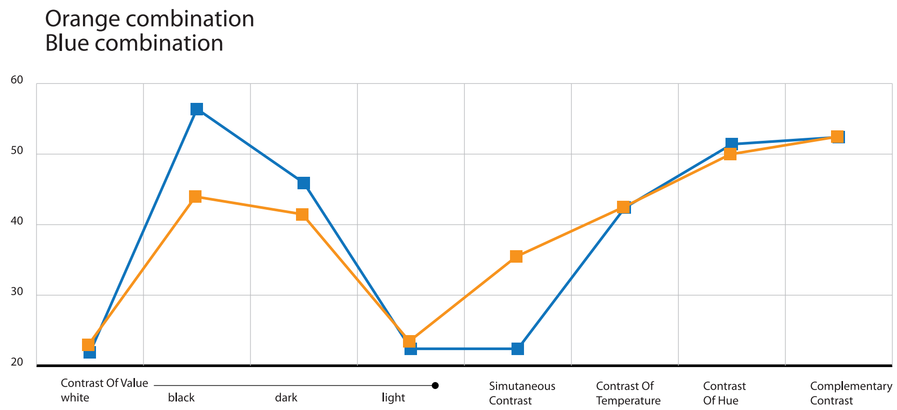
	Contrast Of Value white	black	dark	light	Simutaneous Contrast	Contrast Of Temperature	Contrast Of Hue	Complementary Contrast
	26	45	37	23	41	46	50	56
	20	43	46	24	30	39	50	49
Average	23	44	41.5	23.5	35.5	42.5	50	52.5
Order	1	6	4	2	3	5	7	8



	Contrast Of Value white	black	dark	light	Simutaneous Contrast	Contrast Of Temperature	Contrast Of Hue	Complementary Contrast
	24	60	51	19	23	42	56	49
	20	53	41	26	22	43	47	56
Average	22	56.5	46	22.5	22.5	42.5	51.5	52.5
Order	1	8	5	2	3	4	6	7







Appendix

H

A detailed report of the mathematical formula, and results

The mathematical formula to compare colour complexity and the colour wavelength

CC_1	=	Colour Complexity of Colour One	(Known Data)
CC_2	=	Colour Complexity of Colour Two	(Known Data)
CC_{12}	=	Colour Complexity of Colour One to Two	(Known Data)
CC_{21}	=	Colour Complexity of Colour Two to One	(Known Data)
WL_1	=	Colour Wavelength of colour One	(Known Data)
WL_2	=	Colour Wavelength of colour Two	(Known Data)
C_{1r}	=	0.3	(the colour ratio)
C_{2r}	=	0.7	(the colour ratio)

$$R_1 = \frac{Wl_1}{CC_1}$$

$$R_2 = \frac{Wl_2}{CC_2}$$

$$R_{12r} = C_{1r}\left(R_1\right) + C_{2r}\left(R_2\right)$$

$$R_{12t} = \frac{WL_{12}}{CC_{12}} = \frac{C_{1r}\left(WL_1\right) + C_{2r}\left(WL_2\right)}{CC_{12}}$$

$$\boxed{\partial_{12} = \frac{R_{12r}}{R_{12t}}}$$

$$R_{21r} = C_{2r}\left(R_1\right) + C_{1r}\left(R_2\right)$$

$$R_{21t} = \frac{WL_{21}}{CC_{21}} = \frac{C_{2r}\left(WL_1\right) + C_{2r}\left(WL_2\right)}{CC_{21}}$$

$$\boxed{\partial_{21} = \frac{R_{21r}}{R_{21t}}}$$

The mathematical formula to compare colour complexity and the colour wavelength

CC_1	=	.37	Orange
CC_2	=	.35	Blue
CC_{12}	=	.79	
CC_{21}	=	.9	
WL_1	=	620	Orange
WL_2	=	470	Blue
C_{1r}	=	.3	
C_{2r}	=	.7	

$$R_1 = \frac{Wl_1}{CC_1} = \frac{620}{.37} = 1675$$

$$R_2 = \frac{Wl_2}{CC_2} = \frac{470}{.35} = 1342$$

$$R_{12r} = C_{1r}(R_1) + C_{2r}(R_2) = .3(1675) + .7(1342) = 1442$$

$$R_{12t} = \frac{WL_{12}}{CC_{12}} = \frac{C_{1r}(WL_1) + C_{2r}(WL_2)}{CC_{12}} = \frac{.3(620) + .7(470)}{.79} = 651$$

$$\boxed{\partial_{12} = \frac{R_{12r}}{R_{12t}} = \frac{1442}{651} = \mathbf{2.21}}$$

$$R_{21r} = C_{2r}(R_1) + C_{1r}(R_2) = .7(1675) + .3(1242) = 1575$$

$$R_{21t} = \frac{WL_{21}}{CC_{21}} = \frac{C_{2r}(WL_1) + C_{2r}(WL_2)}{CC_{21}} = \frac{.7(620) + .3(470)}{.9} = 638$$

$$\boxed{\partial_{21} = \frac{R_{21r}}{R_{21t}} = \frac{1575}{638} = \mathbf{2.47}}$$

furmula of the wavelenth over a CC

Colour 1	Red	Orange	Red	Yellow	Red	Green	Red	Blue
Colour 2	Orange	Red	Yellow	Red	Green	Red	Blue	Red
CC1	0.44	0.37	0.44	0.43	0.44	0.38	0.44	0.35
CC2	0.37	0.44	0.43	0.44	0.38	0.44	0.35	0.44
CC12	0.81	0.81	0.6	0.56	0.92	0.76	0.89	0.89
CC21	0.81	0.81	0.56	0.6	0.76	0.92	0.89	0.89
WL1	700	620	700	580	700	530	700	470
WL2	620	700	580	700	530	700	470	700
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1675.68	1590.91	1348.84	1590.91	1394.74	1590.91	1342.86
R2	1675.68	1590.91	1348.84	1590.91	1394.74	1590.91	1342.86	1590.91
R12r	1650.25	1616.34	1421.46	1518.29	1453.59	1532.06	1417.27	1516.49
R12t	795.06	834.57	1026.67	1185.71	631.52	853.95	605.62	708.99
alpha 1-2	2.08	1.94	1.38	1.28	2.30	1.79	2.34	2.14

Colour 1	Red	Violet	Orange	Yellow	Orange	Green	Orange	Blue
Colour 2	Violet	Red	Yellow	Orange	Green	Orange	Blue	Orange
CC1	0.44	0.35	0.37	0.43	0.37	0.38	0.37	0.35
CC2	0.35	0.44	0.43	0.37	0.38	0.37	0.35	0.37
CC12	0.87	0.82	0.66	0.48	0.73	0.85	0.79	0.9
CC21	0.82	0.87	0.48	0.66	0.85	0.73	0.9	0.79
WL1	700	420	620	580	620	530	620	470
WL2	420	700	580	620	530	620	470	620
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1200.00	1675.68	1348.84	1675.68	1394.74	1675.68	1342.86
R2	1200.00	1590.91	1348.84	1675.68	1394.74	1675.68	1342.86	1675.68
R12r	1317.27	1473.64	1446.89	1577.62	1479.02	1591.39	1442.70	1575.83
R12t	579.31	751.22	896.97	1266.67	763.01	697.65	651.90	638.89
alpha 1-2	2.27	1.96	1.61	1.25	1.94	2.28	2.21	2.47

Orange	Violet	Yellow	Green	Yellow	Blue	Yellow	Violet
Violet	Orange	Green	Yellow	Blue	Yellow	Violet	Yellow
0.37	0.35	0.43	0.38	0.43	0.35	0.43	0.35
0.35	0.37	0.38	0.43	0.35	0.43	0.35	0.43
0.63	0.82	0.76	0.81	0.68	0.69	0.73	0.87
0.82	0.63	0.81	0.76	0.69	0.68	0.87	0.73
620	420	580	530	580	470	580	420
420	620	530	580	470	580	420	580
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
1675.68	1200.00	1348.84	1394.74	1348.84	1342.86	1348.84	1200.00
1200.00	1675.68	1394.74	1348.84	1342.86	1348.84	1200.00	1348.84
1342.70	1532.97	1380.97	1362.61	1344.65	1347.04	1244.65	1304.19
761.90	682.93	717.11	697.53	739.71	792.75	641.10	611.49
1.76	2.24	1.93	1.95	1.82	1.70	1.94	2.13

Green	Blue	Green	Violet	Blue	Violet
Blue	Green	Violet	Green	Violet	Blue
0.38	0.35	0.38	0.35	0.35	0.35
0.35	0.38	0.35	0.38	0.35	0.35
0.74	0.69	0.82	0.76	0.76	0.9
0.69	0.74	0.76	0.82	0.9	0.76
530	470	530	420	470	420
470	530	420	530	420	470
0.3	0.3	0.3	0.3	0.3	0.3
0.7	0.7	0.7	0.7	0.7	0.7
1394.74	1342.86	1394.74	1200.00	1342.86	1200.00
1342.86	1394.74	1200.00	1394.74	1200.00	1342.86
1358.42	1379.17	1258.42	1336.32	1242.86	1300.00
659.46	742.03	552.44	653.95	572.37	505.56
2.06	1.86	2.28	2.04	2.17	2.57

the effect of value

furmula of the wavelenth over a CC

Colour 1	Red	white	Orange	White	Yellow	White	Green	White
Colour 2	white	Red	White	Orange	White	Yellow	White	Green
CC1	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC2	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC12	0.61	0.27	0.42	0.32	0.37	0.48	0.52	0.24
CC21	0.27	0.61	0.32	0.42	0.48	0.37	0.24	0.52
WL1	700	700	620	620	580	580	530	530
WL2	700	700	620	620	580	580	530	530
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R2	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12r	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12t	1147.54	2592.59	1476.19	1937.50	1567.57	1208.33	1019.23	2208.33
alpha 1-2	1.39	0.61	1.14	0.86	0.86	1.12	1.37	0.63

Colour 1	Red	Black	Orange	Black	Yellow	Black	Green	White
Colour 2	Black	Red	Black	Orange	Black	Yellow	White	Green
CC1	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC2	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC12	0.77	0.73	0.73	0.69	0.76	0.82	0.85	0.64
CC21	0.73	0.77	0.69	0.73	0.82	0.76	0.64	0.85
WL1	700	700	620	620	580	580	530	530
WL2	700	700	620	620	580	580	530	530
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R2	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12r	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12t	909.09	958.90	849.32	898.55	763.16	707.32	623.53	828.13
alpha 1-2	1.75	1.66	1.97	1.86	1.77	1.91	2.24	1.68

Blue	White
White	Blue
0.35	0.35
0.35	0.35
0.39	0.32
0.32	0.39
470	470
470	470
0.3	0.3
0.7	0.7
1342.86	1342.86
1342.86	1342.86
1342.86	1342.86
1205.13	1468.75
1.11	0.91

Violet	White
White	Violet
0.35	0.35
0.35	0.35
0.45	0.26
0.26	0.45
420	420
420	420
0.3	0.3
0.7	0.7
1200.00	1200.00
1200.00	1200.00
1200.00	1200.00
933.33	1615.38
1.29	0.74

Blue	White
White	Blue
0.35	0.35
0.35	0.35
0.97	0.85
0.85	0.97
470	470
470	470
0.3	0.3
0.7	0.7
1342.86	1342.86
1342.86	1342.86
1342.86	1342.86
484.54	552.94
2.77	2.43

Violet	White
White	Violet
0.35	0.87
0.87	0.35
1	0.87
0.87	1
420	420
420	420
0.3	0.3
0.7	0.7
1200.00	482.76
482.76	1200.00
697.93	984.83
420.00	482.76
1.66	2.04

Colour 1	Red	Gray	Orange	Gray	Yellow	Gray	Green	Gray
Colour 2	Gray	Red	Gray	Orange	Gray	Yellow	Gray	Green
CC1	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC2	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC12	0.42	0.45	0.66	0.48	0.58	0.55	0.37	0.42
CC21	0.45	0.42	0.48	0.66	0.55	0.58	0.42	0.37
WL1	700	700	620	620	580	580	530	530
WL2	700	700	620	620	580	580	530	530
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R2	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12r	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12t	1666.67	1555.56	939.39	1291.67	1000.00	1054.55	1432.43	1261.90
alpha 1-2	0.95	1.02	1.78	1.30	1.35	1.28	0.97	1.11

Colour 1	Red	Dark	Orange	Dark	Yellow	Dark	Green	Dark
Colour 2	Dark	Red	Dark	Orange	Dark	Yellow	Dark	Green
CC1	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC2	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC12	0.73	0.82	0.6	0.74	0.74	0.56	0.69	0.76
CC21	0.82	0.73	0.74	0.6	0.56	0.74	0.76	0.69
WL1	700	700	620	620	580	580	530	530
WL2	700	700	620	620	580	580	530	530
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R2	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12r	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12t	958.90	853.66	1033.33	837.84	783.78	1035.71	768.12	697.37
alpha 1-2	1.66	1.86	1.62	2.00	1.72	1.30	1.82	2.00

Blue	Gray
Gray	Blue
0.35	0.35
0.35	0.35
0.37	0.35
0.35	0.37
470	470
470	470
0.3	0.3
0.7	0.7
1342.86	1342.86
1342.86	1342.86
1342.86	1342.86
1270.27	1342.86
1.06	1.00

Violet	Gray
Gray	Violet
0.35	0.87
0.87	0.35
0.39	0.32
0.32	0.39
420	420
420	420
0.3	0.3
0.7	0.7
1200.00	482.76
482.76	1200.00
697.93	984.83
1076.92	1312.50
0.65	0.75

Blue	Dark
Dark	Blue
0.35	0.35
0.35	0.35
0.82	0.66
0.66	0.82
470	470
470	470
0.3	0.3
0.7	0.7
1342.86	1342.86
1342.86	1342.86
1342.86	1342.86
573.17	712.12
2.34	1.89

Violet	Dark
Dark	Violet
0.35	0.87
0.87	0.35
0.69	0.68
0.68	0.69
420	420
420	420
0.3	0.3
0.7	0.7
1200.00	482.76
482.76	1200.00
697.93	984.83
608.70	617.65
1.15	1.59

Colour 1	Red	Light	Orange	Light	Yellow	Light	Green	Light
Colour 2	Light	Red	Light	Orange	Light	Yellow	Light	Green
CC1	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC2	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC12	0.42	0.4	0.7	0.39	0.44	0.4	0.45	0.4
CC21	0.4	0.42	0.39	0.7	0.4	0.44	0.4	0.45
WL1	700	700	620	620	580	580	530	530
WL2	700	700	620	620	580	580	530	530
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R2	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12r	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12t	1666.67	1750.00	885.71	1589.74	1318.18	1450.00	1177.78	1325.00
alpha 1-2	0.95	0.91	1.89	1.05	1.02	0.93	1.18	1.05

the effect of value (Avrege)

furmula of the wavelenth over a CC

Colour 1	Red	white	Orange	White	Yellow	White	Green	White
Colour 2	white	Red	White	Orange	White	Yellow	White	Green
CC1	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC2	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC12	0.374	0.5433	0.374	0.5433	0.374	0.5433	0.374	0.5433
CC21	0.5433	0.374	0.5433	0.374	0.5433	0.374	0.5433	0.374
WL1	700	700	620	620	580	580	530	530
WL2	700	700	620	620	580	580	530	530
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R2	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12r	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12t	1871.66	1288.42	1657.75	1141.17	1550.80	1067.55	1417.11	975.52
alpha 1-2	0.85	1.23	1.01	1.47	0.87	1.26	0.98	1.43

Blue	Light
Light	Blue
0.35	0.35
0.35	0.35
0.31	0.42
0.42	0.31
470	470
470	470
0.3	0.3
0.7	0.7
1342.86	1342.86
1342.86	1342.86
1342.86	1342.86
1516.13	1119.05
0.89	1.20

Violet	Light
Light	Violet
0.35	0.87
0.87	0.35
0.42	0.29
0.29	0.42
420	420
420	420
0.3	0.3
0.7	0.7
1200.00	482.76
482.76	1200.00
697.93	984.83
1000.00	1448.28
0.70	0.68

Blue	White
White	Blue
0.35	0.35
0.35	0.35
0.374	0.5433
0.5433	0.374
470	470
470	470
0.3	0.3
0.7	0.7
1342.86	1342.86
1342.86	1342.86
1342.86	1342.86
1256.68	865.08
1.07	1.55

Violet	White
White	Violet
0.35	0.35
0.35	0.35
0.374	0.5433
0.5433	0.374
420	420
420	420
0.3	0.3
0.7	0.7
1200.00	1200.00
1200.00	1200.00
1200.00	1200.00
1122.99	773.05
1.07	1.55

Colour 1	Red	Black	Orange	Black	Yellow	Black	Green	Black
Colour 2	Black	Red	Black	Orange	Black	Yellow	Black	Green
CC1	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC2	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC12	0.9075	1	0.9075	1	0.9075	1	0.9075	1
CC21	1	0.9075	1	0.9075	1	0.9075	1	0.9075
WL1	700	700	620	620	580	580	530	530
WL2	700	700	620	620	580	580	530	530
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R2	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12r	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12t	771.35	700.00	683.20	620.00	639.12	580.00	584.02	530.00
alpha 1-2	2.06	2.27	2.45	2.70	2.11	2.33	2.39	2.63

Colour 1	Red	Gray	Orange	Gray	Yellow	Gray	Green	Gray
Colour 2	Gray	Red	Gray	Orange	Gray	Yellow	Gray	Green
CC1	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC2	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC12	0.5079	0.5492	0.5079	0.5492	0.5079	0.5492	0.5079	0.5492
CC21	0.5492	0.5079	0.5492	0.5079	0.5492	0.5079	0.5492	0.5079
WL1	700	700	620	620	580	580	530	530
WL2	700	700	620	620	580	580	530	530
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R2	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12r	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12t	1378.22	1274.58	1220.71	1128.91	1141.96	1056.08	1043.51	965.04
alpha 1-2	1.15	1.25	1.37	1.48	1.18	1.28	1.34	1.45

Blue	Black
Black	Blue
0.35	0.35
0.35	0.35
0.9075	1
1	0.9075
470	470
470	470
0.3	0.3
0.7	0.7
1342.86	1342.86
1342.86	1342.86
1342.86	1342.86
517.91	470.00
2.59	2.86

Violet	Black
Black	Violet
0.35	0.87
0.87	0.35
0.9075	1
1	0.9075
420	420
420	420
0.3	0.3
0.7	0.7
1200.00	482.76
482.76	1200.00
697.93	984.83
462.81	420.00
1.51	2.34

Blue	Gray
Gray	Blue
0.35	0.35
0.35	0.35
0.5079	0.5492
0.5492	0.5079
470	470
470	470
0.3	0.3
0.7	0.7
1342.86	1342.86
1342.86	1342.86
1342.86	1342.86
925.38	855.79
1.45	1.57

Violet	Gray
Gray	Violet
0.35	0.87
0.87	0.35
0.5079	0.5492
0.5492	0.5079
420	420
420	420
0.3	0.3
0.7	0.7
1200.00	482.76
482.76	1200.00
697.93	984.83
826.93	764.75
0.84	1.29

Colour 1	Red	Dark	Orange	Dark	Yellow	Dark	Green	Dark
Colour 2	Dark	Red	Dark	Orange	Dark	Yellow	Dark	Green
CC1	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC2	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC12	0.8327	0.8406	0.8327	0.8406	0.8327	0.8406	0.8327	0.8406
CC21	0.8406	0.8327	0.8406	0.8327	0.8406	0.8327	0.8406	0.8327
WL1	700	700	620	620	580	580	530	530
WL2	700	700	620	620	580	580	530	530
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R2	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12r	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12t	840.64	832.74	744.57	737.57	696.53	689.98	636.48	630.50
alpha 1-2	1.89	1.91	2.25	2.27	1.94	1.95	2.19	2.21

Colour 1	Red	Light	Orange	Light	Yellow	Light	Green	Light
Colour 2	Light	Red	Light	Orange	Light	Yellow	Light	Green
CC1	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC2	0.44	0.44	0.37	0.37	0.43	0.43	0.38	0.38
CC12	0.4803	0.4469	0.4803	0.4469	0.4803	0.4469	0.4803	0.4469
CC21	0.4469	0.4803	0.4469	0.4803	0.4469	0.4803	0.4469	0.4803
WL1	700	700	620	620	580	580	530	530
WL2	700	700	620	620	580	580	530	530
C1r	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C2r	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
R1	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R2	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12r	1590.91	1590.91	1675.68	1675.68	1348.84	1348.84	1394.74	1394.74
R12t	1457.42	1566.35	1290.86	1387.33	1207.58	1297.83	1103.48	1185.95
alpha 1-2	1.09	1.02	1.30	1.21	1.12	1.04	1.26	1.18

Blue	Dark
Dark	Blue
0.35	0.35
0.35	0.35
0.8327	0.8406
0.8406	0.8327
470	470
470	470
0.3	0.3
0.7	0.7
1342.86	1342.86
1342.86	1342.86
1342.86	1342.86
564.43	559.12
2.38	2.40

Violet	Dark
Dark	Violet
0.35	0.87
0.87	0.35
0.8327	0.8406
0.8406	0.8327
420	420
420	420
0.3	0.3
0.7	0.7
1200.00	482.76
482.76	1200.00
697.93	984.83
504.38	499.64
1.38	1.97

Blue	Light
Light	Blue
0.35	0.35
0.35	0.35
0.4803	0.4469
0.4469	0.4803
470	470
470	470
0.3	0.3
0.7	0.7
1342.86	1342.86
1342.86	1342.86
1342.86	1342.86
978.56	1051.69
1.37	1.28

Green	Light
Light	Green
0.35	0.35
0.35	0.35
0.4803	0.4469
0.4469	0.4803
420	420
420	420
0.3	0.3
0.7	0.7
1200.00	1200.00
1200.00	1200.00
1200.00	1200.00
874.45	939.81
1.37	1.28

I

One result from the mathematical formula

The effect of the average Complexity factor regarding the combination of wavelength

	White	Black	Dark	Light	Gray	Temp	Hue	Complementary
	Red							
high	0.5	0.63	0.6	0.34	0.34	0.84	0.5	0.83
low	0.22	0.6	0.68	0.33	0.37	0.78	0.46	0.65
Averege	0.36	0.615	0.64	0.335	0.355	0.81	0.48	0.74
	Orange							
high	0.41	0.71	0.58	0.68	0.64	0.64	0.7	0.8
low	0.31	0.67	0.72	0.38	0.47	0.81	0.75	0.89
Averege	0.36	0.69	0.65	0.53	0.56	0.73	0.73	0.85
	Yellow							
high	0.4	0.69	0.47	0.34	0.46	0.7	0.58	0.77
low	0.31	0.64	0.62	0.36	0.49	0.7	0.45	0.7
Averege	0.36	0.67	0.55	0.35	0.48	0.70	0.52	0.74
	Green							
high	0.23	0.61	0.4	0.72	0.38	0.7	0.67	0.83
low	0.49	0.81	0.35	0.66	0.42	0.82	0.74	0.65
Averege	0.36	0.71	0.375	0.69	0.4	0.76	0.705	0.74
	Blue							
high	0.4	1	0.84	0.32	0.38	0.61	0.77	0.89
low	0.33	0.88	0.68	0.43	0.36	0.66	0.93	0.8
Averege	0.37	0.94	0.76	0.38	0.37	0.64	0.85	0.85
	Violet							
high	0.47	0.6	0.42	0.25	0.23	0.82	0.82	0.7
low	0.27	0.74	0.57	0.25	0.27	0.71	0.74	0.4
Averege	0.37	0.67	0.50	0.25	0.25	0.765	0.78	0.55

* 1= the most complex combination.

J

The process of selecting adjectives that described the terms simple and complex

The process of selecting the list of words to describe the terms simple and complex colour combination involved analysing some selected definitions and finding words and meanings that would describe the quotes.

"Simple colours are the proper colours of the element" Aristotle (384-322 B.C.)

balanced, unbalanced, coherence

LOW CONTRAST, HIGH CONTRAST, POWERFUL

"Perfection, then, is finally achieved, not when there is nothing left to add, but when there is nothing left to take away." Antoine de Saint-Exupéry. (Brace, 2008)

BASIC, COMPLICATED, HARMONY

"Simplicity is the lack of obstruction, or lack of complexity." Jacob Nielsen - The beauty of simplicity. (2000)

"Simplicity keeps things visual, clear and focused." Luke Wroblewski (2010) Visual simplicity vs information density.

CLEAR, CONFUSED, INTERESTING

"One way to measure complexity is by the amount of time required to learn the item." Don Norman (2010) Living with complexity.

EASY, DIFFICULT, POOR

"Simplicity is achieved when everyone can easily understand and use the design, regardless of experience, literacy, or concentration level. Basic guidelines" William Lidwell, Kritina Holden, and Jill Butler (2003)

EFFORTLESS, CHALLENGING, RICH

"Simplicity is not an end in art, but we usually arrive at simplicity as we approach the true sense of things." Constantin Brancusi. (Brace, 2008)

Focused, unfocused, pleasing

TRUST, NOISY, QUALITY

"The ability to simplify means to eliminate the unnecessary so that the necessary may speak." Hans Hofmann. (Brace, 2008)

QUITE, LOUD, POWERLESS

K

A sample of the online questionnaire used to verify the data study

• This activity is voluntary and you can withdraw at any time.

• This activity is for designers and design students only.

• Please be aware that your response will be used in an academic research and publications; however, they are anonymous and will be kept strictly confidential. By answering the questionnaire, you are accepting the terms and conditions of Bournemouth university.

***1. Which category below includes your age?**

- ◯ 17 or younger
- ◯ 18-20
- ◯ 21-29
- ◯ 30-39
- ◯ 40-49
- ◯ 50-59
- ◯ 60 or older

***2. Are you male or female?**

- ◯ Male
- ◯ Female

***3. Are you a designer or a design student?**

- ◯ Designer
- ◯ Design Student
- ◯ Other (please specify)

Page 1 - 14

The images A, B & C presenting different colour combination.

A

B

C

***4. which image is the most simpler one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

***5. Which image is the most complex one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

Page 2 - 14

The images A, B & C presenting different colour combination.

A

B

C

***6. which image is the most simpler one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

***7. Which image is the most complex one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

Page 3 - 14

The images A, B & C presenting different colour combination.

A

B

C

***8. which image is the most simpler one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

***9. Which image is the most complex one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

Page 4 - 14

The images A, B & C presenting different colour combination.

A

B

C

***10. which image is the most simpler one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

***11. Which image is the most complex one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

Page 5 - 14

The images A, B & C presenting different colour combination.

A

B

C

***12. which image is the most simpler one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

***13. Which image is the most complex one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

Page 6 - 14

The images A, B & C presenting different colour combination.

A

B

C

***14. which image is the most simpler one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

***15. Which image is the most complex one to read time?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

Page 7 - 14

The images A, B & C presenting different colour combination.

A

B

C

***16. Which image is the most simpler one to see the cow?**

- Image A
- Image B
- Image C

***17. Which image is the most complex one to see the cow?**

- Image A
- Image B
- Image C

Page 8 - 14

The images A, B & C presenting different colour combination.

A

B

C

***18. Which image is the most simpler one to see the cow?**

- Image A
- Image B
- Image C

***19. Which image is the most complex one to see the cow?**

- Image A
- Image B
- Image C

Page 9 - 14

The images A, B & C presenting different colour combination.

A

B

C

***20. Which image is the most simpler one to see the cow?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

***21. Which image is the most complex one to see the cow?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

Page 10 - 14

The images A, B & C presenting different colour combination.

A

B

C

***22. Which image is the most simpler one to see the cow?**

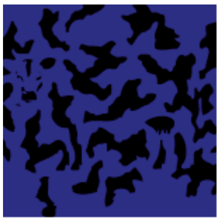
- ◯ Image A
- ◯ Image B
- ◯ Image C

***23. Which image is the most complex one to see the cow?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

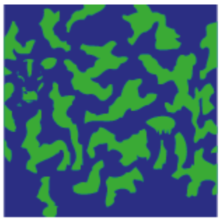
Page 11 - 14

The images A, B & C presenting different colour combination.



A

B



C

***24. Which image is the most simpler one to see the cow?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

***25. Which image is the most complex one to see the cow?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

Page 12 - 14

The images A, B & C presenting different colour combination.

A

B

C

***26. Which image is the most simpler one to see the cow?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

***27. Which image is the most complex one to see the cow?**

- ◯ Image A
- ◯ Image B
- ◯ Image C

Page 13 - 14

The images are sorted from the simplest to the most complex colour combination.

قم باختيار ٥ مرادفات تعبر عن العلاقة اللونيه البسيطة

the simplest the most complex

***28. Choose the most 5 adjective that express the word Simple colour combination.**

- [ ] balanced
- [ ] basic
- [ ] challenging
- [ ] clear
- [ ] coherence
- [ ] complicated
- [ ] confused
- [ ] difficult
- [ ] easy
- [ ] effortless
- [ ] focused
- [ ] harmony
- [ ] high contrast
- [ ] interesting
- [ ] loud
- [ ] low contrast
- [ ] noisy
- [ ] pleasing
- [ ] poor
- [ ] powerful
- [ ] powerless
- [ ] quality
- [ ] quite
- [ ] rich
- [ ] trust
- [ ] unbalanced
- [ ] Unfocused

Page 14 - 14

The images are sorted from the simplest to the most complex colour combination.

the simplest the most complex

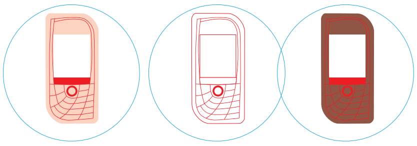
***29. Choose the most 5 adjective that express the word Complex colour combination.**

قم باختيار ٥ مرادفات تعبر عن العلاقة اللونيه المعقده

- [ ] balanced
- [ ] basic
- [ ] challenging
- [ ] clear
- [ ] coherence
- [ ] complicated
- [ ] confused
- [ ] difficult
- [ ] easy
- [ ] effortless
- [ ] focused
- [ ] harmony
- [ ] high contrast
- [ ] interesting
- [ ] loud
- [ ] low contrast
- [ ] noisy
- [ ] pleasing
- [ ] poor
- [ ] powerful
- [ ] powerless
- [ ] quality
- [ ] quite
- [ ] rich
- [ ] trust
- [ ] unbalanced
- [ ] Unfocused

L

The final colour combination used in the data verification study



Contrast of Value
42
%70 Light Red
%30 Red

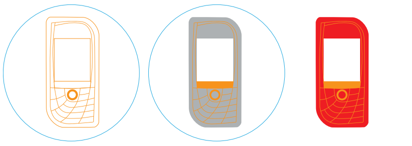
Contrast of Value
61
%70 White
%30 Red

Contrast of Value
73
%70 Dark Red
%30 Red

Contrast of Value
Complexity Factor 42
%70 Light Red
%30 Red

Contrast of Value
Complexity Factor 61
%70 White
%30 Red

Contrast of Value
Complexity Factor 73
%70 Dark Red
%30 Red



Contrast of Value
41
%70 White
%30 Orange

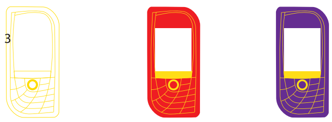
Simutaneous Contrast
66
%70 Gray
%30 Orange

Contrast of Hue
81
%70 Red
%30 Orange

Contrast of Value
Complexity Factor 41
%70 White
%30 Orange

Simutaneous Contrast
Complexity Factor 66
%70 Gray
%30 Orange

Contrast of Hue
Complexity Factor 81
%70 Red
%30 Orange



Contrast of Value
7
%70 White
%30 Yellow

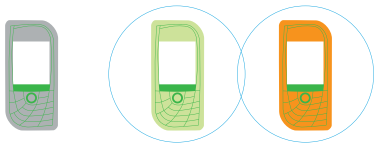
Contrast of Hue
60
%70 Red
%30 Yellow

Complementary Contrast
87
%70 Violet
%30 Yellow

Contrast of Value
Complexity Factor 37
%70 White
%30 Yellow

Contrast of Hue
Complexity Factor 60
%70 Red
%30 Yellow

Complementary Contrast
Complexity Factor 87
%70 Violet
%30 Yellow



Simutaneous Contrast
37
%70 Gray
%30 Green

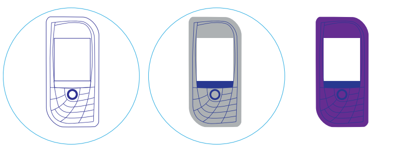
Contrast of Value
45
%70 Light Green
%30 Green

Contrast of Temperature
73
%70 Orange
%30 Green

Simutaneous Contrast
Complexity Factor 37
%70 Gray
%30 Green

Contrast of Value
Complexity Factor 45
%70 Light Green
%30 Green

Contrast of Temperature
Complexity Factor 73
%70 Orange
%30 Green



Contrast of Value
38
%70 White
%30 Blue

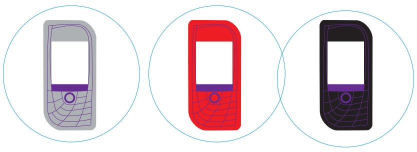
Simutaneous Contrast
37
%70 Gray
%30 Blue

Contrast of Hue
90
%70 Violet
%30 Blue

Contrast of Value
Complexity Factor 38
%70 White
%30 Blue

Simutaneous Contrast
Complexity Factor 37
%70 Gray
%30 Blue

Contrast of Hue
Complexity Factor 90
%70 Violet
%30 Blue



Simutaneous Contrast
39
%70 Gray
%30 Violte

Contrast of Temperature
87
%70 Red
%30 Violte

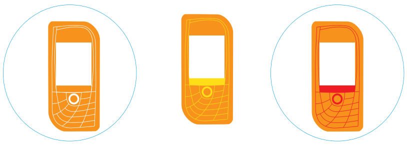
Contrast of Value
100
%70 Black
%30 Violte

Simutaneous Contrast
Complexity Factor 39
%70 Gray
%30 Violte

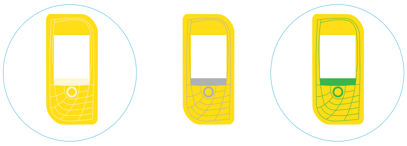
Contrast of Temperature
Complexity Factor 87
%70 Red
%30 Violte

Contrast of Value
Complexity Factor 100
%70 Black
%30 Violte

Contrast of Value	Simutaneous Contrast	Complementary Contrast
Complexity Factor 27	Complexity Factor 45	Complexity Factor 92
%70 Red	%70 Red	%70 Red
%30 White	%30 Gray	%30 Green

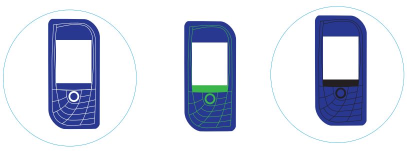


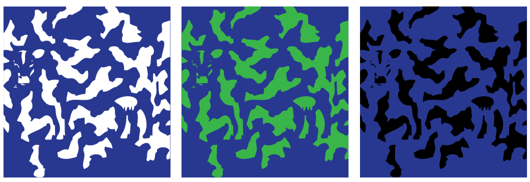
Contrast of Value	Contrast of Hue	Contrast of Hue
Complexity Factor 32	Complexity Factor 66	Complexity Factor 81
%70 Orange	%70 Orange	%70 Orange
%30 White	%30 Yellow	%30 Red



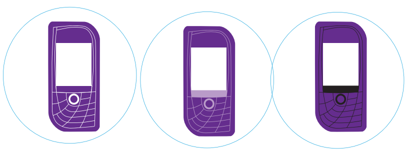
Contrast of Value	Simutaneous Contrast	Contrast of Temperature
Complexity Factor 40	Complexity Factor 55	Complexity Factor 76
%70 Yellow	%70 Yellow	%70 Yellow
%30 Light Yellow	%30 Gray	%30 Green

Contrast of Value	Contrast of Value	Complementary Contrast
Complexity Factor 24	Complexity Factor 40	Complexity Factor 76
%70 Green	%70 Green	%70 Green
%30 White	%30 Light Green	%30 Red





Contrast of Value	Contrast of Hue	Contrast of Value
Complexity Factor 32	Complexity Factor 69	Complexity Factor 85
%70 Blue	%70 Blue	%70 Blue
%30 White	%30 Green	%30 Black



Contrast of Value	Contrast of Value	Contrast of Value
Complexity Factor 26	Complexity Factor 42	Complexity Factor 87
%70 Violte	%70 Violte	%70 Violte
%30 White	%30 Light Violte	%30 Black

Appendix

M

The detailed report of the data verification study

The results of the verification the data study

1. Which category below includes your age?

Answers Option		Response Percent	Response Count
17 or younger		0	0
18-20		19	10
21-29		**65**	**35**
30-39		15	8
40-49		2	1
50-59		0	0
60 or older		0	0
	answers question	100	54

2. Are you male or female?

answers option		Response Percent	Response Count
Male		**81**	**44**
Female		19	10
	answers question	100	54

3. Are you a designer or a design student?

answers option		Response Percent	Response Count
Designer		20	11
Design Students		**65**	**35**
Other		15	8
	answers question	100	54

A B C

4. which image is the most simpler one to read time? Red

Answers Option	Response Percent	Response Count
Image A*	**85**	**46**
Image B	15	8
Image C	0	0
answers question	100	54

5. which image is the most complex one to read time? Red

answers option	Response Percent	Response Count
Image A	0	0
Image B	0	0
Image C*	**100**	**54**
answers question	100	54

A B C

6. which image is the most simpler one to read time? Orange

Answers Option	Response Percent	Response Count
Image A	0	0
Image B*	**83**	**45**
Image C	17	9
answers question	100	54

7. which image is the most complex one to read time? Orange

answers option	Response Percent	Response Count
Image A*	**83**	**45**
Image B	0	0
Image C	17	9
answers question	100	54

8. which image is the most simpler one to read time? **Yellwo**

Answers Option	Response Percent	Response Count
Image A	11	6
Image B	24	13
Image C*	**65**	**35**
answers question	100	54

9. which image is the most complex one to read time? **Yellwo**

answers option	Response Percent	Response Count
Image A	26	14
Image B*	**63**	**34**
Image C	11	6
answers question	100	54

10. which image is the most simpler one to read time? **Green**

Answers Option	Response Percent	Response Count
Image A*	**94**	**51**
Image B	6	3
Image C	0	0
answers question	100	54

11. which image is the most complex one to read time? **Green**

answers option	Response Percent	Response Count
Image A	0	0
Image B	0	0
Image C*	**100**	**54**
answers question	100	54

A B C

12. which image is the most simpler one to read time? **Blue**

Answers Option	Response Percent	Response Count
Image A	0	0
Image B*	**93**	**50**
Image C	7	4
answers question	100	54

13. which image is the most complex one to read time? **Yellwo**

answers option	Response Percent	Response Count
Image A*	**98**	**53**
Image B	0	0
Image C	2	1
answers question	100	54

A B C

14. which image is the most simpler one to read time? **Violet**

Answers Option	Response Percent	Response Count
Image A	13	7
Image B	0	0
Image C*	**87**	**47**
answers question	100	54

15. which image is the most complex one to read time? **Green**

answers option	Response Percent	Response Count
Image A	37	20
Image B*	**63**	**34**
Image C	0	0
answers question	100	54


A


B


C

16. which image is the most simpler one to see the cow? Red

Answers Option	Response Percent	Response Count
Image A*	**83**	**45**
Image B	11	6
Image C	6	3
answers question	100	54

17. which image is the most complex one to see the cow? Red

answers option	Response Percent	Response Count
Image A	4	2
Image B	19	10
Image C*	**78**	**42**
answers question	100	54


A


B


C

18. which image is the most simpler one to see the cow? Orange

Answers Option	Response Percent	Response Count
Image A	13	7
Image B*	**65**	**35**
Image C	22	12
answers question	100	54

19. which image is the most complex one to see the cow? Orange

answers option	Response Percent	Response Count
Image A*	**67**	**36**
Image B	0	0
Image C	33	18
answers question	100	54

20. which image is the most simpler one to see the cow? Yellow

Answers Option	Response Percent	Response Count
Image A	17	9
Image B	33	18
Image C*	**50**	**27**
answers question	100	54

21. which image is the most complex one to see the cow? Yellow

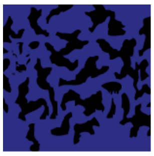
answers option	Response Percent	Response Count
Image A	35	19
Image B*	**43**	**23**
Image C	22	12
answers question	100	54

22. which image is the most simpler one to see the cow? Green

Answers Option	Response Percent	Response Count
Image A*	**56**	**30**
Image B	39	21
Image C	6	3
answers question	100	54

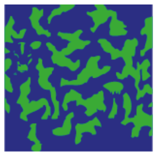
23. which image is the most complex one to see the cow? Green

answers option	Response Percent	Response Count
Image A	2	1
Image B	11	6
Image C*	**87**	**47**
answers question	100	54



A

B



C

24. which image is the most simpler one to see the cow? **Blue**

Answers Option	Response Percent	Response Count
Image A	7	4
Image B*	**72**	**39**
Image C	20	11
answers question	100	54

25. which image is the most complex one to see the cow? **Blue**

answers option	Response Percent	Response Count
Image A*	**81**	**44**
Image B	6	3
Image C	13	7
answers question	100	54

A

B

C

26. which image is the most simpler one to see the cow? **Violet**

Answers Option	Response Percent	Response Count
Image A	39	21
Image B	11	6
Image C*	**50**	**27**
answers question	100	54

27. which image is the most complex one to see the cow? **Violet**

answers option	Response Percent	Response Count
Image A	17	9
Image B*	**83**	**45**
Image C	0	0
answers question	100	54

28. Choose the most 5 adjective that express the word Simple colour combination.

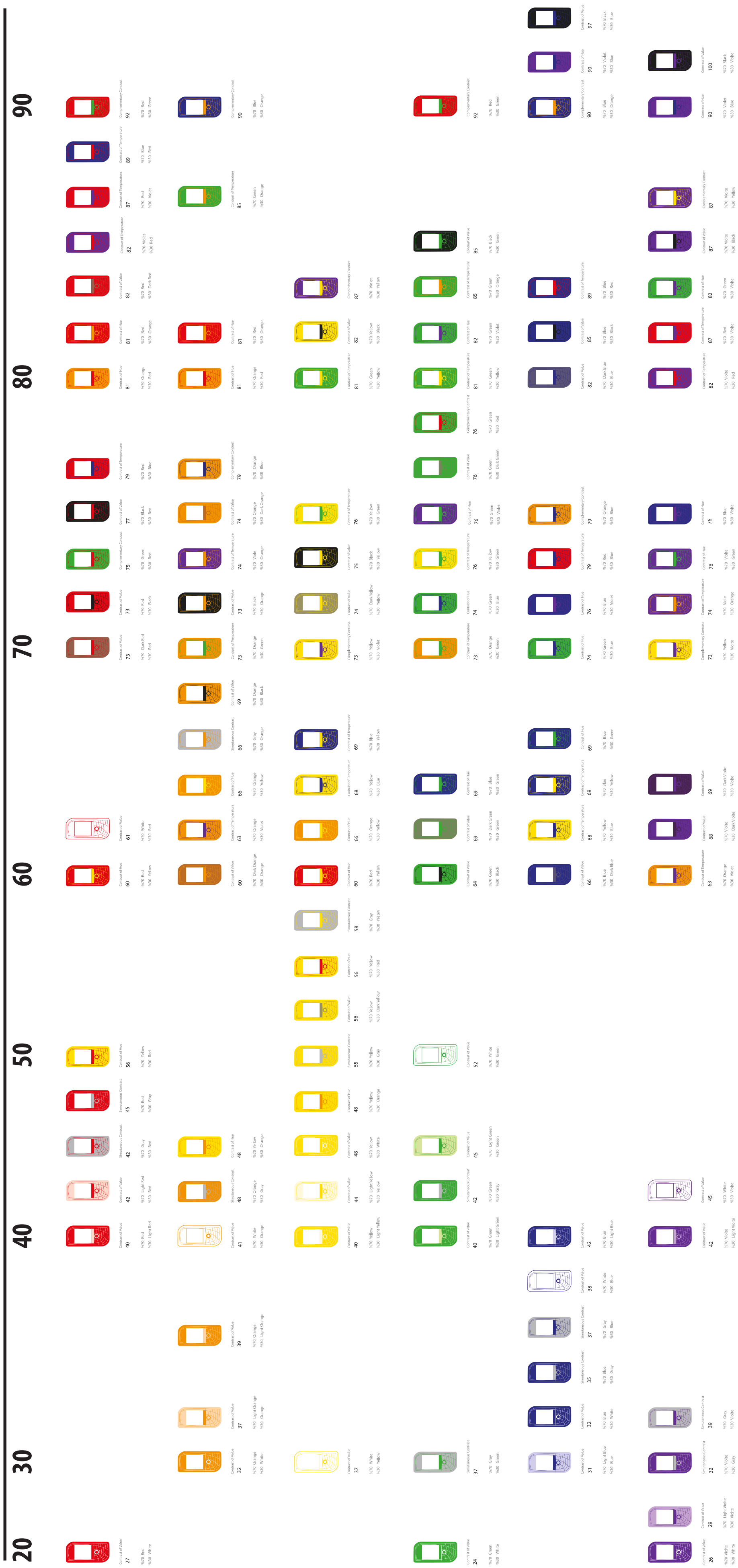
Answers Option	Response Percent	Response Count
balanced	**11**	**31**
basic	10	27
clear	**16**	**43**
easy	**12**	**33**
effortless	5	13
focused	5	14
low contrast	3	8
quite	3	7
trust	3	9
coherence	2	6
harmony	8	21
interesting	3	9
poor	0	1
rich	2	5
pleasing	5	15
powerful	3	8
powerless	1	3
quality	5	14
unbalanced	0	0
complicated	0	0
confused	0	1
difficult	0	0
challenging	0	0
Unfocused	0	1
high contrast	0	0
loud	0	1
noisy	0	0
answers question	100	270

28. Choose the most 5 adjective that express the word complex colour combination.

Answers Option	Response Percent	Response Count
balanced	0	0
basic	0	0
clear	0	0
easy	0	0
effortless	0	0
focused	0	0
low contrast	0	0
quite	0	0
trust	0	0
coherence	0	0
harmony	0	0
interesting	1	4
poor	4	11
rich	1	2
pleasing	0	1
powerful	6	15
powerless	1	3
quality	0	1
unbalanced	**11**	**31**
complicated	7	18
confused	11	30
difficult	**14**	**37**
challenging	7	19
Unfocused	7	18
high contrast	8	21
loud	8	21
noisy	**14**	**38**
answers question	100	270

N

Presentation of the different degrees of complexity of the colour combinations


20
30
40
50
60
70
80
90

O

A sample of the tool testing questionnaire

Tool Evaluation

Intro

• This activity is voluntary and you can withdraw at any time.
• This activity is for designers and design students only.
• Please be aware that your response will be used in an academic research and publications; however, they are anonymous and will be kept strictly confidential. By answering the questionnaire, you are accepting the terms and conditions of Bournemouth university.

1. Which category below includes your age?

- 17 or younger
- 18-20
- 21-29
- 30-39
- 40-49
- 50-59
- 60 or older

*2. Are you a designer or a design student?

- Designer
- Design Student
- Other (please specify)

Tool Evaluation

Clarity and Design

7. Does the tool name have a clear meaning?

- ○ Extremely clearly
- ○ Very clearly
- ○ Moderately clearly
- ○ Slightly clearly
- ○ Not at all clearly

8. How did you find the tool layout?

- ○ Extremely clearly
- ○ Very clearly
- ○ Moderately clearly
- ○ Slightly clearly
- ○ Not at all clearly

9. How did you find the design decision used in the tool?

- ○ Extremely well
- ○ Very well
- ○ Moderately well
- ○ Slightly well
- ○ Not at all well

10. How did you find the text size used on the tool?

- ○ Extremely readable
- ○ Very readable
- ○ Moderately readable
- ○ Slightly readable
- ○ Not at all readable

11. How easy did you find the information attached to each design?

- ○ Extremely easy
- ○ Very easy
- ○ Moderately easy
- ○ Slightly easy
- ○ Not at all easy

12. Have you found the tool layout pleasing?

- ○ Yes
- ○ No

13. Have you found the icons for the colour contrast relevant?

- ○ Extremely relevant
- ○ Very relevant
- ○ Moderately relevant
- ○ Slightly relevant
- ○ Not at all relevant

14. Was the colour GRAY suited to be used in the tool design?

- ○ Yes
- ○ No

15. Additional comments:

Tool Evaluation

Functionality

16. How did you find Learning to use the tool.

◯ Extremely easy ◯ Very easy ◯ Moderately easy ◯ Slightly easy ◯ Not at all easy

17. How did you find Learning to select a Colour contrast.

◯ Extremely easy ◯ Very easy ◯ Moderately easy ◯ Slightly easy ◯ Not at all easy

18. How did you find the experience with the tool functionality?

◯ Extremely easy ◯ Very easy ◯ Moderately easy ◯ Slightly easy ◯ Not at all easy

19. Was the tool easy to navigate?

◯ Extremely easy ◯ Very easy ◯ Moderately easy ◯ Slightly easy ◯ Not at all easy

20. Were the colours used in the tool enough to give you an idea of what other colours can do?

◯ Extremely agree ◯ Very agree ◯ Moderately agree ◯ Slightly agree ◯ Not at all agree

21. Did the process become automatic after a while?

◯ Extremely agree ◯ Very agree ◯ Moderately agree ◯ Slightly agree ◯ Not at all agree

22. Additional comments:

Tool Evaluation

Information and Agreement

23. Was the information presented with each design helpful?

- ◯ Extremely helpful
- ◯ Very helpful
- ◯ Moderately helpful
- ◯ Slightly helpful
- ◯ Not at all helpful

24. Did you agree with the information presented?

- ◯ Extremely agree
- ◯ Very agree
- ◯ Moderately agree
- ◯ Slightly agree
- ◯ Not at all agree

25. Were you surprised with some of the results?

- ◯ Yes
- ◯ No

26. Will you be revisiting the tool to check the colour complexity in future work?

- ◯ Yes
- ◯ No
- ◯ Maybe

27. will you be influenced by the tool information?

- ◯ Yes
- ◯ No
- ◯ Maybe

28. Were you inspired by the extra three designs at the tool foot?

- ◯ Yes
- ◯ No
- ◯ I didn't find it

29. Additional comments:

Tool Evaluation

Tool Experience

30. Has this exercise changed your view of colour in design?

◯ Extremely agree ◯ Very agree ◯ Moderately agree ◯ Slightly agree ◯ Not at all agree

31. Do you think the system enhances creativity and design?

◯ Extremely agree ◯ Very agree ◯ Moderately agree ◯ Slightly agree ◯ Not at all agree

32. Can you see this tool being used in a design decision?

◯ Extremely agree ◯ Very agree ◯ Moderately agree ◯ Slightly agree ◯ Not at all agree

33. Do you think the system enhances creativity and design?

◯ Extremely agree ◯ Very agree ◯ Moderately agree ◯ Slightly agree ◯ Not at all agree

34. Did the tool provide a stimulus for idea for colour combination?

◯ Extremely agree ◯ Very agree ◯ Moderately agree ◯ Slightly agree ◯ Not at all agree

35. How effective do you think this tool will be as colour decision-making?

◯ Extremely effective ◯ Very effective ◯ Moderately effective ◯ Slightly effective ◯ Not at all effective

36. Do you think colour combination choose in important in design?

◯ Extremely agree ◯ Very agree ◯ Moderately agree ◯ Slightly agree ◯ Not at all agree

37. Additional comments:

38. What do you like most about this tool?

39. What changes would most improve this tool?

P

A detailed report on the tool test results

Appendix O
Survey questionnaire results

The results of the Colour Complexity Calculator evaluation are shown below; they are expressed as specific response distributions as well as in narrative format. There were twenty evaluation participants in total in this study.

Demographics

1. Which category below includes your age?

Answers Option	Response Percent	Response Count
17 or younger	0%	0
18-20	0%	0
21-29	**60%**	**12**
30-39	40%	8
40-49	0%	0
50-59	0%	0
60 or older	0%	0
	answered question	20
	skipped question	0

The participants ranged in age from 21 through 39 with 60% of participants being between the ages of 21 and 29 and 40% being between ages 30 and 39.

3. Are you a designer or a design student?

answers option	Response Percent	Response Count
Designer	**50%**	10
Design Students	**50%**	**10**
	answered question	20
	skipped question	0

There was an even split between professional designers and design students with 50% of participants falling into the professional designer category and 50% of participants falling into the design student category.

layout and design

1. Does the tool name have a clear meaning?

Answers Option	Response Percent	Response Count
Extremely clear	**40%**	**8**
Very clear	**40%**	**8**
Moderately clear	20%	4
Slightly clear	0%	0
Not at all clear	0%	0
	answered question	20
	skipped question	0

The majority of participants felt that the tool name, Colour Complexity Calculator, had a clear meaning with 40% of participants responding 'Extremely clear' and 40% responding 'Very clear'. Twenty percent of respondents felt that the meaning was 'Moderately clear'.

2. How did you find the clarity of the tool layout?

answers option	Response Percent	Response Count
Extremely clear	30%	6
Very clear	**60%**	**12**
Moderately clear	10%	2
Slightly clear	0%	0
Not at all clear	0%	0
	answered question	20
	skipped question	0

Most respondents felt that the tool layout was 'Very clear' and 30% felt that the tool layout was 'Very clear'. Only 10% felt that it was 'Moderately clear' and none of the participants felt that the tool layout was 'Not clear at all' or even 'Slightly clear'.

3. How did you find the text size used on the tool?

answers option	Response Percent	Response Count
Extremely readable 80%	**16**	
Very readable	20%	4
Readable	0%	0
Slightly unreadable 0%	0	
Unreadable	0%	0
	answered question	20
	skipped question	0

Participants appear to be satisfied with the text size used on the tool with 80% stating that it was 'Extremely readable' and 20% stating that it was 'Very easy' to read.

4. How easy did you find the information attached to each design?

answers option	Response Percent	Response Count
Extremely easy	**80%**	**16**
Very easy	20%	4
Moderately easy	0%	0
Slightly easy	0%	0
Not at all easy	0%	0
	answered question	20
	skipped question	0

All participants indicated that the information attached to each design was 'Extremely easy' (80%) or 'Very easy' (20%) to understand.

5. Overall, the tool layout has a good design decision?

Answers Option		Response Percent	Response Count
Yes	**Yes**	**100%**	**20**
No	No	0%	0
		answered question	20
		skipped question	0

One hundred percent of the participants indicated that the tool layout was representative of a good design decision.

6. Have you found the icons for the colour contrast relevant?

answers option		Response Percent	Response Count
Extremely relevant	**70%**	**14**	
Very relevant		15%	3
Moderately relevant	10%	2	
Slightly relevant		5%	1
Not at all relevant		0%	0
		answered question	20
		skipped question	0

Seventy percent of the participants found the icons for the colour contrast to be 'Relevant', while 15% felt they were 'Very relevant'. However, 10% found the icons only 'Moderately relevant', and 5% found them to be only 'Slightly relevant'.

7. Was the colour grey suited to be used in the tool design?

answers option	Response Percent	Response Count
Yes	**90%**	**18**
No	10%	2
	answered question	20
	skipped question	0

Ninety percent of participants agreed that the use of the colour grey in the tool design was 'Acceptable'. Ten percent felt that the use of grey was 'Not acceptable'.

Functionality

8. How easy did you learn using the tool?

Answers Option	Response Percent	Response Count
Extremely easy	**80%**	**16**
Very easy	20%	4
Easy	0%	0
Slightly easy	0%	0
Not at all easy	0%	0
	answered question	20
	skipped question	0

Eighty percent of participants felt that learning how to use the tool was 'Extremely easy'. The remaining 20% felt it was 'Very easy' to learn.

9. How did you find the experience with the tool functionality?

answers option		Response Percent	Response Count
Extremely functional		**80%**	**16**
Very functional		5%	1
Moderately functional		15%	3
Slightly functional	0%	0	
Not at all functional	0%	0	
	answered question	20	
		skipped question	0

Eighty-five percent of the participants felt that the tool was 'Extremely functional' or 'Very functional', and 15% of participants felt that it was 'Moderately functional'.

10. Was the tool easy to navigate?

answers option	Response Percent	Response Count
Extremely easy	**95%**	**19**
Very easy	0%	0
Moderately easy	5%	1
Slightly easy	0%	0
Not at all easy	0%	0
	answered question	20
	skipped question	0

Ninety-five percent of participants felt that the tool was 'Easy to navigate' and 5% felt that it was 'Moderately easy to navigate'.

11. Were the colours used in the tool enough to give you an idea of what other colours can be?

answers option	Response Percent	Response Count
Extremely agree	**75%**	**15**
Very agree	10%	2
Moderately agree	15%	3
Slightly agree	0%	0
Not at all agree	0%	0
	answered question	20
	skipped question	0

Eighty-five percent of the participants answered that they "Strongly agreed' that the colours used in the tool provided an idea of what other colour combinations would be like. Fifteen percent 'Moderately agreed'.

12. Did the process become Intuitive after a while?

Answers Option	Response Percent	Response Count
Extremely agree	**100%**	**20**
Very agree	0%	0
Moderately agree	0%	0
Slightly agree	0%	0
Not at all agree	0%	0
	answered question	20
	skipped question	0

One-hundred percent of participants felt that the tool provided for this research became intuitive after some time of use.

Information and Agreement

13. Was the information presented with each design helpful?

answers option	Response Percent	Response Count
Extremely helpful 60%	**12**	
Very helpful	30%	6
Moderately helpful 10%	2	
Slightly helpful	0%	0
Not at all helpful	0%	0
	answered question	20
	skipped question	0

Ninety percent of participants felt that the information presented with each design was helpful. Ten percent found the information presented with each design model to be 'Moderately helpful'.

14. Did you agree with the information presented?

answers option	Response Percent	Response Count
Extremely agree	**75%**	**15**
Very agree	10%	2
Moderately agree	15%	3
Slightly agree	0%	0
Not at all agree	0%	0
	answered question	20
	skipped question	0

Eighty-five percent of participants either answered 'Very agree' or 'Extremely agree'. The remaining 15% of participants 'Moderately agree' that they agreed with the information presented by the tool.

15. Will you revisit the tool in future work, to check the colour complexity?

answers option	Response Percent	Response Count
Extremely	10%	2
Very	**70%**	**14**
Moderately	20%	4
Slightly agree	0%	0
Not at all agree	0%	0
	answered question	20
	skipped question	0

With regard to whether participants would revisit the tool to check the colour complexity, 80% said they were 'Extremely likely' or 'Very likely' to revisit the tool. Twenty percent said they were only 'Moderately likely' to revisit the tool.

16 Have you been influenced by the tool information?

Answers Option	Response Percent	Response Count
Extremely	**90%**	**18**
Very	10%	2
Moderately agree	0%	0
Slightly agree	0%	0
Not at all agree	0%	0
	answered question	20
	skipped question	0

With regard to whether participants were influenced by using the tool information, 100% stated that they were 'Strongly' or 'Very much' influenced by the information provided by the tool.

17. Were you inspired by the extra three designs at the tool foot?

answers option	Response Percent	Response Count
Extremely	**85%**	**17**
Very	5%	1
Moderately	10%	2
Slightly helpful	0%	0
Not at all helpful	0%	0
	answered question	20
	skipped question	0

When asked whether they were inspired by the three extra designs at the bottom of the tool, 90% of participants indicated that they were 'Extremely' or 'Very much' inspired by the presence of the three designs.

Tool Experience

18. Has this exercise changed your view of colour in design?

answers option	Response Percent	Response Count
Extremely agree	**85%**	**17**
Very agree	15%	3
Moderately agree	0%	0
Slightly agree	0%	0
Not at all agree	0%	0
	answered question	20
	skipped question	0

When asked if the exercise that they completed for this study changed their view of colour design, 100% of participants indicated that they 'Agree' or 'Strongly agree' that the study had changed their views about use of colour in design.

19. Can you see this tool being used in a design colour decision?

answers option	Response Percent	Response Count
Extremely agree	**85%**	**17**
Very agree	10%	2
Moderately agree	5%	1
Slightly agree	0%	0
Not at all agree	0%	0
	answered question	20
	skipped question	0

Ninety-five percent of participants answered that they 'Agree' or 'Very agree' that they could see this tool being used in a design colour decision.

20. Do you think the system enhances creativity and design?

Answers Option	Response Percent	Response Count
Extremely agree	**75%**	**15**
Very agree	25%	5
Moderately agree	0%	0
Slightly agree	0%	0
Not at all agree	0%	0
	answered question	20
	skipped question	0

One-hundred percent of participants felt that the system enhanced creativity and design. Seventy-five percent stated that they 'Agree'. Twenty-five percent of participants stated they 'Strongly agree'.

21. Did the tool provide a stimulus of ideas for colour combinations?

answers option	Response Percent	Response Count
Extremely agree	**75%**	**15**
Very agree	15%	3
Moderately agree	10%	2
Slightly helpful	0%	0
Not at all helpful	0%	0
	answered question	20
	skipped question	0

Ninety percent of participants 'Agree' or 'Strongly agree' that the tools stimulated ideas for colour combinations. Ten percent 'Moderately agreed'.

22. How effective do you think this tool will be in colour decision-making in design?

answers option	Response Percent	Response Count
Extremely effective 70%	**14**	
Very effective	30%	6
Moderately effective 0%	0	
Slightly agree	0%	0
Not at all agree	0%	0
	answered question	20
	skipped question	0

When asked how effective this tool might be in colour decision-making for design, 100% of respondents felt that it would be effective: 70% said 'Extremely effective' and 30% said 'Very effective'.

23. Do you think colour combination choice is important in design?

answers option	Response Percent	Response Count
Extremely agree	**100%**	**20**
Very agree	0%	0
Moderately agree	0%	0
Slightly agree	0%	0
Not at all agree	0%	0
	answered question	20
	skipped question	0

One hundred percent of the participants believed that colour combination choice is important in design.

24. Additional comments:
1. I like the way in which the information was presented, and how one led to another.
2. I was surprised by the effect of colour on design form.
3. I like the way you can apply the colour combinations to different designs.
4. I definitely will visit the site in my future work.
5. I wonder if there are more colours.

25. What do you like most about the tool:
1. I like the favourite option. I like to get back again to old selections.
2. The easy use.
3. Nice design, not busy.
4. Simplicity.
5. The icons in the top.
6. I like the idea of the adjustable complexity factor.
7. Nice touch of the RGB, Pantone colour code.
8. The use of grey in all the design elements.

26. What changes would most improve this tool:
1. If I can upload my design to test the colour combination on it.
2. If I get more options of design application to apply the colour combination on.
3. If I can save the favourite or share it with a friend via email.
4. The text is too small.
5. Absence of print option.
6. More design options for the application are needed.
7. Information regarding the upper part needs to be made available.
8. Lack of comparison of two or more colour combinations on one page.
9. Upload my design.