Graphic Legibility Enhancement using Simplification Guidelines

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

This study explores an approach to app icon legibility enhancement. Four areas of research are included: (1) design process; (2) the trend of logo/app icon redesign; (3) graphic legibility and (4) graphic simplification. It presents the results of five experiments designed to capture and compare design principles. Firstly, the result categorised the characteristics of simple shape. Secondly, the agreement of simplification judgement was summarised based on the average score of participants. Thirdly, the impact of each simplification criterion was compared and represented as a ratio; a measurement template and simplification guidelines were also generated at this stage. Fourthly, how this design principle (simplification guidelines) can be applied in practical use by student designers was examined. Finally, the legibility enhancement test was proved by the results of reaction time and accuracy improvement. The findings of this study determined the impact of simplification criteria with regard to: component, open-closed, weight, form, symmetry, angles and straight-curved respectively. After identifying these design principles (simplification guidelines), graphic designers, user interface designers and other users will be enabled to design a more legible logo/app icon design required for display on small devices.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Research background

Instagram, the photo sharing app owned by Facebook, responsible for several cultural highlights, has debuted a new logo (Parkinson, 2016). The previous logo, shown in Figure 1.1 (Left), a retro-look camera, was redesigned as a white outline camera with sunset colours as the background, as shown in Figure 1.1 (right). The new logo was announced via news, blog posts and even self-updating app systems, and has been widely discussed, garnering both positive and negative comments. Apart from personal preference, what are the possible reasons for app icon design trends?

Figure 1.1: Instagram app icon (Instagram official website, 2016).

With dozens of user interface (UI) guidelines, the common issue in the digital world is dealing with small screens. Flat design is a possible solution to alleviate concerns about limited space, especially since new innovations such as smart watches have been published. The focus has to be simplicity and minimalism. Another significant redesign factor is Apple's operating system, the iOS7 user interface, which was announced in 2013. Skeuomorphism, defined as "making stuff looks as if it is made of something else", has been applied in the Apple user interface from the beginning of the iOS system to iOS6 (Judah, 2013). Human perception has reached a stage where we are able to recognise bookshelves on phones or photo-albums on phones, even if they don't look like the actual objects in the real world. The test of flat design started with iOS7 (shown in Figure 1.2).

Figure 1.2: iOS6 and iOS7 comparison (Williams, 2015).

The numerous functions that smart devices provide mean that a lot of data needs to be displayed on a limited screen. Humans gradually become able to recognise the actual object being displayed in a simple icon image on digital devices. The solution for UI design is to be ‘simple’. However, simple is not a new idea in design. Many design guidelines, principles and textbooks mention that the core of good design is to be simple and easy for use. However, simple is a terminology described as ‘easily understood’, or ‘presenting no difficulty’, which makes it a subjective term. Therefore how can simple be defined? How can a graphic be simplified? How does simplifying a graphic enhance the legibility? What is the proper method to simplify a graphic?

While discussing this issue, some factors need to be considered. A symbol is always the central element of brand equity and the key differentiating characteristic of a brand as it can create awareness, associations and liking or feelings which in turn can affect loyalty and perceived quality (Aaker, 1991, p.197). The logo is a graphic mark that is applied by companies to aid public recognition and identification (Wheeler, 2009). Thus, a good logo/symbol/app icon design has to represent the brand image well. For this purpose, logo/symbol/app icon design involves two factors – ‘meaning’ and ‘recognition’. However, as stated, this study focuses on legibility enhancement through the graphic simplification method rather than meaning or aesthetics. Even though the final application took logo/app icons as samples, in order to avoid variables (such as aesthetics and meaning), this study mainly analyses ‘simple’ as the only factor.

Furthermore, three categories of logos exist: (1) typographic - letterforms which include some graphic organisation or addition to its content for enhancing; (2) abstract/symbolic – takes the descriptive mark one step further, literally incorporating a figurative element, in order to communicate the intangible or abstract; (3) descriptive - uses visual imagery relating to the client`s product or service as addressed by Thomas (2000, p.19). This study focuses on the abstract/symbolic logo type for the sample selection.

1.2 Research direction and focus

Following the research background, a particular problem in the real world is considered. The current issue is how to apply graphic simplification to logos and app icons, maintaining legibility on a small screen. Therefore, this study is defined as problem-solving research. To address the issue of logo/app icon legibility enhancement, some essential factors are included; firstly, understanding the principles of design thinking and determining the current gap. This step is necessary in order to understand how designers work. Secondly, reviewing the current application issue is required, which helps to understand the needs and difficulties. Thirdly, the definition of legibility and previous experimental methods need to be studied using both qualitative and quantitative research. Finally, as stated, 'simple' as either a graphic tool or trend, to display on a limited screen, has to be reviewed. Figure 1.3 shows the four main areas of the secondary research of this study, (1) design thinking, (2) logo and app icon evolution, (3) graphic legibility, and (4) graphic simplification.

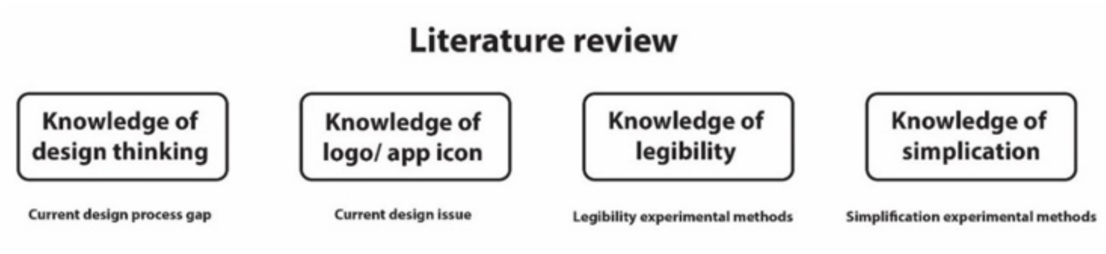


Figure 1.3: Knowledge required for this study.

1.3 Aim and objectives

Aim: This study aims to apply effective graphic simplification methods as a modification guideline for graphic legibility enhancement.

Objectives:

1. To review essential secondary research: (a) to understand the current design process through reviewing the literature on both theoretical and practical models; (b) to analyse current logo and app icon design through reviewing design evolution trends; (c) to examine the enhancement of legibility experimental results by reviewing previous legibility testing

methods; and (d) to determine the definition of simplicity through reviewing previous secondary research in psychology, computing science and shape analysis.

2. To identify an overview of simplification definition through experiment.
3. To provide an overview of the research methodology in order to develop a systematic method to measure the level of simplification.
4. To establish the ratio of each simplification criteria's influence on simplification judgement.
5. To generate simplification guidelines for designers' modification work.
6. To examine the enhancement of final graphic legibility in practical use.
7. To discuss the strengths and weaknesses of the research outcomes.

1.4 Research questions

Research question 1: What is the definition of simplicity for each criterion? What would be an appropriate simplification method for a logo and how can its effectiveness be measured?

Research question 2: Does agreement of simplicity judgement exist?

Research question 3: Can simplicity judgement be predictable from the data collection results of research question 1 and research question 2?

Research question 4: Do the simplicity guidelines work properly? How do they work?

Research question 5: Which level of simplicity design has legibility limitations? Do simplicity criteria improve legibility in applications?

1.5 Research methodology

Once the problem has been defined, the method of solution has to be discovered. Following from the research questions stated above, specific research methods for answering each question are required. Research question 1 (defining simplicity), research question 2 (simplification judgement), and research question 3 (simplicity criteria comparison), aim to generate ideas and hypotheses which require quantitative research to gather general decisions from participants. Research question 4 (simplification guidelines application) aims to examine how the guidelines can be used and how they work with designers applying them. Here, qualitative research is more appropriate. Finally, research question 5 examines the outcome of legibility enhancement, which again requires quantitative research to confirm whether the simplification guidelines are applicable.

1.6 Thesis structure

Chapter 1 introduces the current design issue and research area, and presents the aim, objectives and research questions of this study. Chapter 2 reviews the relevant literature required to solve the design problem stated in Chapter 1, mainly focusing on the four areas, (1) design thinking, (2) graphic legibility, and (3) graphic simplification. Chapter 3 reviews previous logo and app evolutions as case study. Chapter 4 examines the research methods for answering the five research questions stated in Section 1.4, (1) research purpose, (2) research strategy, (3) data collection, (4) data analysis, and (5) sampling. Chapter 5 applies shape analysis to identify which elements can be used to measure overall simplicity and could lead to better shape recognition. Chapter 6 investigates how people judge the level of a graphic and organises the results into a measurement template. Chapter 7 evaluates the criteria for shape influencing simplification judgement in terms of ratios. Chapter 8 presents designers' work, applying simplification guidelines. The results, with and without simplification guidelines, are used as samples for comparison in the next chapter. Chapter 9 examines the graphic legibility enhancement of applying the simplification guidelines. Chapter 10 is the conclusion of the research and discusses the key findings and limitations. Thesis structure shown in Figure1.4.

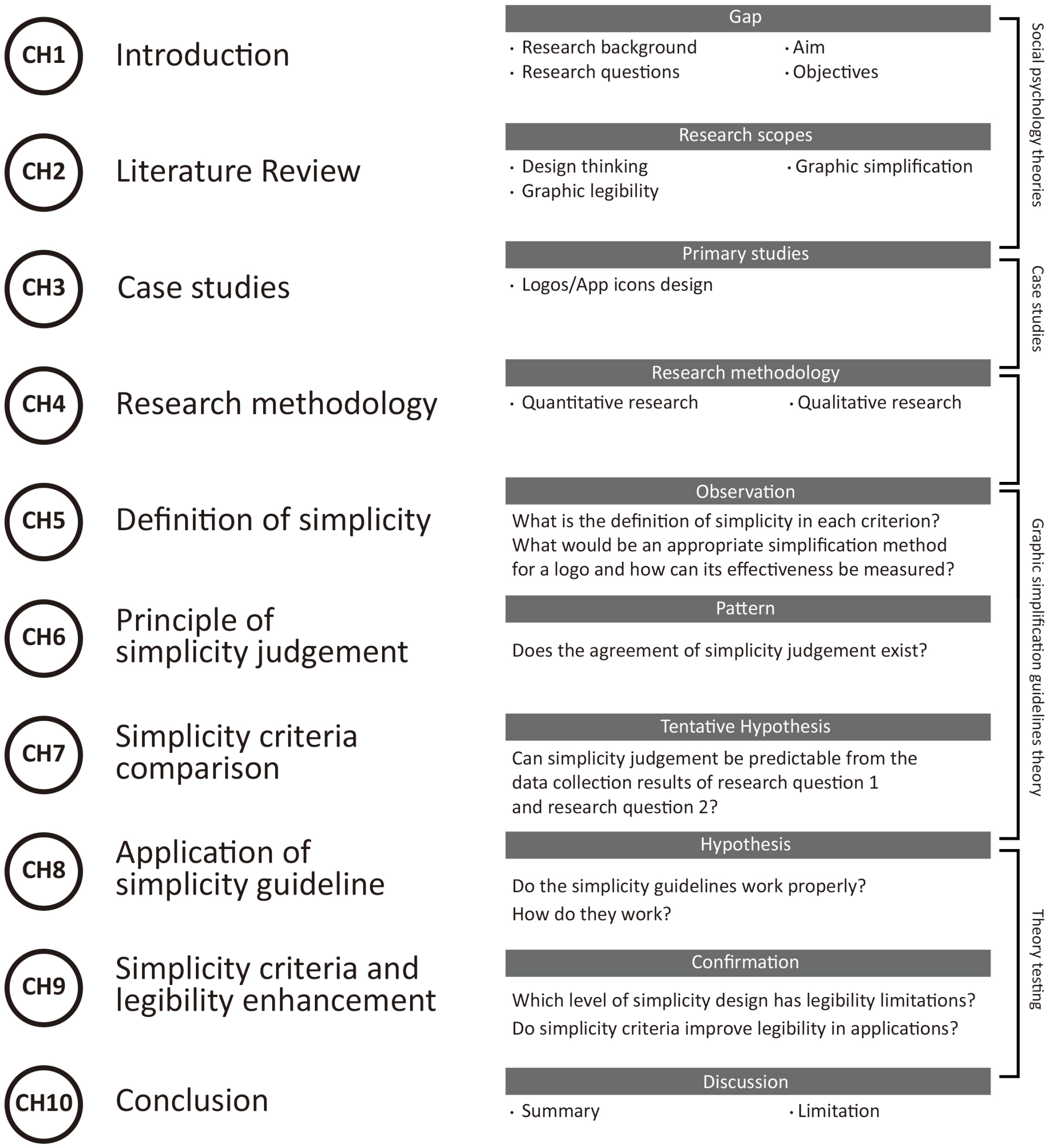


Figure 1.4: Thesis structure.

Chapter 2: Literature review

2.1 Introduction

As mentioned in Chapter 1, the aim of this study is to discuss legibility improvement via the simplification design process. Over the past two decades, the field of graphic design application in the computer area has greatly expanded its scope. As the computer becomes a common platform for the dissemination of information, it has become increasingly important to re-examine and extend legibility research regarding the presentation of graphic icon/logo to this medium. In this case, “graphic design has begun to be viewed, not only as a discipline that produces aesthetically pleasing forms, but also as a discipline that produces effective communication tools” (Kang, 2009). Thus, design in this study is defined as a ‘tool’ to solve the current issue (logo/app icon legibility). To achieve this, wide study areas were required in secondary research. Following on from the aim – graphic legibility enhancement in logo/app icon design, a review of the ‘subject’ - designers’ role in the whole design process is the first step. Secondly, a study of the evolution of app icons and logos is essential. Exploring the trend of app icon and logo evolution will help to understand the requirements and current challenges. Thirdly, many studies have examined font legibility use for sign, textbook, and other digital areas; however, only a few of them have mentioned an app icon legibility solution. Therefore, reviewing how to define legibility, the methods of testing and improvement based on previous experiments is required. Fourthly, with simplification as the ‘method’ to enhance the legibility issue, previous studies of simplification such as definition, application and experimental research will be reviewed. This chapter is divided into four aspects: (1) design thinking; (2) graphic legibility; (3) graphic simplification methods and measurement (Figure 2.1).

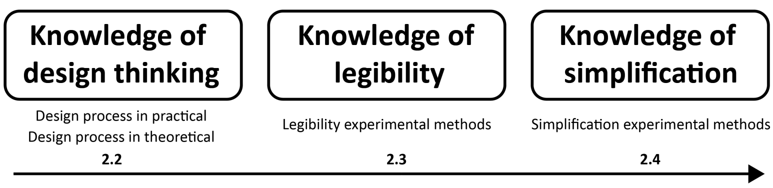


Figure 2.1: Literature review structure.

2.2 Design thinking

Graphic design is understood as the activity for organising visual communication in society which aims at developing the efficiency of communication and the technology used for its social responsibility. Bennett (2006, p.28) differentiated two concerns from this idea – perceptual and behavioural. The former sometimes involves visual detection problems and communication problems which include visibility, legibility, and aesthetics. The latter has to do with the way graphic communication affects the attitudes and behaviour of its audience.

In the past, graphic design has often been associated with work which has aesthetic or stylistic sense. However, the movement away from aesthetics and stylistic innovations as determinants of quality started in the early 1950s, when investigations relating to perceptual psychology - Gestalt, provided some theoretical concepts for visual fundamentals knowledge. This involved a rationalisation of part of the design process and was parallel to developments in the study of legibility, which itself was the expression of an interest that went beyond the aesthetic structure of the visual field, stepping into a concern for communication efficiency (Bennett, 2006, p.29).

The design research, which includes a literature review and audience survey, provides relevant resources to create a design concept and solve the given design problem. In the traditional design process, the design outcome based on the design research is accepted as a final solution. However, the design outcomes for interactive computer applications need to be verified through empirical study to see if the proposed solution is usable. Paper prototypes and three-dimensional models are explored in the design process. To conduct a usability evaluation with the prototype design, a working prototype is required in this design phase. Thus, it requires a logical framework to discuss the relationship of each role.

In a design paradigm, Tarbox (2006) defined the subject as the designer, and the object as the creation of a total piece that is effective at conveying information, not only for aesthetic purposes but also a model for design research (Figure 2.2). Tarbox's research model is built fundamentally on Engeström's human activity model which represents the stimulus as a subject, the response as an object, and mediated action as tools/mediating artefacts (shown in Figure 2.2). It explains each activity component and their relationship in an activity system. As the model presents, the community comprises multiple individuals and/or subgroups who share the same general object and the rules indicates the explicit and implicit regulations, norms and conventions that constrain actions and interactions within the activity system (Engeström, 1993, p.67). The subject and the object in the middle level are mediated by the tools in the top level. The six components of an activity theory system are continuously developed and reformulated by the rules in the activity system. Tarbox further defined these components as applied in a design research-based relationship. The designer acts as a subject and the tools/artefacts as sources of information; objective/goal is the development of a specific piece and contextual needs of users (problem space); rules are existing thoughts (such as Gestalt, principle of visual literacy); community is the users, and division of labour is those people who are involved in the overall production process.

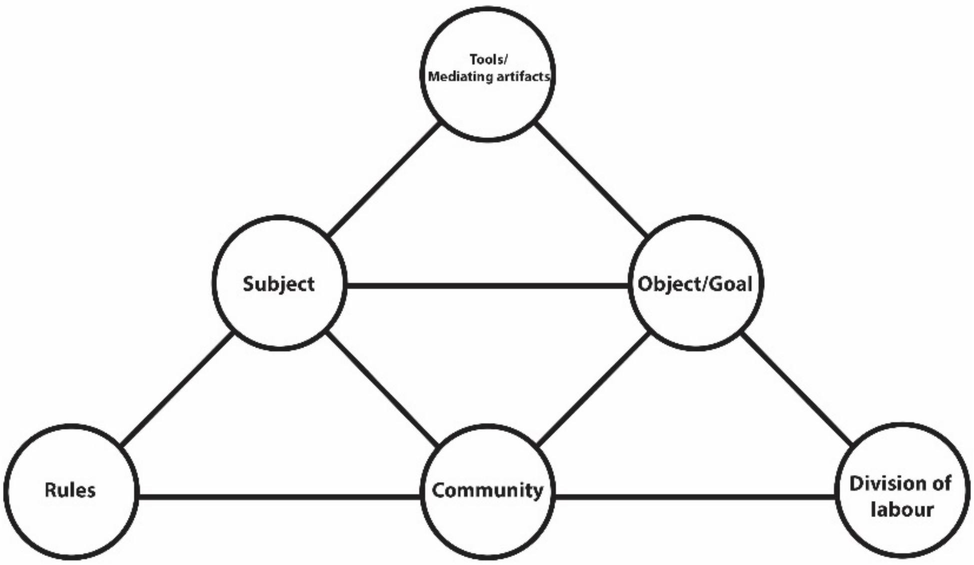


Figure 2.2: Design research model (reproduced from Tarbox, cited in Bennett, 2006, p.79; Engeström, 1993, p.68)

Following from the research model above, six components in the research model were defined as follows (Figure 2.3). In the model, the subject refers to the designers whose agency is chosen as the point of view in the analysis. In Engeström’s definition, the object refers to legibility enhancement at which the activity is directly transformed into outcomes with the help of physical and symbolic, external and internal tools (mediating instruments and signs). Therefore, tool/mediating artefact refers to design in this study (app icon/logo). The community comprises a target audience which is defined as the users in this study. The division of labour refers to people involved in the overall production process which is all the participants in this study. Finally the rules refer to the simplification study that understands and constrains actions and interactions within the activity system.

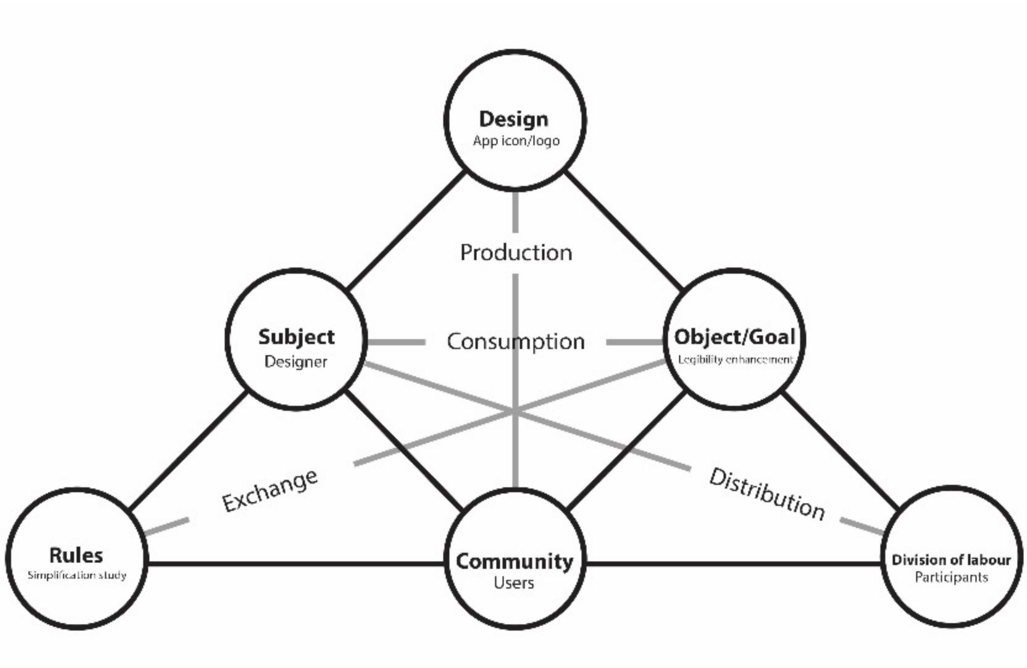


Figure 2.3: Design research model adapted from Tarbox, 2006 and Engeström, 1993.

As mentioned above, design is a communication tool to mediate between the subject and the object; design research is always helpful to develop and utilise ideas. Figure 2.3 shows how Engeström’s model was adapted to the design process. The design research includes planning for outcomes from a given object and target audience research (subject). The audience research includes an analysis of the target audience’s cultural and social backgrounds (community), regulations and requirement (rules) in both design elements and contents, and involvement of decision makers (division of labour). In this phase, the role of the designer is to be a mediator between the subject and the object. The design research that relates to the rules, community, and the division of labour are explored but not evaluated with the end audience.

Because the design process is a problem-solving process, it requires a 'method' as a mediator to solve the problem. The goal of this study is how graphic design can enhance app icon legibility in the digital age. The design process starts with a simplification study. This design process consists of three phases which have been used in previous research (Kang, 2009) - problem solving, understanding in contexts and refining the design. Thus, as a method of legibility enhancement, simplification is the core study among subject, object and design. Figure 2.4 shows the structure of adapting Engeström's model for the simplification design process. In the first phase, problem solving through simplification mainly discussed the relationship between subject, object and design.

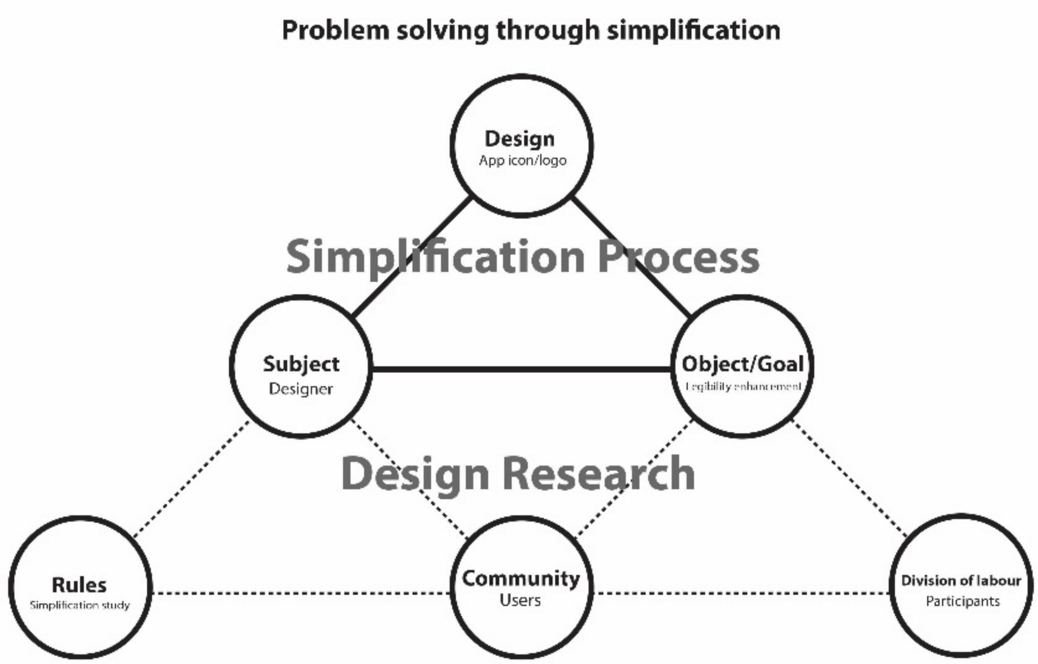


Figure 2.4: Phase 1 - Problem solving (reproduced from Kang, 2009, p.322).

Secondly, the goal of understanding simplification in context is to verify the proposed design solutions from a real live audience through empirical study. Figure 2.5 shows the bottom level of this section which provides a framework of target user studies. In this phase, a simplification study will firstly explore existing rules. Secondly, the data of participant simplicity agreement will be collected through quantitative research. Thirdly, the criteria of simplification judgement will be reproduced and fourthly applied by designers. Finally, connecting all the components in the design research section enables the generation of an initial theory of simplification guidelines.

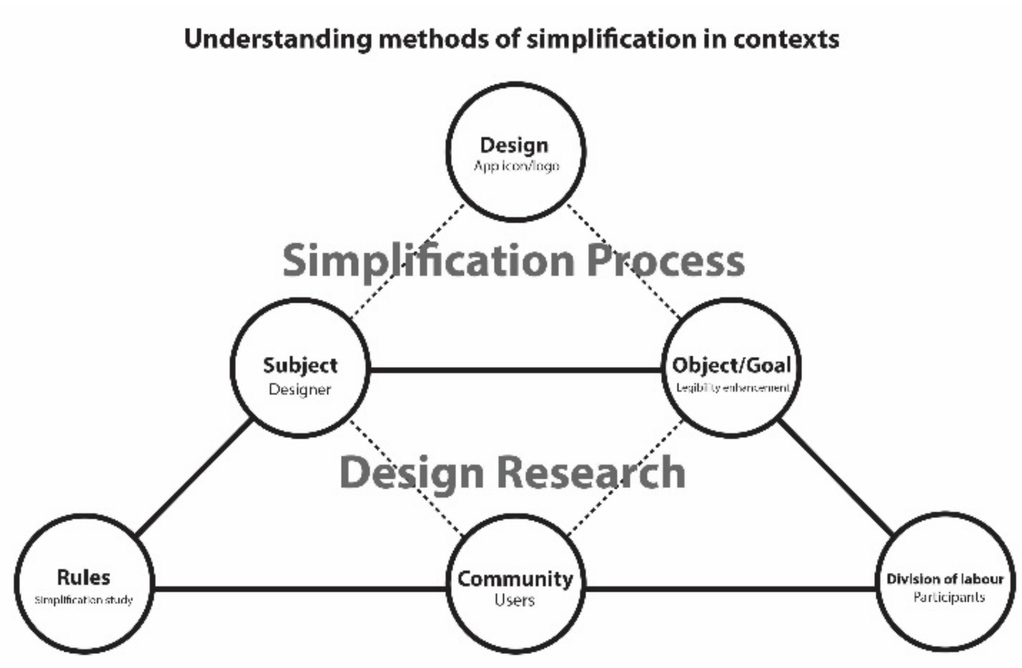


Figure 2.5: Understanding methods of simplification in contexts (reproduced from Kang, 2009, p.322).

In the last process of this research, when all components have reached the object/goal, it is considered to be about outcome production (Figure 2.6). This outcome is mediated between the subject and the object within its community. However rules, tools (design process), and division of labour (participants) are invisible to the audience yet they are an influence on their activities and actions with the subject, object, and community. Outcome in this study will focus upon three areas. In the practical application, a principle of graphic simplification will be suggested. In the theoretical application, a systematic measurement of graphic legibility will be provided. Combining both of them will benefit both designers and users and also help in evaluating and developing the current design process.

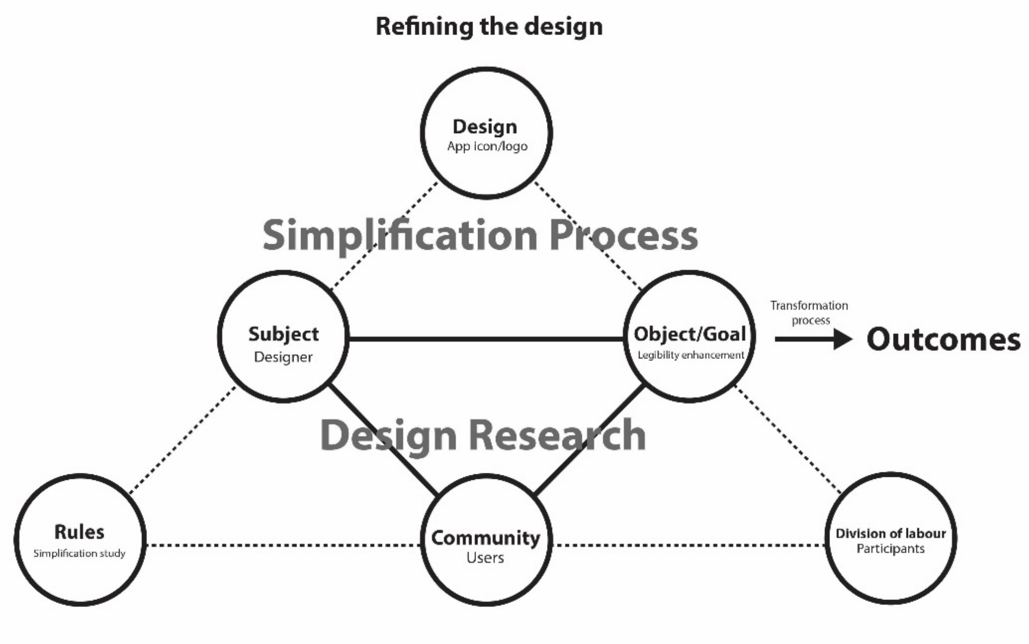


Figure 2.6: Outcomes transformation.

2.2.1 Design process

The questions and hypothesis from phase one (problem solving) are answered through audience-usability testing. The refining design phase develops based on the recommendations from phase two (understanding simplification contexts). Thus, structuring the relationship of each component, if we see the design process as a 'tool' with an understanding of internal and external mental processes within a cultural and social context, then activity theory could provide an alternative way of thinking about the graphic design process to enhance visual communication in human-computer interaction. This theory has had the attention of the HUI community which focused on how to apply human activity to computer applications, especially in user interface, and how to apply the psychology to computer science (Kang, 2009).

While designer approach to designing differs somewhat, it is possible to construct a model of the design process that includes the basic tasks and activities involved. The basic design process can be broken down into two distinct phases (Figure 2.7). The first phase of the design process starts with investigating the design problem and the creation of strategies; the end of this phase will address the specific issues found. Secondly, the process will go on to develop design concepts and further refine prototypes and solutions (Nini, 2004).

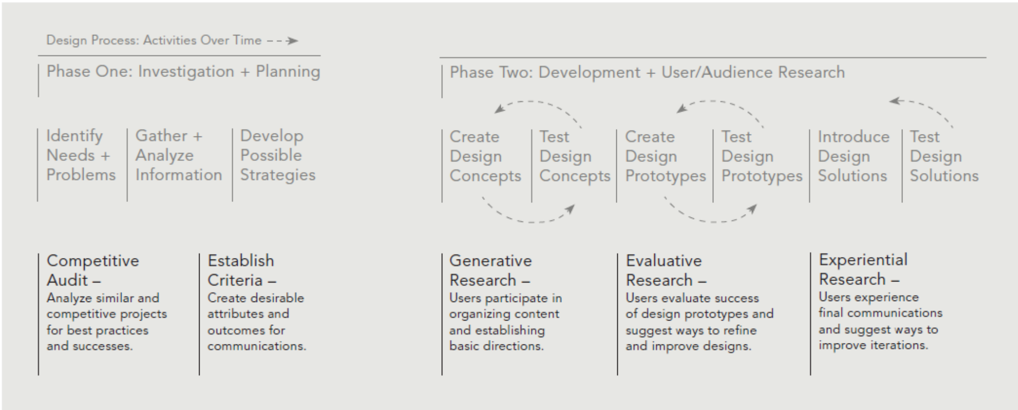


Figure 2.7: Typical activities during the design process (Nini, 2004).

Design is stated as a process that turns a brief or requirement into a finished product or design solution (Ambrose and Harris, 2010, p.10) and is never evaluated in absolute formal terms, but rather, succeeds or fails on the basis of how well a particular problem is solved (Mullet and Sano, 1995, p.26). One of the solutions to the problem when looking for how graphic design enhances human interaction in the digital age is the usability test (Kang, 2009).

Moreover, design methods are all the techniques, rules, or ways of doing things that are employed by a design discipline. Some of the methods for design thinking include traditional HCI methods and some of others are creativity training. Design process is the way in which the methods come together through a series of actions, events, or steps (Waloszek, 2012). Comparison of several design thinking process models is presented in Figure 2.8. The thinking process is generally divided into the following phases: (1) Understand the problem – get an initial understanding of the problem; (2) observe users; (3) interpret the results – interpret the empirical findings; (4) generate ideas; (5) prototype/experiment - narrow down the solution, experimental phase; (6) test – refine the design.

Prototypical Stages	Wikipedia /Herbert Simon	IDEO Toolkit	Tim Brown (IDEO)	d.school/D-School (HPI)	d.school Bootcamp Bootleg (HPI) – Modes	Baeck & Gremett (2011)	Mark Dziersk (Fast Company)
Understand the problem	Define	Discovery	Inspiration	Understand	Empathize: Observe, engage, immerse	Define the problem to solve	(1) Define the problem
Observe users	Research			Observe		Look for inspiration	
Interpret the results		Interpretation		Point of View	Define (Problem statement)	—	
Generate ideas (Ideate)	Ideation	Ideation	Ideation	Ideate	Ideate	Ideate multiple ideas	(2) Create and consider many options
Prototype, experiment	Prototype	Experimentation	Implementation	Prototype	Prototype	Generate prototypes	(3) Refine selected directions(3.5) Repeat (optional; steps 2 and 3)
Test, implement, improve	Objectives/ChooseImplementLearn	Evolution		Test	Test (includes *refine* and *improve* solutions)	Solicit user feedback	(4) Pick the winner, execute

Figure 2.8: Design thinking process (adapted from Waloszek, cited in Curedale, 2013, p.107).

Comparing various design-thinking process steps, the order of processing is generated in the same way. Within the design process, seven steps can be identified: brief defining, background research, solution ideating, resolving prototyping, rationale selecting and delivery implementation (Ambrose and Harris, 2010). First of all, the design problem and the target users need to be defined. The understanding of the problem/issues allows more accurate solutions to be developed. Therefore, the problem in this research is defined as current app icon legibility improvement. Secondly, the research stage reviews information such as the history/background of the design problem, user research and identifies potential limitations. Thirdly, ideation is the stage of finding solutions for current issues, perhaps through brainstorming or other methods. Between the solution-ideating stage and further prototyping, selecting and implementing stage, legibility improvement was categorised in this section. Adapting the designer perspective of the design-thinking process in this study, the application is to enhance the phases between generating possible ideas (ideate), narrowing solutions and experimental phase (prototype), and selecting a proper final outcome with rationale disciplines (select). Shown in Figure 2.9.

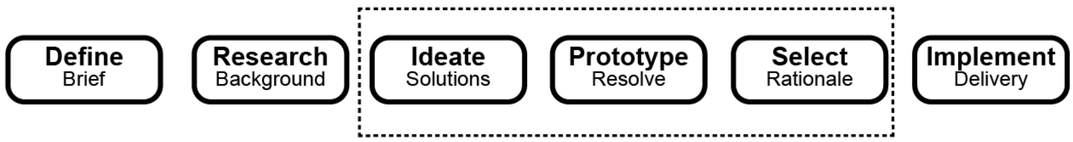


Figure 2.9: Design process (Ambrose and Harris, 2010) and the focus in this study.

2.2.2 Design research method

To fill the gap in the practical design process, a proper design research method is essential. Cooke (2006, p.132) suggested a design methodology model (shown in Figure 2.10). The first phase of research methodology focuses on the research problem definition. The content of stage one of the process involves the definition of the project, including aims and objectives. At this stage the researcher asks a series of questions to establish the nature of the problem - whether visual communications can make a significant contribution towards reducing that problem (Noble and Bestley, 2005, p.32; Cooke, 2006, p.132). Defining the design problem, some questions had to be asked in order to complete this process. First of all, is the design problem significant? As stated in Chapter 1, the legibility of app icons on a small screen is a new challenge. Secondly, can visual communications contribute to its reduction? The hypothesis of this study states that graphic simplification will help visual communication especially on small screens. Design is the cause of the problem in this study (defined as app icon legibility), seeking to apply visual communication for contributing to reduction of the problem. As mentioned in Chapter 1, it is highly likely that app icons which are displayed on limited-sized devices cause legibility problems. Thus, target users for this research are app users and designers. This research is divided into two main perspectives – (1) revision of new app icons for app users and (2) simplicity measurement and guidelines for designers.

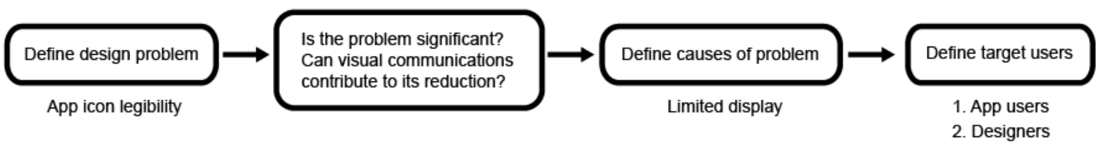


Figure 2.10: Design research methodology process –stage 1 definition

The second stage of research methodology is divergence (Figure 2.11), which narrows down the factors of leading design problems though a broad range of primary and secondary research methods. The design problem can be enhanced through three common data collection types – visually researching the target, gathering quantitative data and gathering qualitative data. Originally, visually researching the target was in order to gain enough knowledge about the audience to enable the design team to tap into their aesthetic values and also to understand some of the cognitive processes behind their tastes (Cooke, cited in Bennett, 2006); however, this study focuses on a simple image decision instead of aesthetic preferences. Another two data collection types have widely been used in all other research subjects. Qualitative research at this stage seeks to understand people in the context of their daily experiences, obtaining insights about attitudes and emotions which are used to develop an initial understanding. Quantitative research uses mathematical and statistical methods for recommending a final course of action (Curedale, 2013, p.136). In this case, a designer`s role is to mediate and modify current logo problems. Therefore, in order to generate an agreement of simplification judgement, gathering user opinion is essential. Quantitative data was applied for simplicity agreement and determines the feature of it; qualitative data involved collecting revision sketches to evaluate the improvement when using simplification guidelines. These findings further refined the framework within which the design team would later operate and gave a greater understanding of user potential visual legibility principles.

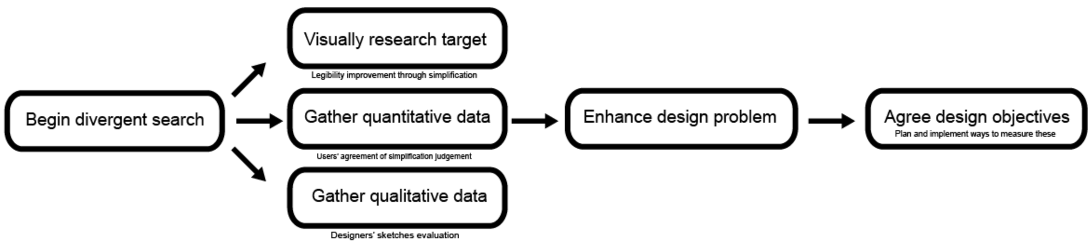


Figure 2.11: Design research methodology process – stage 2 divergence

The third section, transformation, explains the development and testing of a range of potential visual solutions, centring on the range of visual experiments by focus groups (Figure 2.12). Feedback given by them is for generating the range of criteria: the use of colour, clarity and legibility of information. This stage aims to build on the knowledge gained by conducting a thorough analysis of the context for the final work (stage 2), allied to a strong understanding of the intentions outlined in the brief (stage 1), in order to propose well-grounded, functional visual solutions (Noble and Bestley, 2005, p.37). In short, it is a stage to examine visual solutions. Thus, designing prototype graphics involved producing a whole range of visual solutions – from rough, conceptual forms to fully resolved layouts. In this case, the research process of this study produces a current logo and modified version for comparison. Target audience testing is essential to evaluate the appropriate graphic form. The previous phase used testing to help refine its design and move towards an outcome that was more likely to fulfil the design objectives. Once the graphics were considered appropriate, the design team could then test the design on a small scale (Cooke, 2006, p.140).

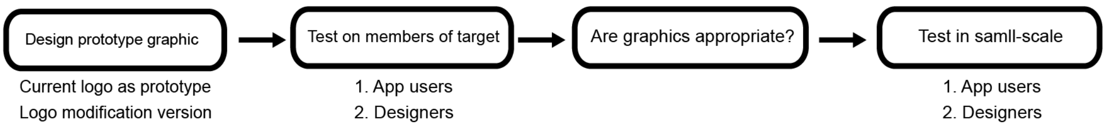


Figure 2.12: Design research methodology process – stage 3

The final stage in the design process (Figure 2.13) - convergence - is the correlation of the results of all research and experimentation conducted throughout each of the previous stages in order to create an appropriate and functional final outcome (Noble and Bestley, 2005, p.38). Once the project had completed the previous phases, the design team could then continue with the process of measuring effectiveness by assessing the product's performance against the design objectives set out at the beginning of the project. This is an ongoing process which enables the team to recommend further improvements to the leaflet, and the process itself. In this study, the final measurement is based on the comparison of the logo modification version. The methods of how to measure will be further discussed in Chapter 3 (Research methodology). The design outcome of this whole study will be some simplification guidelines for legibility enhancement.

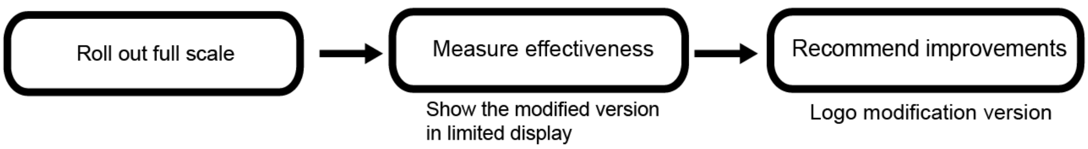


Figure 2.13: Design research methodology process – stage 4 convergence

2.2.3 Summary of design thinking

The general practical design process has been widely regarded as a tool to solve current issues. Designers commonly start a project by defining, researching, ideating, making a prototype, selecting and then implementing. This process has been discussed in various types of explanations and definitions (Noble and Bestley, 2005; Cooke, cited in Bennett, 2006; Curedale, 2013) by design researchers seeking and making concrete subjective ideas in order to generate objective principles/theories. It is valuable to discuss how design research methods combine with social science research methods to generate a principle/theory for design process development. As stated in the beginning of this section, there are six components: subject (designer), object (goal/aim), tool (design), rules (simplification guidelines), community (users) and division of labour (participants). Design is a tool to mediate the gap between designer and design problem, and the design-method process stated in section 2.2.2 is a logical process model for generating a theory in the design practical process model.

There is no doubt that the design process and design research methods process are both logical ways to run a project. An interesting point in the design research methods process is that following on from the design research method model in section 2.2.2, two types of outcomes can be generated – a practical outcome and a theoretical outcome. First of all, from a designer point of view, the design process will be helpful in reminding them of the logical process to run a completed project; it is a 'what to do' process recommendation. However, the design research method model is the method for describing 'how to do'. For example, the first phase in the design process is 'define brief', but in the design method, it is 'define problem, define causes of problem, define problem significant or not, define target audience.' The next phase in the design process is described as 'research background'; however, in the design research method, it is 'gathering qualitative, quantitative data, enhance problem.' Thus, the difference between the design process and design research methods can be understood as 'what to do', and 'how to do' for design studies. In this definition, a design research method acts really as a 'method' for explaining how to put the design process into practice.

Secondly, the outcome which is possible to be generated from the design research method model is a 'theory/guideline/principle.' As stated in section 2.2.2, starting from a design issue 'app icon legibility enhancement' requires various primary and secondary resources to build up a solid solution. In this task, the design research method model has to start with a literature review, gathering data through qualitative and quantitative research, statistical analysis, and user testing and improvement recommendation. Therefore, once this procedure is completed, the final outcome is 'recommend improvement' which can be either a product for practical use or a principle for theoretical research use. The former is almost the same as what the design process does, but with more sophisticated process guidance. The latter, which it is arguable is the final theory run by the design research method process, can be a new theory to evaluate the current design process. As explained in section 2.2.2, the four phases 'definition, divergence, transformation and convergence' already provide a clear research methodology model in the design area. Even though this research model is a good starting point for the design research area, it still has deficiencies and more work needs to be done on it. Therefore, social science research methodology is required for defining the types of research questions, the method of data collection, and the methods of statistical analysis and data representation. Combining both research models will be more robust for generating the theory in the design area.

Concluding this section, evaluating the current design process is essential and design research methods stated as producing a product and generating a principle to enhance the design process, the outcome of design research methods will be either a theory or a product. Based on section 2.2.1, the design process is generally categorised as 'define brief, research background, ideate solutions, prototype resolve, and select rationale and implement delivery.' As stated in the aim, the legibility of app icons is the problem issue which might be improved. This legibility-examining issue normally occurs in the design process between ‘ideate solutions, prototype resolve and select rationale’ (shown in Figure 2.9). Therefore, the outcome generated from the design research method is the new theory for developing the design process. In detail, the simplification guidelines will be generated to fill in the design process gap.

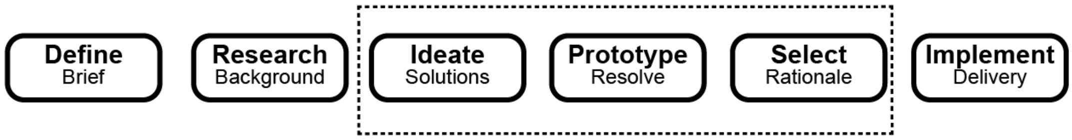


Figure 2.9: Design process (Ambrose and Harris, 2010) and the focus in this study.

2.3 Graphic legibility

“Legibility is the most important criterion on small screens” (Zwick et al., 2005, p.128). The term ‘legibility’ found wide usage in printing and digital display. “The meaning of legibility was anything but clear. Quickness of perception, speed of reading, perceptibility, and other criteria of legibility have been employed” (Tinker, 1944, p.385). Legibility experiment is not a new issue; it has been carried out for decades. In general, attention to these issues begins with improving reading speed towards an interest in cognitive processes of reading. Furthermore, academic interest in legibility has been widely concerned with the new media in which a large portion of research on legibility is relevant for typeface – and graphic designers (Beier, 2009, p.15).

Due to the invention of the smartphone, the design of small-screen interfaces is subject to the same basic design principles and considerations as those that apply to larger screens. However, the available space is much smaller, and this limits the visual effect of the screen, because it only occupies a small part of the user’s field of vision. Design principles and techniques must therefore be used in a clear and logical manner so that the user can quickly grasp the underlying functionality. This means that all design resources must serve to visualise information, structure the content and the interaction possibilities before any decorative and illustration aspects are considered (Zwick et al., 2005, p.127).

As mentioned above, experimental testing on legibility has been widely applied in various areas; some common arguments of whole legibility measurement issues are as follows: “Do you mean (1) easy to read, (2) easy to read at a distance, (3) easy to read in dim light, (4) easy to read when you haven’t your glasses, (5) easy on the brain, (6) not tiring to the eyes, (7) possible to grasp in big gulps of meaning, (8) pleasant to read, (9) inviting to the eye, or (10) something else?” (Whittenmore, 1948 cited in Beier, 2009, p.24). Thus, according to various types of legibility questions and determinations, it is essential to determine the application of this study, methods of legibility testing, features of evaluations and legibility enhancement. This section will review some experiments which have applied the legibility test, the methods of testing and some potential features which might influence legibility, and finally the initial methods of legibility enhancement.

2.3.1 Applications of legibility study

A wide range of issues has been studied, including type size, line spacing, line length, type style, serifs and more. However, it is still not a common view among designers to see legibility issues as a limitation of app icon design. Modern thinking is that legibility research is best conducted to solve specific problems and to test specific typefaces for known purposes, particularly where legibility is a critical functional issue (Waller, 2007, p.2). If the image has a very small display, it may not be legible, making it difficult to read. Some users may not be able to read it even with visual correction and some might be able to read it with some effort (Salvendy, 2012, p.877). Following on from the requirement of the app icon section, “legibility is the most important criterion on small screens; narrow letter spacing and robust characters are needed due to limited space and insufficient resolution for typographical refinements” (Zwick et al., 2005, p.128). One of the most important solutions is to make sure the design is scalable.

Legibility study is widely applied in various applications. However, as Buckingham (1931, cited in Waller, 2007, p.2) pointed out relatively early on, these factors interact in complex ways apparently unrecognised by many of the researchers. Instead, modern thinking is that legibility research is best conducted to solve specific problems and to test specific typefaces for known purposes, particularly where legibility is a critical functional issue. Recent examples are the development of fonts for people with visual impairments and for use in highway signs. This research follows in that tradition, and is a highly focused study designed to solve one specific problem.

Typeface legibility experiment tests have been widely used for packaging, logos for a computer company, headlines in magazines, signs in airports, adverts for a fast car, traffic signs, and so on (Waller, 2007, p.10). Graphic legibility also plays an important role in the digital age. Smartphone interaction is nowadays part of everyday human behaviour which involves digital reading, health care, digital tickets scanning and other tasks, in order to speed up user convenience. Moreover, a new current issue which requires graphic legibility is the smartphone interface. Undoubtedly, it is the core of interaction between phone functions and users which is required to perform well along with visual elements (Gatsou, et al., 2012).

2.3.2 The methods of legibility test

Even though the legibility test for shapes or icons has still not been developed yet, tests for vision legibility have been researched in other fields for many decades. In typographic literature, some specific fonts are generally believed to have a significant impact on readability (Poulton, 1972; Dyson and Kipping, 1997; Arditi and Cho, 2005; Waller, 2007). Two main reasons have been determined to explain why a specific type of font should enhance legibility. It is valuable to reference how legibility has been tested in other fields. Two main questions for understanding legibility methods are stated as: (1) How can legibility be tested? and (2) What elements are required to be examined?

The various test methods applied in most legibility studies have all emerged from the need to solve problems related to existing methods. Beier (2009, p.26) sorted the most essential tests into four categories: continuous reading, search task, threshold, and reader’s opinion. First of all, one of the methods is available for the study of continuous reading; this task asks participants to read a text aloud and then record the number of errors or the time course afterwards. This method is very effective and widely used in typeface legibility experiments. However, this study aims for graphic legibility in which it is not necessary to ‘read aloud.’ Another method in this category is errors. Differing from previous methods, errors can also be measured in silent reading without the limitation of text included. In addition, this method tests speed of reading, and involved participants reading a series of short paragraphs. Thirdly, the search task requests participants to locate spelling errors or specific words. Fourthly, the method of visual accuracy threshold focuses on letter and word identification with comprehension as a non-priority. Variable distance is one of the distance threshold studies which investigates the relationship between fixed type size or fixed distance to the eye. The study of distance accuracy of a signage typeface has rarely been questioned. Another method is a short exposure study in which participants are exposed to the stimulus (app icons in this study) for a specific period of time; then, after a rapid exposure, the participants have to move from one stimulus to another, and the participants are asked to identify the material shown.

Experiment tests in many previous studies used sample pair comparison to determine which sample is better/faster/preferable/usable/legible. Therefore, the first challenge in the first step is selecting a proper sample for testing. Determining the issue, and avoiding irrelevant variables is the key point of sample selection. A study to determine the minimum legible size of small typefaces firstly categorised typefaces into four types – Universe (capital and lowercase), Times New Roman, Perpetua (Figure 2.14). Poulton (1972) categorised each typeface feature into body size, height, total letter height, vertical spacing, total line height and average number of ingredients found.

TYPEFACE AND MEAN NUMBER OF INGREDIENTS FOUND IN TWENTY-FIVE SECONDS

Monotype series No.	Monotype series Name	Body size (in pt.)	x height (in mm.)	Total letter height[a] (in mm.)	Vertical spacing between lines (in mm.)	Total line height[b] (in mm.)	Average no. of ingredients found
Exp. 1[c]							
689	Univers						
	Capitals	4.8		1.21	.69	1.90	7.6
	Lowercase	6.6	1.19	2.13	.20	2.33	7.8
327	Times New Roman	7.0	1.24	2.27	.18	2.45	8.3[f]
239	Perpetua	9.2	1.28	2.90	.33	3.23	8.4[f]
Exp. 2[d]							
689	Univers						
	Capitals	5.7		1.44	.82	2.26	7.4
	Lowercase	6.6	1.19	2.13	.20	2.33	7.5
327	Times New Roman	6.6	1.19	2.18	.17	2.35	7.6
239	Perpetua	8.6	1.20	2.72	.31	3.03	7.9
Exp. 3[e]							
689	Univers						
	Capitals	4.8		1.21	.69	1.90	6.6[g]
		5.7		1.44	.82	2.26	7.5
	Lowercase	6.6	1.19	2.13	.20	2.33	7.4
		8.2	1.48	2.64	.25	2.89	7.9

Figure 2.14: Typeface experiment samples (Poulton, 1972, p.157).

The typeface legibility test categorises features by size, height and spacing; on the other hand, graphic legibility in this study will categorise samples based on the graphic features defined in logo type chapter (Chapter 3). The categories will be divided into abstract/descriptive, figure/text, greyscale or colour, and shapes of sample outline (circle, triangle, rectangle, and so on). Therefore, in the final graphic legibility test, all the variables were limited into non-font uses, greyscale. One more feature will be added based on the designer sketching experiment.

When comparing pair samples, how can one be evaluated as more legible than the other? A paper which described an experiment that tested the ease of reading specific formats used the mean score of reading rate for sample comparison (Dyson and Kipping, 1997). The total reading time per document was converted into a reading rate of words per second. To assess comprehension, a calculation was based on the percentage of correct answers combining two aspects of performance.

Another similar experiment tested the effects of font type and size on the legibility and reading time of online text (Bernard et al., , 2001), and examined the differences in legibility through reading time and general preference (Figure 2.15). During the experiment procedure, the participants were requested to read as quickly and accurately as possible. To accurately determine font legibility and its associated effect on reading time, an effective reading score was used. Therefore, font legibility in this experiment is the means of reading efficiency. The result of reading time and preference were represented in a scatter chart and bar chart.

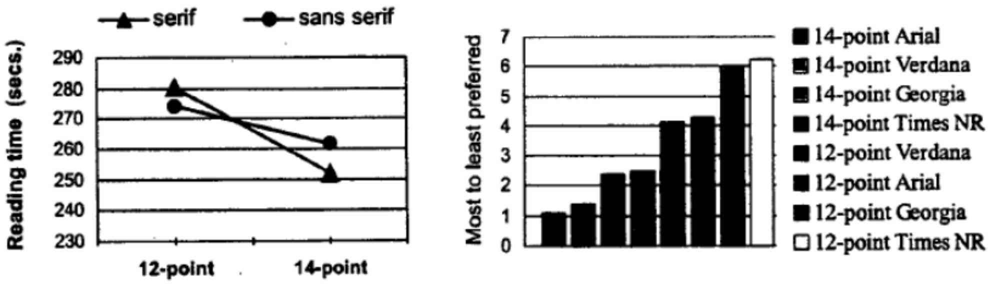


Figure 2.15: Results representation example (Bernard et al, 2001).

According to Arditi and Cho's (2005) experiment, they assessed the relative legibility of fonts with different size serifs, and with different inter-letter spacing using three different criteria for legibility: (1) size thresholds (visual acuity) for letter identification; (2) reading speeds using rapid serial visual presentation. More legible fonts, by this criterion, allow faster reading, while less legible fonts prevent faster reading. Reading speed is a less common measure of legibility but it is perhaps more representative of ordinary reading than is size threshold; (3) continuous reading on paper.

Another common technique for assessing legibility test is distance testing. Referencing Waller's (2007) experiment, the typeface comparison of airport signs is highly recommended to be made aware of the height of the sign and the limitation of typeface legibility. In this case, the participant moves towards the test object, until they can correctly identify its content. In Waller's (2007) experiment, the typeface that can be accurately seen from furthest away is the most legible. However, graphic legibility in this study which already has a certain size of app icon canvas reference. Therefore, considering the suggestion of sample distance awareness, this study will transfer distance testing into a sample with a fixed size.

In conclusion, various legibility testing methods have been applied in the typeface area; however, this study concerns graphic legibility; some methods were adopted and some of them required adjustment. Reviewing previous experiments, the common evaluation of legibility is based on continuous reading, visual acuity, reading speed, errors and reader's opinion. Graphic legibility has no text included and does not require participants to read aloud. In addition, it does not involve a paragraph to ascertain the level of comprehension. Furthermore, it does not include user preference but just focuses on the functional. Therefore, the graphic legibility experiment in this study will test users' reaction time and errors with a specific size of samples for evaluating legibility enhancement.

2.3.3 Features of legibility influence

Legibility in the typeface area has been discussed over many decades; evaluating some features of legible fonts is also possible to provide some ideas for graphic legibility enhancement. This section is going to review and extract some methods of legibility enhancement through both a typeface legibility and graphic legibility literature review.

In typeface legibility recommendation, taking the example from an airport sign experiment (Waller, 2007), five types of font were examined – Frutiger Bold, Frutiger Roman, BAA Sign, Vialog, Garamond Italic. Figure 2.16 shows the average recognition speed in seconds for each font tested: the shorter the line, the more legible the sample. As shown in Figure 2.16, Frutiger Bold and Frutiger Roman are the fonts with the shortest reaction time for users, and then BAA Sign, Vialog, Garamond Italic respectively. Frutiger Bold and Frutiger Roman are both sans-serif fonts, the only difference being the thickness of font structure. In addition, the reaction time of BAA Sign is around 1 second shorter than Vialog. Even though BAA Sign is a serif font and Vialog is sans-serif, according to this experiment, BAA Sign still has better legibility than Vialog. Therefore, when the condition is the same (both sans- serif), bold font is more legible. However, even serif font is not as clear as sans-serif; if the font is present in bold, it is still possible to be more legible than san-serif font without bold. Unsurprisingly, a serif font without bold effect and italic (Garamond Italic) took users the longest reaction time in this experiment. This result indicates that the priority of user judgement is for bold, and secondly is for sans-serif font.

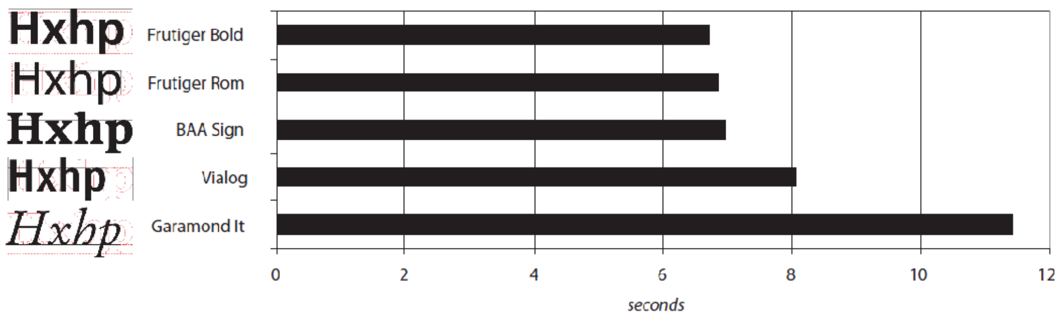


Figure 2.16: Effect of typefaces on word recognition time (Waller, 2007, p.5).

According to this result, Waller (2007) concluded that the reason for legible effectiveness is the width of typefaces — the widest typeface as the most legible and the narrowest as the least legible. Based on this typeface legibility experiment, the features of font were categorised into sans-serif or serif, regular or bold or italic. To transfer these features into graphic explanation, it can be represented as the angles, symmetry and weight of shape. The shape with less complex angles (serif), symmetry (regular rather than italic) and thickness outline (bold) will be more legible.

In graphic legibility recommendation, when designing an icon, some techniques provided by the Apple official website for making it more legible may be a good start as reference. In general, template icon design should include two versions – one for the unselected appearance and one for the selected appearance; therefore some designs call for variations on this approach. The selected appearance is commonly designed with a filled-in version of the unselected appearance (Figure 2.17). For example, Radio and Keypad icons are filled-versions which invert the details of the unselected version. Another type of icon design has to consider the features of the original one. Take the icons of Timer and Podcasts for example; both of them are with open areas. Thus, the selected versions condense the strokes a bit into a circular enclosure. The Voice Mail icon applies the simplest way to distinguish selected and unselected versions by using a heavier stroke. However, sometimes an icon's shape has details that are not suitable for presentation in stroked outline like Music and Artists icons. It is easier to use the fill-in appearance for both versions of the icon in this case.

Figure 2.17: Icons (Apple, 2015).

Thus, categorising the tips on how to maintain the legibility of icons, three rules may be summarised. First of all, invert the details, as the same idea as figure ground theory; inverting the details may make it possible to lighten or emphasise the important details. Secondly, a graphic which has either an open or closed area is an important point to be aware of. It is highly recommended to modify the icon into a closed outline. Thirdly, a good alternative is to use a heavier stroke to modify it. Fourthly, filled or outline? Sometimes, an icon's shape has details that do not look good in a stroked outline. In this case, using the filled-in appearance for both versions of the icon will be more appropriate.

2.3.4 Methods of legibility enhancement

As stated before, the smaller the icon to be developed, the fewer the individual features the motif can contain (Zwick et al., 2005, p.131). It is clearly understood that the design of small-screen interfaces is subject to the same basic design principles and considerations as those that apply to larger screens. Due to the available space being much smaller, and thus limiting the visual effect on the screen, design principles and techniques must therefore be used in a clear and logical manner so that the user can quickly grasp the underlying functionality (Zwick et al., 2005, p.140).

The app icon is a part of the graphic user interface, which has been discussed in human-centred interaction for decades. When speaking of visual design disciplines, it attempts to solve communication problems in a way that is at once functionally effective and aesthetically pleasing. Thus, once the problem is stated as legibility enhancement, how does one produce a design which is able to immediately solve a problem completely in a highly economical way? Simplicity plays a central role in all timeless designs. The most powerful designs are always the result of a continuous process of simplification and refinement; the benefits of simplicity are functional as follows: approachability, recognisability, immediacy and usability (Mullet and Sano, 1995, p.18).

When stating the methods of legibility enhancement, reduction through successive refinement is the only path to simplicity. To create the solution, anything that is not essential to the communication task must be removed. To apply this technique to interface design, the designers must simplify the icon as much as possible and question the functionality being presented when the resulting display is still too complex.

However, how do you define the parts which are removable? How do you simplify an icon in a proper, effective and economical way? Visual perception in this issue is a direct study to explore the phenomenon and problem solution of the legibility issue. The Gestalt laws address a series of rules that formulate the psychological perception characteristics of humans and designers should use these principles to organise information logically so that the user can understand content quickly and clearly. It is a supportive literature as a guideline for the presentation of information on small-screen interfaces (Zwick et al., 2005, p.140). Gestalt laws summarise the most important principles of perception, and how they affect the design considerations of small-screen interfaces will be discussed in section 2.4.

2.3.5 Summary of graphic legibility

Reviewing previous documents of graphic legibility, the applications of legibility have widely been used in signs, texts, prints and digital interfaces. Due to the new smart devices such as the smartphone and smart watch, more and more companies are trying to make their products wearable. To achieve this requirement, making a product as small as they can is always a big challenge for engineers, app developers, and users. Some standard of legibility enhancement is essential.

Analysing the level of legibility based on statistics, two common methods for examining legibility enhancement are reaction time and accuracy. Participants in the legibility test were asked to read a test object (texts/graph) for a limited time, the shortest being the more legible. Accuracy was based on the ability of participant recognition of stimuli in alternative questions. Then, the results were able to clearly show the percentage of participant recognition errors. The higher the score of accuracy, the greater was the legibility. The important point when running this experiment was either fixed distance or size of stimuli when it was presented to participants. All the samples should be presented in the same standard.

Graphics often need to be modified or redesigned for many occasions and applications. Therefore, some previous designs provided some idea of graphic modification or transformation. Evaluating the features of typefaces, the angles, symmetry and weight of shape are all possible elements to influence legibility. Reviewing the features of current icons, figure ground theory, open or closed areas, heavier stroke and filled-in appearance are all possible techniques to modify original graphics.

It does not matter whether evaluating legibility either from a typeface or graphic perspective, a key point of these features is concentrated on 'simplicity': less angle, less weight, less asymmetry, less stroke and so on. Furthermore, in graphic user interface studies, simplicity is also the key role for reducing visual perception. However, vagueness still surrounds the definition of 'simplicity.' An idea of exploring the solution of legibility enhancement can be found in visual perception studies. From a psychology perspective, the Gestalt laws provide a series of rules that formulate the psychological perception characteristics of humans which allows designers to develop their work.

Overall, various studies have already discussed the application of legibility, experiments of legibility examination, and some features of legibility enhancement. Therefore, in the concluding sections 2.2, 2.3 and 2.4, this study states legibility enhancement as the aim (object), designer as the subject, and simplification as a design tool to solve this issue. Combining all the requirements from this section, visual perception in cognitive psychology is the core knowledge of simplification for graphic legibility enhancement.

2.4 Graphic simplification

As stated in the previous section, visual perception psychology is a fundamental theory for evaluating the way humans perceive information. A designer can and should use these principles to organise information logically so that the user can understand content quickly and clearly. As mentioned in previous sections, evaluating the design trends of logo and app icons, the summary indicated that ‘simple’ design is the tendency for solving legibility on the small screen. But what is the definition of ‘simple’ and how to simplify a shape? These questions have been addressed in psychology for some time. “A specific prediction found in Gestalt psychology of form is that ‘good’ figures will be better remembered than ‘poor’ ones” (Zusne, 1970, p.63). “The principle of good gestalt is a figure with some high degree of internal redundancy” (Attneave, 1954, p.186). This concept claimed that figural goodness is equivalent to redundancy and ‘good’ figures are remembered better because they contain less information. Thus, the Gestalt theory will be an important principle to apply and examine simplification in app icon design. The Gestalt laws are also helpful as a guideline for the presentation of information on small-screen interfaces which Zwick (2005, p.141) addressed, that the law of good form maintains that human perception will look for the greatest degree of simplicity, clarity and regularity. This indicates that simplicity is one of the solutions, or design tools for enhancing graphic legibility. As previous studies have mentioned (e.g. Arnheim, 1967; 1974), simplification is considered a major factor in designing logos and has the ability to increase recognition. As designers sometimes simplify objects to obtain effective communication or a unique style rather than create realistic art works, simplified objects usually can enhance the memory of the images for humans. McCloud (1994) described graphic design as getting a strong impression/image through simplified objects (Figure 2.18).

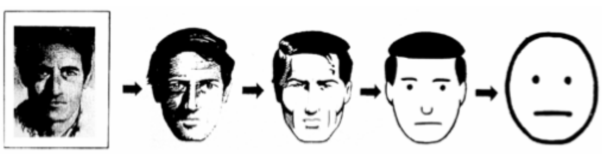


Figure 2.18: Simplification from object to figure (McCloud, 1994).

Graphic simplification is recognisable due to its association with simplicity. “The simplest way to achieve simplicity is through thoughtful reduction” (Maeda, 2006, p.16). The laws of simplicity suggested by Maeda (2006) as it relates to design, technology, business, and life recommend that the easiest way to simplify a system is to remove functionality. Maeda (2006, p.13) indicated that simplifying a design is harder than making it complicated; therefore, some regulations of simplicity have been defined: (1) reduce – through thoughtful reduction to achieve simplicity; (2) organise (Gombrich, 1984) – organisation makes a system simpler; (3) time – savings in time feel like simplicity; (4) learn – everything can be simplified by knowledge; (5) differences – simplicity and complexity need each other; (6) emotion – more emotions are better in simplicity; (7) failure – some things can never be simplified; and (8) the one – simplicity is about deducting the obvious, and increasing the meaningful elements.

Simplification means not only deleting the details of the objects, but also emphasising key points on specific details. Previous studies (Gombrich, 1982; Arnheim, 1969) revealed simplification as the remarkable ability to express the characteristic of the object clearly, in addition to increasing the identity and memory. Moreover, a good figure means to apply the least configuration to convey the identical information since the visual cognition of human beings is inclined to receive the information by the most economical way (Koffka, 1935; Arnheim, 1969; 1974; Goldstein, 2010). To achieve simplification, relevant studies have been found in Gestalt theory, design discipline, symbolism and recognition theory.

The following chapter is going to discuss the fundamental studies of visualisation that will help to develop the measurement of simplification. In this study, two approaches for simplification are used – node quantity and partial quantity; in addition, the measurement of simplification will be tested by reaction time and intelligibility.

2.4.1 Cognitive psychology study

As stated in section 2.2, design theory is moulded from some very specific disciplines that include facets of psychology – specifically cognitive psychology and principles such as Gestalt (Tarbox, cited in Bennett, 2006, p.74). Neisser (1967) defined cognitive psychology as “the study of how people learn, structure, store and use knowledge.” From the beginnings of recorded questioning there have been several approaches to how humans perceive objects. Gregory (1998, p.1) described the term ‘sense data’ that is supposed to be the intermediary between objects and perceptions. The signals must be read by rules and knowledge to make sense. Structuralism and functionalism could be seen as initial stages in psychology studies (Sternberg and Ben-Zeev, 2001).

Structuralism, in general, aims to analyse the elements of an object in order to understand the process and structure of cognition. Structuralists analyse the object, for instance, a flower by its consistency of colour, geometric shape and size to define the cognition of this object. For example, the perception of a flower in structuralist experiments is analysed in terms of the constituent colours, geometric forms and size relationships. The aim of structuralism is generally considered to be the first thought in psychology and aims to understand the structure, and further analyse the mind in terms of its constituent components or contents (Sternberg and Ben-Zeev, 2001, p.21). As some subjective concepts mentioned in the above literature section, structuralism took the first stage toward making psychology a systematic, empirical science and emphasising the analysis of consciousness into constituent components.

An alternative to structuralism suggested that psychologists ought to concentrate on the processes of thought rather than on its contents; however, this concept had a vivid limitation in reducing time for visual perception. Functionalism provides another aspect to understanding what people do and why they do it. In contrast to structuralism which focuses on the elementary contents (structure) of the human mind itself, functionalists try to understand the process of how and why the mind works in human thought and behaviour. Functionalism study mainly emphasises the mental operations and practical use of consciousness (Sternberg and Ben-Zeev, 2001, p.22).

Associationism deals with how events or ideas can become associated with one another in the mind or result in a form of learning that offers the Gestalt law a supportive initial knowledge (contiguity, similarity or contrast). It is mainly concentrated in the middle-level to higher-level mental processes. Compared to functionalism, associationism addresses mental connections between events and ideas (Quinlan, 2008, p.7). However, as a school of thought, it has not survived in its original form because it was overly simplistic and could only be explained on the basis of simple associations rather than in the study of complex cognition (Sternberg and Ben-Zeev, 2001, p.26).

Behaviourism was founded by John Watson in 1913, and addressed psychology as the behaviourist view, and claimed that the focus should be on the relationship between observable behaviour and environmental events (stimuli). Behaviourism may be considered an extreme version of associationism which focuses entirely on the association between the environment and observable behaviour. Following on from this approach, psychology was encouraged to focus on objective, observable reactions to stimuli in the environment (Matlin, 2009, p.6).

Of many critics of behaviourism, Gestalt psychologists stated that people better understand psychological phenomena when they view the objects as organised, structured wholes. Based on this point of view, behaviourism cannot be fully understood when the phenomena are broken down into smaller parts. Gestalt psychology was developed at the beginning of the twentieth century. It emphasises that humans have basic tendencies to actively organise what they see; furthermore, the whole is greater than the sum of its parts (Matlin, 2009, p.7). In accordance with Gestalt psychology, psychological phenomena describe the human tendency to view objects as organised, structured wholes, rather than break them down into smaller pieces (Henle, 1961). The Gestalt psychologists described visual perception as more than the sum of stimuli, organised based on various laws that will be further discussed in later sections.

A more recent approach is cognitivism: the belief that much of human behaviour can be understood in terms of how people think, represent and process information. Cognitivists are in agreement with Gestaltists in that the whole is different from the sum of its parts; however, cognitive psychologists strived to determine which mental mechanisms and which elementary elements of thought make that conclusion true. In the early stage, cognitivists argued a sophisticated concept of behaviourism; however, an important part has been ignored - how people think.

Overall, the first major school of psychological thought was structuralism, which aimed to analyse consciousness into constituent components. Functionalism emphasised mental operations and practical use of consciousness; furthermore, associationism concentrated on associations of ideas and later gave rise to behaviourism which focused on the study of observable emitted behaviour. The most important theory applied in this study is Gestaltism and cognitivism, which focus on the idea of 'principles of perception' and understanding how people think. Thus, to demonstrate how people perceive information, the following sections are going to review the process of object recognition.

2.4.1.1 Object recognition process

In the visual world, an object can be considered as any recognisable, separate, and distinct element. Information about visual objects is cognitively stored in a way that ties significant features together; for instance, according to oriented edges and patches of colour and texture, the pattern can be identified, visually tracked, and remembered (Ware, 2004, p.227) which is categorised into two theories to explain object recognition – image-based and structure-based. The first one indicates that humans recognise an object by matching the visual image with a similar snapshot stored in memory. People have a pronounced ability named “recall” which means they recognise information they have confronted before; moreover, recognition suggests that a visual image can enhance people’s memory, for instance, in remembering information relating to the image. This is the main reason why icons are effective in user interfaces. Objects can be presented as a simplified line drawing rather than a full-coloured image. Object recognition is conceptualised to be a logical process in which the image is divided into simple geometric components (Biederman, 1987, p.115). The schematic of object recognition and components is shown in Figure 2.19.

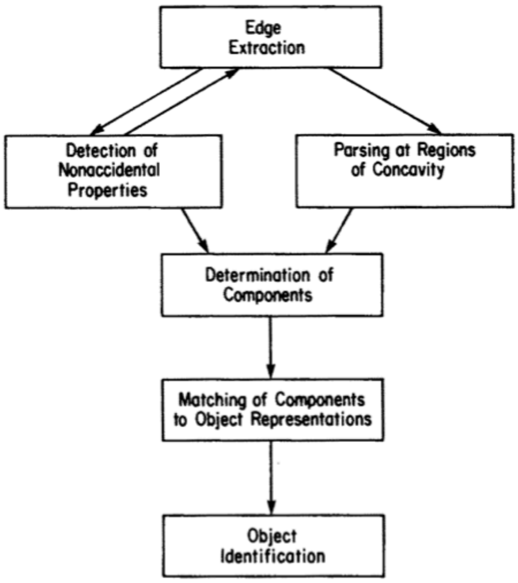


Figure 2.19: Object recognition process (Biederman, 1987, p.118).

Thus, when selecting a sample (object) for graphic simplification and graphic legibility judgement, Zusne (1970, p.298) organised some experimental conditions under which forms were presented for recognition or identification. This study extracts two relevant suggestions as follows: (a) non-representational form, as in randomly constructed shapes. The recognition speed of such shapes can be controlled because all subjects start out with the same degree of familiarity; (b) incomplete closure. When the form stimuli are of the type used in the Gestalt Completion Test, the observer’s task may be the recognition of the object represented by mentally completing the incomplete figure.

Ashcraft (1998, p.47) addressed two steps of recognition process as follows. First of all, humans find the edges of objects, and this process enables them to determine which edge maintains the same relationship to another. Secondly, scanning regions of the pattern where the line intersects commonly places where deep concave angles are formed. The deep concavity of the object sometimes indicates that it is the joint point of another component. The way to distinguish the edge, deep concavity and component combination will be further discussed in section 2.4.2.1.

2.4.1.2 Recognition process systems

People are able to recognise large numbers of images such as a face, the letters of the alphabet and so on. Take the example of recognising letters of the alphabet; how to distinguish a letter from an infinite number of possible retinal images corresponding to a particular letter is a problem (Bruce and Green, 1985, p.169), depending on how the letter is written, the size and the angle at which it is seen. The simplest account offering how humans recognise alphanumeric characters would be that of template matching. In Bruce and Green's (1985, p.169) theory, a solution was determined as follows. Firstly, for each letter or numeral known by the perceiver there would be a template stored in advance in the long-term memory. Then, incoming patterns would be matched against the set of templates, and if there was sufficient overlap between a novel pattern and a template then the pattern would be recognised as belonging to the class captured by that template. Secondly, a pattern could be standardised in terms of its orientation and size. This template-matching programme could provide normalising procedures sufficient to render the resulting patterns unambiguous. However, this method included too many limitations. An 'R' alphabet could match an 'A' template and the bar which distinguishes a 'Q' from an 'O' may be located in a variety of places. The example given by Bruce and Green (1985, p.170) is shown in Figure 2.20.

Figure 2.20: Example (Bruce and Green, p.170).

To consider how people know the difference between ‘A’ and ‘R’ or even ‘Q’ and ‘O’, it seems that there are some certain features which distinguish one from another. One possibility is that perhaps a model in which combinations of features were detected, named feature analysis, would be more successful than one based on templates. Feature analysis models of recognition were popularised as a model of alphanumeric recognition by Lindsay and Norman (1972 cited in Bruce and Green, 1985, p.171). These models of recognition were popular with psychologists and computer scientists during the 1960s and consisted of a number of different classes of ‘demon.’ The most important of these for our purposes are the feature demons and the cognitive demons. In their model, the feature demons were assumed to respond selectively when particular local configurations (right angles, vertical lines) are presented. On the other hand, cognitive demons, which work as representations of particular letters, look for particular combinations of features from the feature demons. Thus, the cognitive demon representing the letter H might look for two vertical and one horizontal line, plus four right angles. The more features present, the louder will the cognitive demons ‘shout’ to the highest level (Figure 2.21).

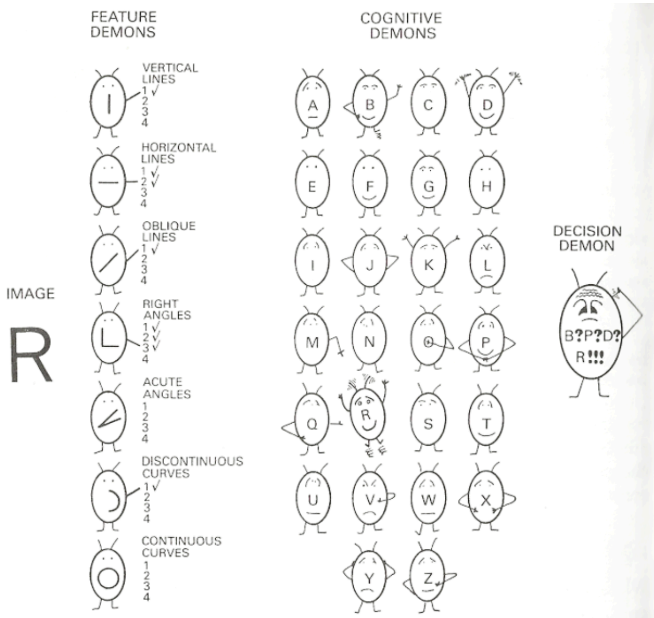


Figure 2.21: (Bruce and Green, 1985, p.172).

Object recognition theory has been proposed to explore the processes involved in recognising two-dimensional and three-dimensional stimuli. Research on object recognition explains the processes of object recognition from different perspectives such as template theories and feature theories. The basic notion of the template theory is sometimes seen as a minor copy stored in the long-term memory which has a system of template matching to recognise the closest match to the stimulus input (Eysenck, 2001, p.66).

This recognition begins with the idea of extraction of features from the presented images. It is necessary to consider the relationships between features as well as simply the features themselves. Another example is the alphabet letter “A”, that has crucial features which are two straight lines and a connecting cross-bar. This set of features stored in the memory has the advantage that visual stimuli vary greatly in minor details (Eysenck, 2001, p.68).

However, the limitations of both template and feature theories are clearer with three-dimensional than with two-dimensional stimuli. Observers can generally recognise three-dimensional objects even when some of the major features are hidden from view (Eysenck, 2001, p.72). Numerous theories have been put forward to account for object recognition especially those proposed by Marr (1982) and Biederman (1987) (in section 2.5.3).

2.4.2 Visual perception

The theory of visual form explains why contours are perceived, and how various spatial and temporal factors affect contour perception. Once a contour is perceived, it becomes possible for the organism to perform additional operations on it such as comparing two contours present in the visual field (to discriminate) or a contour and its memory trace (to recognise it). Discrimination and recognition shift the emphasis to the experiencing organism to learn, compare and make decisions (Zusne, 1970, p.16). This section includes a few comprehensive theories of behaviour and perception that deal with the perception of form, discussing this from different points of view – physiological and physical.

Ware (2004, p.187) indicated that the human being has a three-stage model of perception (Figure 2.22); the visual image is analysed in terms of original factors of form, motion, colour and stereoscopic depth at the first stage of feature abstraction. The second 2-D pattern perception stage; the features are revealed and according to texture, colour, motion and contour, the visual world is divided into dissimilar regions. Next, the object structures are observed; information has become the conjunction between component parts.

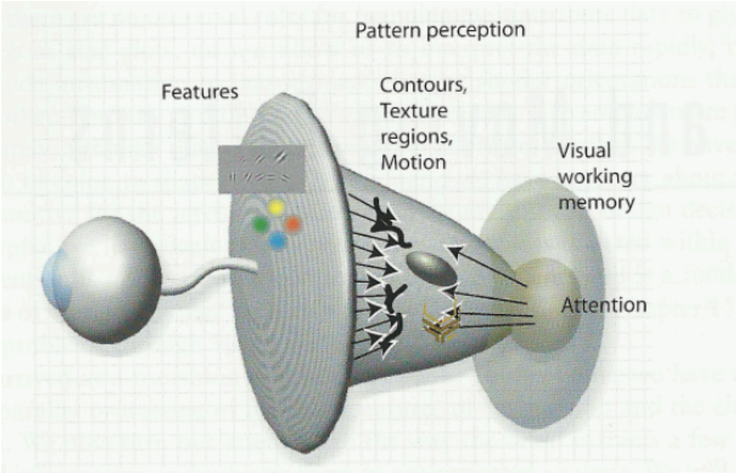


Figure 2.22: Pattern perception forms a middle ground where the bottom-up process of feature processing meets the requirements of active attention (Ware, 2004, p.188).

In the first stage, a great quantity of entire images occurs to prompt perception from the bottom up, but through active attention, object and visual search recognition is prompted from the top down to meet the demands of visual thinking. Pattern perception is the flexible intermediate zone where objects are chosen from patterns of features. Active processes of attention reach down into the pattern space to keep track of those objects and to analyse them for particular tasks; the essentially bottom-up processing of original features meets the top-down processes of cognitive perception. People's ability to organise data and perceive important structure can be explained by understanding pattern perception as above (Ware, 2004, p.188).

On the other hand, symbol is a clear idea of understanding the relationship between people and information. Symbols can be recognised and recalled to a surprising extent. The power of recall of symbols varies in significance, but due to the economy of elements, symbols are much more amenable to availability in storage (Gombrich, 1982, p.16). A symbolism researcher - Peirce (1991, p.8) asserted that the meaning of the graph is developed by object, sign and interpretant. Peirce depicted a sign as a product of a three-way interaction (Figure 2.23) (Goonetilleke et al., 2001). In addition, Mitchell (1986) categorised symbols into: picture, pictogram, ideogram and finally a sign for recognition in the mind (Figure 2.24).

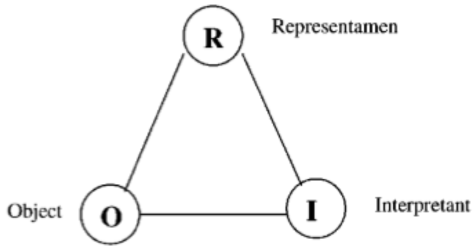


Figure 2.23: The components related to the interpretation of a sign (Goonetilleke et al., 2001).

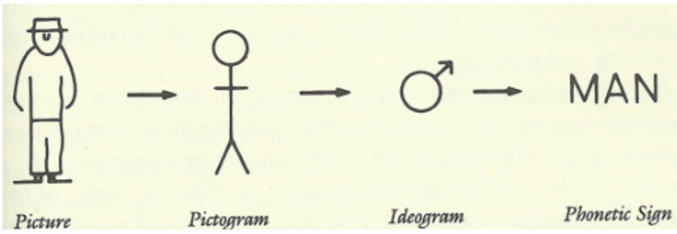


Figure 2.24: The category of symbols (Mitchell, 1986, p.27).

Marr (1982, p.20) indicated that a representation is a formal system for making explicit entities or types of information, together with a specification of how the system achieves the result of using a representation to describe a given entity in that representation. Take two kinds of number representation (Arabic and binary systems) for example, the Arabic number representation consists of symbols drawn from the set {0,1,…,9}. The number thirty-seven equals $3\times10^1+7\times10^0$; however, the representation in binary system of the number thirty-seven is 100101, and this representation makes clear the number's decomposition into powers of 2. The reason is simply that humans deal with information processing by using symbols to stand for things to represent them. This example reveals that even in an object with different order and arrangement, the total of the result can be the same.

2.4.2.1 The perception of form

The beginning of form perception was applied by the concept of Gestalt psychology which addressed that the perception of form is innate and basic;

furthermore, the fundamental constituent of form being its contour. Mostly, visual perception has been settled in the neurophysiological area of vision. It has uncovered some important properties of cells in the visual pathway; however, a proper understanding of the jobs that these cells are doing and the process of visual perception should be considered at a more computational level (Bruce, 1998, p.73).

Schumann (1900 cited in Helson and Fehrer, 1932, p.82) addressed a few points based on Gestalt psychology: (1) equal distances between members help form groups; (2) surfaces between groups appear larger than equal surfaces between members of groups; (3) nearness helps in the formation of groups; (4) contours of unities tend to stand out in perception; (5) incomplete figures tend to be seen as complete; (6) ambiguous figures may be seen as 'good' figures; (7) certain figures display properties characteristic of them as such; (8) some parts of a figure bring out certain properties while others bring out still other properties; (9) vertical symmetry is conducive to connectedness; (10) probably the main locus of the properties of figures is to be sought in central factors.

Forms may be simplified by reducing the number of turns or by increasing their regularity or symmetry. Green and Courtis (1966 cited in Zusne, p.64) discussed cartoon-drawing techniques that usually convey full information about the subject by using clever blank spaces or gaps in the contour that normally contain some angle like a homogeneous contour rather than an explicit statement. One of the consequences of structural theories of perception addressed by Ware (1999, p.251) is that simplified views should be easier to read. Ryan and Schwartz (1956 cited in Ware, 2004) showed that a cartoon image was recognised more rapidly than a photograph (Figure 2.25).

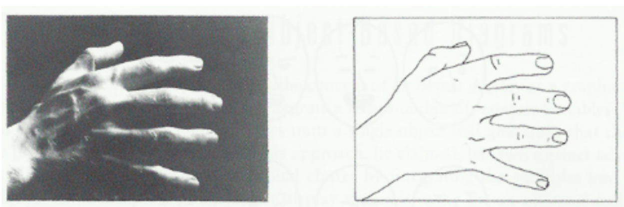


Figure 2.25: A photograph of a hand and simplified line drawing of the hand (Ware, 2004, p.237).

Since simpler forms contain less information, they should be easier to process. Simplicity leads to the consideration of certain Gestalt psychology that plays an important role since the simple figure is also a ‘good’ Gestalt. If a ‘good’ figure is one that is organised, therefore simpler, more symmetric, showing closure and good continuation, then all the concepts can be reformulated and hence also be quantified.

Gestalt theory indicated the importance of the law of Prägnanz (section 2.4.2.2), according to which the perceptual world is organised into the simplest and the best shape; however, it lacked definition to explain which shape is the simplest and best (Eysenck, 2001, p.24). Thus, a new method may decide the simplest perceptual organisation. Chater (1997) has indicated that simple things have slight descriptions; complex things have long descriptions. However, the limitation of human processing leads to us often failing to achieve the simplest possible perceptual organisation of the visual environment. Therefore, Chater (1997) mentioned that: “The cognitive system cannot find the shortest possible description for an object; but it can choose the shortest description that it can find.”

2.4.2.2 Gestalt psychology

The first serious attempt to understand pattern perception was undertaken by Gestalt theory which firstly addressed the idea of perception, and mentioned that human perception has the ability to systematically deny the possibility of ‘innocent eye.’ Furthermore, Köhler (1925, cited in Gordon, 2004, p.21) stated: a part will suggest a whole only if it is a genuine part. “There is an observable bias in our perception for simple configurations, straight lines, circles and other simple orders and we will tend to see such regularities rather than random shapes in our encounter with the chaotic world outside” (Gombrich, 1979, p.4). Gestalt psychologists proposed a set of laws to explain how vision groups elements in order to recognise objects (Pelli et al., 2009, p. 36). The word `gestalt` simply means pattern in German and produced a set of Gestalt laws of pattern perception. These are robust rules that describe the way people perceive a pattern in visual displays (Ware, 2004, p.189).

Zusne (1970, p.127) proposed degrees of goodness of visual form: configurational concepts do not represent absolutes. Perceptual organisation will go in a direction that secures the minimum amount of change and difference. Therefore, (a) in Figure 2.26 is considered as one object because the circle is a ‘better’ (symmetrical) object than either (b) and (c). The configuration in (d), however, is seen as two because each part separately is simpler than the two together. In terms of object goodness, whether one or two shapes will be seen can always be explained.

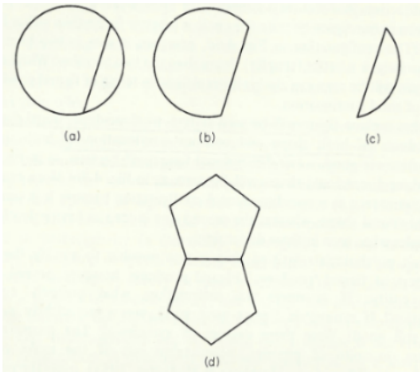


Figure 2.26: Degrees of configurational goodness (Zusne, 1970, p.128).

The Gestalt principles of organisation refer to the distribution of information in form; furthermore, those portions of a pattern showing symmetry, continuation, similarity, proximity and closure have less uncertainty. As stated in Gestalt psychology, the whole is more than the sum of its separate parts and not, in the positivistic sense, the sum alone. Katz (1951, p.6) explains that the principle maintains the phenomenon that human eyes tend to observe objects in their entirety rather than perceiving their individual parts initially. This emphasis on “whole” is the central idea of Gestalt psychology to lead the determining principles to proposing a number of rules that they called “laws of perceptual organisation” (Goldstein, 2007, p.99). This theory tries to understand the principles behind the ability to acquire and maintain stable percepts in a complex image. Thus, this law is a series of rules for explaining how human beings organise small parts into wholes. Overall, Gestalt psychology suggests 6 laws shown in the following paragraphs: (1) law of Prägnanz; (2) law of closure; (3) law of proximity; (4) law of similarity; (5) law of continuity and (6) law of symmetry.

Law of Prägnanz

"Of several geometrically possible organisations one will actually occur which possesses the best, simplest and most stable shape" (Koffka, 1935, p.138). Prägnanz translated from the German means `good figure`, and it indicates that the perceptual field and objects within it take on the simplest and most impressive structure permitted by the given conditions in its broadest form (Ash, 1995, p.224). The word 'Prägnanz' addressed in Gestalt psychology can mean clean-cut, concise or succinct. Gordon (2004, p.18) depicted a further explanation that when people suddenly see a face in the amorphous configuration of a cloud or a dying fire, this is a change towards perceptual simplicity. Nevertheless, once the face appears, the details become emphatic. This is a tension-enhancing rather than a tension-reducing process.

In terms of the law of Prägnanz, it related existing stationary organisations to certain maximum-minimum principles. In other words, minimum simplicity will be the simplicity of uniformity; maximum simplicity will be that of perfect articulation (Koffka, 1935, p.171); the first kind in after-image experiments and in other effects of reduced external forces of organisation; the second in examples of good shape and continuation. This law, also called the law of simplicity, states that "every stimulus pattern is seen in such a way that the resulting structure is as simple as possible" (Goldstein, 2007, p.99). The law of simplicity concentrates on the idea of conciseness that is the central idea in Gestalt theory. It can explain the phenomenon that the elements of the object usually tend to be perceptually recognised as the same object by people when formed as a regular, simple and orderly pattern. Simplicity implies that in order to observe and help the mind create meaning, people tend to delete complexity and unfamiliar elements when perceiving the image or object individually (Figure 2.27).

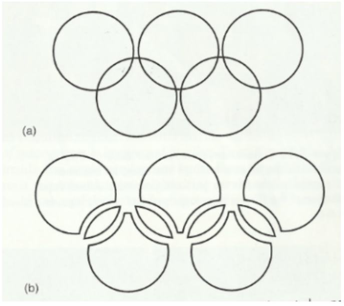


Figure 2.27: Example of Prägnanz (Goldstein, 2007, p.99).

Law of closure

Visual forms may be open or closed, complete or incomplete. Of several geometric perceptual organisations, that one will be seen which produces a ‘closed’ rather than an ‘open’ figure. (Bruce et al., 2003, p.125). Koffka (1935, p.167) stated that closed areas were more stable and therefore more readily produced than unclosed ones. When observing things at the beginning, humans are inclined to perceive independent elements as a closed pattern (Figure 2.28). More specifically, human brains will form a nonexistent line automatically by filling the blank between independent elements.

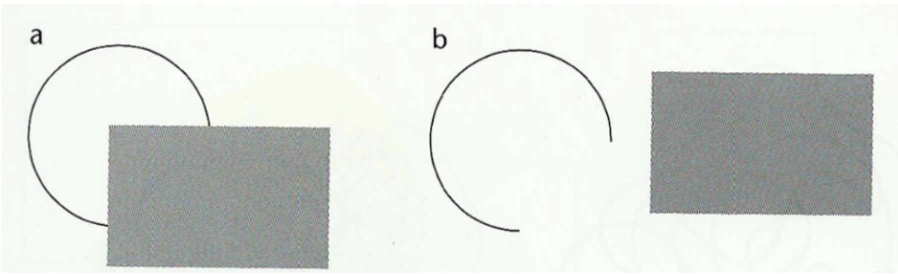


Figure 2.28: Example of closure (Ware, 2004, p.195).

Law of proximity

Spatial proximity is a powerful perceptual organising principle, describing that things close together are perceptually grouped in the human mind (Ware, 2004, p.189). Proximity explains that things near to each other appear to be grouped together (Goldstein, 2007, p.100). In Figure 2.29, only a small change in spacing enables recognition. The first picture (a) will be seen as 7 horizontal lines; however, picture (b) tends to be seen as 7 verticals. Thirdly, picture (c) will be categorised into two groupings of dots naturally (Figure 2.29).

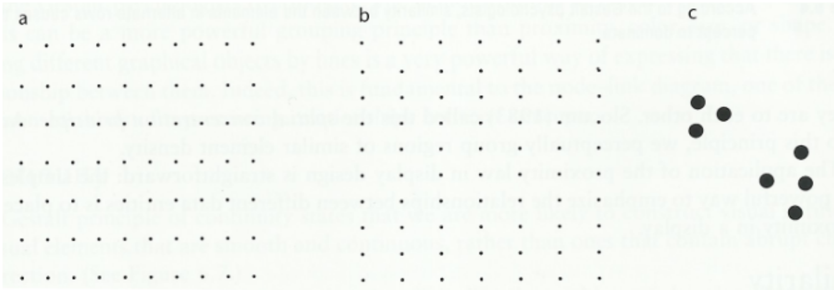


Figure 2.29: Examples of proximity (Ware, 2004, p.189).

Law of similarity

Most people perceive the Figure in 2.30 as vertical columns of circles due to similar things appearing to be grouped together (Goldstein, 2007, p.99). The shape of individual pattern elements can also decide how they are grouped. Similar elements tend to be grouped together (Ware, 2004, p.190). Shown in Figure 2.30.

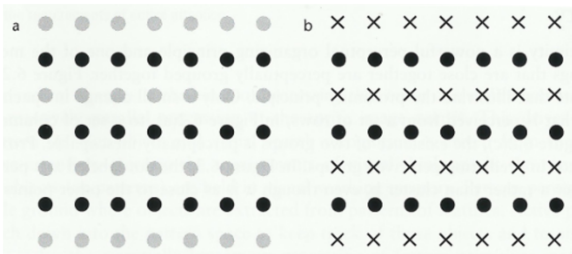


Figure 2.30: Examples of similarity (Ware, 2004, p.190).

Law of continuity

The law of continuity suggests that when points are connected in straight or smoothly curving lines, are seen as a group. Goldstein, (2007, p.100) addressed that lines tend to be seen to follow the smoothest path. Figure 2.31 shows an example of the Gestalt principle of continuity. Humans tend to construct visual elements that are smooth and continuous (Ware, 2004, p.191).

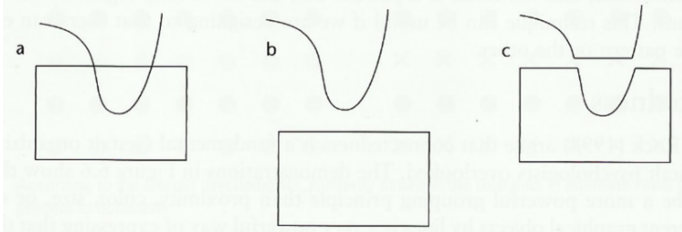


Figure 2.31: Examples of continuity (Ware, 2004, p.191).

Law of symmetry

Symmetrically located pattern elements will tend to organise and associate elements into groups; in addition, this principle is related to the aspect of the figure-ground phenomenon (Zusne, 1970, p.129). Symmetry in Figure 2.32 shows that the left hand side figure may be the reason why the cross shape is perceived, as opposed to the shape on the right, even though the second option is no more complicated (Ware, 2004, p.193). Humans tend to interpret the left pattern as a cross rather than two separated objects as in the right hand side pattern.

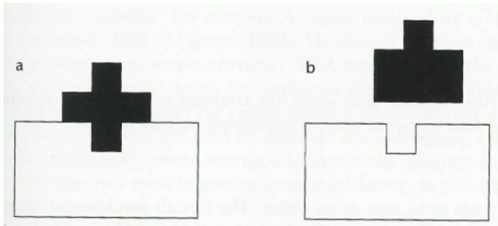


Figure 2.32: Examples of symmetry (Ware, 2004, p.193).

The most crucial idea of Gestalt hypothesis proposed that all objects appear as closed units originally if formed into wholes by the factors mentioned without experience (Katz, 1951, p.23). Gestalt psychology explained some visual phenomena such as the grouping principle and figure-ground. However, it mostly assessed detection rather than identification of compound objects (Pelli et al., 2009, p. 36). Gestalt theory emphasised the importance of the law of Prägnanz based on the perceptual world being organised into the simplest and best shape; however, they lacked any effective means of assessing what shape is the simplest and best (Eysenck, 2001, p.24). Thus, to assess grouping in object recognition, Section 2.4.3 summarises a measurement for identifying the simplified object based on Gestalt psychology.

However, as the description in the previous section, Gestalt psychology provided a remarkable concept of perception phenomenon but no available evidence to prove how the process happened. The missing element from Gestalt theory has been an account of the Gestalt theorists' view as to why perception is as Gestalt psychologists claimed (Gordon, 2004, p.21). Why is perception dynamic? What causes the degree of organisation that has been described in previous literature? How can the behaviour of stimuli be predicted in new situations - how do we know what something will look like? A set of descriptions cannot answer these questions. Therefore, theories of perceptual development are attempts to explain the Gestalt theory, not invalidate it. Vernon (1970) developed a further experiment to explain the process of visual perception based on the idea of Gestalt psychology. Vernon (1970, p.10) indicated that infants looked longest at vertical lines rather than at other simple line stimuli; moreover, they also followed with their eyes the contour of a brightly coloured triangle. When infants are able to perceive complex patterns clearly, it would seem that in this task they spend more time examining the complex rather than the simple in order to grasp all their details. However, there is some argument regarding the term ‘complexity’, as to the aspects of form to be determined.

2.4.3 Simplification methods study

Simplicity is defined as the effect certain phenomena have upon the observer and its meaning may be limited to such subjective reactions. When things are arranged with simplicity so as to represent to people by the senses humans can easily imagine, and in consequence, easily remember them (Arnheim, 1969, p.44). However, simplicity cannot only be defined by the number of elements; the regular square with four edges and four angles is simpler than the irregular triangle. Even though the triangle has fewer elements, the size and location has no symmetry. The four edges of the square are equal in length and the same distance from the centre, only two directions are used – vertical and horizontal, and all angles are of the same size which means that the whole pattern is highly symmetrical (Figure 2.33).

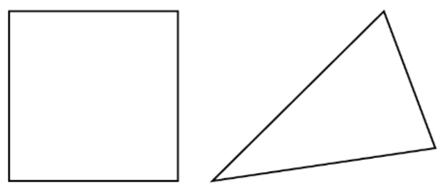


Figure 2.33: Square and triangle (Arnheim, 1969, p.47).

Arnheim (1969) defined that a thing is simple when it consists of a small number of structural features. In this argument, the term feature is not equal to element and can be described in terms of distance and angle. An example explained by Arnheim (1969), even a straight line is the simplest connection between points a and *b* only as long as the fact that a curve will make for a simpler total pattern is overlooked (Figure 2.34).

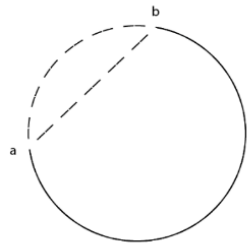


Figure 2.34: Example of simpler pattern (Arnheim, 1969, p.50).

The tendency towards the simplest structure in the brain field makes the percept as simple as possible; moreover, Arnheim (1969, p.50) suggested that the simplicity of the resulting experience also depends on: (1) the simplicity of the stimulus, which gives rise to the percept; (2) the simplicity of the meaning to be conveyed by the percept; (3) the relationship between meaning and percept and (4) the mental ‘set’ of the individual observer. The stimulus is the geometric pattern projected upon the retina of the eyes. In Figure 88, if someone looks straight at this picture, the stimulus pattern projected upon the background consists of four equal round dots. Four of the distances between the dots are equal; in four cases, three dots form a right-angular constellation. Psychologically, these geometric properties press for straight-line connections between the units and for the establishment of right angles.

On the other hand, the simplest possible connection of the four units would be a circle if the simplicity of the percept were the only factor to be considered. However, the perceptual result is determined by the structure of the stimulus in its interaction with the striving for greatest simplicity in the brain field; thus, the perceived pattern will be the one that combines the conditions of the retinal stimulus and the dynamic tendencies of the brain field in the simplest possible structure. Therefore, in Figure 2.35, the overriding of the potential rectangularity of the stimulus by the tendency to circularity in the brain would produce less simplicity than the brain’s willingness to settle for the less simple square which fits the stimulus better.

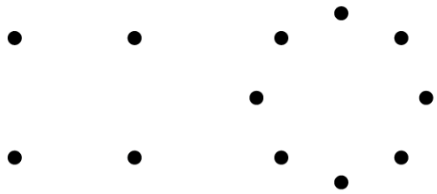


Figure 2.35: Examples of four dots and eight dots (Arnheim, 1969, p.43).

In Figure 2.35, the rectangular relationship between the units of the stimulus is less compelling, and the circular form is more closely approximated by the locations of the eight dots; therefore, according to these conditions a victory of circularity provides the simplest solution. According to the explanation by Gestalt psychology, these examples indicate that simplicity requires a correspondence of structure between meaning and tangible pattern.

The tendency to simplification will manifest itself in the way in which subdivision of patterns occurs, the eight dots of Figure 2.36 will be seen as a circle (A) rather as the star (B) or the combination of three units in (C); the nine dots of (D) will split up into two main units – the circle plus the outsider (Arnheim, 1969, p.58).

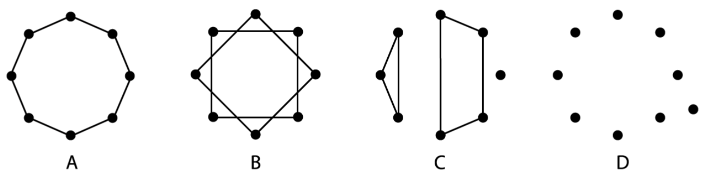


Figure 2.36: Examples of simplest organisation (Arnheim, 1969, p.60).

Subdivision of the whole is thus lawfully controlled by the familiar principle (Arnheim, 1969, p.60). Figure 2.37 (A) is an unbroken, unified disk to everybody; (B) is a star, characterised by a subdivision into spikes; however, in (C) the continuity of the surrounding outline explodes. Observers tend to find its shape; the whole pattern splits into triangle and rectangle.

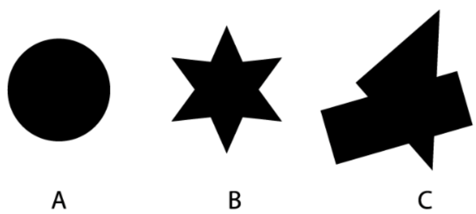


Figure 2.37: Examples of simplest organisation (Arnheim, 1969, p.60).

2.4.3.1 Node Quantity

Shape and form perception could be a development based on templates, prototype, characteristics, nodes and recognition-by-components theory. The template method is described as a model with high quality details, where humans might have the ability to recognise the form based on comparing the form with a model in their mind. Prototype is a further concept of the template. Prototype means a set of relevant objects or forms which include typical or distinctive characteristics. It means that it doesn't have to be hundred percent accurate or have to match any form completely. The characteristic method provides another explanation where humans tend to compare the characteristics of the form and the characteristics in memory. This study obtains the initial idea from first (redundancy) and second (organise) law. In order to figure out an appropriate measurement for the degree of simplification, the following sections are going to discuss two simplification methods – node quantity and component quantity (Section 2.4.3.2).

Graphic drawing aims to present graphs pleasantly and to be read easily. In terms of graphics, it is a structure which comprises nodes and edges. A square will be seen as square; however, in Figure 2.38 (a), most people tend to see spontaneously a square rather than the other figures suggested in (b) or (c).

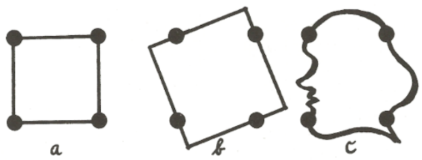


Figure 2.38: Example of node linking (Arnheim, 1969, p.43).

Some people observe circles or a square appearing in the centre of the crosses shown in Figure 2.39, even though there is no trace of a circular or square-shaped contour. The basic law of visual perception in Gestalt psychology explained this phenomenon.

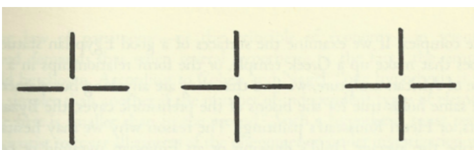


Figure 2.39: Example of Gestalt psychology (Arnheim, 1969, p.44).

Attneave and Aroult (1956) proposed an experiment in which 80 subjects were asked to approximate curved shapes by placing 10 points on their contours and connecting them with straight lines. The results presented a substantial agreement among subjects in the placement of the points: most of them coincided with the points of greatest change in the degree of curvature in the form. Therefore, Zusne (1970, p.62) argued that forms might be made simpler with more redundancy by decreasing the number of turns or by adding their regularity or symmetry. That simpler forms include less information is a well-established principle. Hick (1952) measures simplicity by applying reaction time and the information content of visual stimuli, then proposes a conclusion that reaction time was directly related to the average amount of information transmitted as the subject performed a task, regardless of whether uncertainty was related to the stimulus or to the response. After this a substantial number of experiments were conducted on either reaction time or other response measures indicative of information processing, with shapes and other visual displays as stimuli.

The measurement of node quantity is supported by: (1) Gestalt psychology; (2) object recognition; and (3) Attneave's theory that the central core is node decreasing to make graphs simple. Partial quantity based on (1) Marr and (2) Biederman's object recognition theory addressed that decreasing components makes graphics simple. This chapter explores the measurement of simplification that applies to the development of logo/app icon design.

2.4.3.1.1 Contours and curves

Contours may be described as the path that they follow in space which is the one-dimensional interface between figure and ground, changing in some gradient: colour, shadow, parallel lines seen in perspective; in addition an edge stands out against another surface of some other colour or texture (Zusne, 1970, p.17). Gibson (1950 cited in Zusne, p.191) proposed a basic description of straight and curved lines. A line is completely specified by stating its direction (left slant, right slant, zero slant) and curvature (convex, straight, concave) after stating its length. Because the process that leads to the identification of contours is considered as essential to object perception, contour detection has received important attention from vision researchers (Ware, 2004, p.199). Contour is the one-dimensional interface between figure and ground, changing in some gradient: colour, shadow, parallel lines seen in perspective; in addition an edge stands out against another surface of some other colour or texture (Zusne, 1970, p.17). Marr (1982, p.215) indicated four basic ways in which contours can arise in an image: (1) discontinuities in distance from the viewer (occluding contours), (2) discontinuities in surface orientation, (3) changes in surface reflectance and (4) illumination effects like shadows, light sources, and highlights. Contours are all two-dimensional and yield information about three-dimensional shape (Figure 2.40).

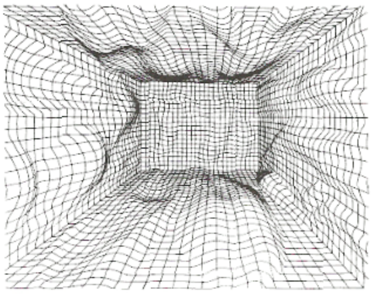


Figure 2.40: Example of two-dimensional contours in an image that imparts three-dimensional information to the viewer (Marr, 1982, p.217).

Forgus (1966) and Hochberg (1964 cited in Zusne, 1970, p.17) indicated that while both a contour and an edge can delineate only one of two adjacent areas to which they are common, a contour may easily change its “allegiance”, delineating now one, now the other area, if the conditions favour both areas as figures. An edge does not do this because it has no particular property. Comparing contours and edges to figure out similarity and differences explains the phenomenon of reversible figure-ground configurations such as Rubin’s vase-face figure and Escher’s woodcut ‘Day and night’ (Figure 2.41). The figure vase-face is produced by edges where the faces are at a disadvantage because the eyes and backs of heads are incomplete, whilst the vase is complete. In contrast, if the whole group of birds in the figure ‘Day and Night’ are looked at once, attention must be shifted in order to see just the dark or light birds. However, natural objects simply do not have this ability. The difference between Escher’s artwork and actual objects is the difference between thought and actuality. “Thought can produce possible, probable, improbable, and plainly impossible ideas and images” (Zusne, 1970, p.18).

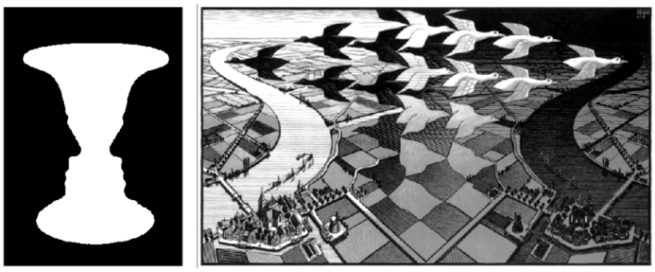


Figure 2.41: Rubin’s vase-face and M.C. Escher’s 1983 woodcut ‘Day and Night’ (Poole, 2015).

A contour is a continuous perceived boundary between regions of visual image that can be separated by line or a boundary between regions of different colour (Ware, 2004, p.198). “Certain combinations of incomplete figures give rise to clearly visible contours even when the contours do not actually exist, it appears that such contours are supplied by the visual system” (Kanizsa, 1976, p.48). To examine the conditions that give rise to visible contours, a contour is usually perceived when there is a jump in the stimulation between adjacent areas. Figure 2.42 shows the example of people’s tendency of viewing illusory contour.

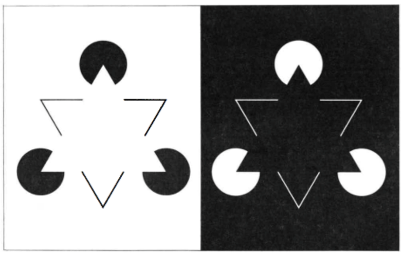


Figure 2.42: Illusory contour (Kanizsa, 1976, p.48).

Occluding contours are simply contours that mark a discontinuity in depth, and usually conform to the silhouette in a two-dimensional projection (Marr, 1982, p.218). Silhouettes have an influence on determining the process of perceiving objects. Thus, line drawings are often silhouettes that infer human ability to interpret objects; furthermore, in perceptual processing, the same neural contour-extraction mechanisms have been stimulated by the silhouette boundaries of objects and the simplified line drawings of those objects (Ware, 1999, p.249). Each object has a particular silhouette that is easily recognisable (Figure 2.43).

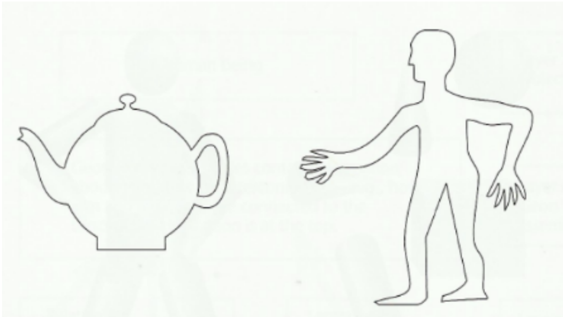


Figure 2.43: Many objects have canonical silhouettes, defined by the viewpoints from which they are most easily recognised (Ware, 2004, p.236).

In Marr's (1982) point of view, contour information is used in segmenting an image into its component solids. Marr and Nishihara (1978 cited in Ware, 2004, p.235) depicted that concave sections of the outline are the major judgement in defining the different solid parts (Figure 2.44).

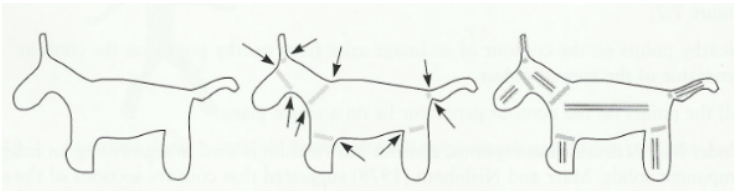


Figure 2.44: Concave sections of the silhouette define subparts of the object (Ware, 2004, p.236).

2.4.3.1.2 Experimental task

In the procedure of simplification, "the very fine detail is ignored or, rather, averaged out in the interest of a more economical representation of the object" (Zusne, 1970, p.60). The first step in applying information theory to the measurement of form was to show where information was contained in form. Zusne (1970, p.59) demonstrated that "information is concentrated at points where there is a change in an otherwise continuous gradient". It indicates that the contours of a form mark the change from ground to figure, also at any inflection along the contour where the direction of the contour changes most rapidly (Attneave, 1955). Figure 2.45 shows the ability of re-organisation of the object showing that important information has been retained. Thus, this section is going to review previous experiments which determine the limitation of object recognition based on numbers of node.

Figure 2.45: A curvilinear object (left) represented by straight lines (right) (Zusne, 1970, p.60).

The concepts of visual information and Gestalt psychology summarised that "information along visual contours is concentrated in regions of high magnitude of curvature, rather than being distributed uniformly along the contour" (Feldman and Singh, 2005). Zusne (1970) argued that the node of a polygon is the concentrated point for human vision rather than a straight line. The information puts more emphasis on "the points where a contour changes direction most rapidly" (Attneave, 1954). Thus, an experiment of image simplification addressed by Attneave is shown as follows (Figure 2.46). In Attneave's experiment, there are thirty-eight points of maximum curvature from the contour of the cat.

Figure 2.46: Sample simplification (Attneave, 1954, p.185).

The rate of error in guessing the outline of a form varies depending on the amount of information contained in any particular portion of the outline; thus, using this guessing technique, Attneave (1954) demonstrated that principles of perceptual grouping, such as similarity and good continuation, refer to various types of redundancy which may exist within a static visual field, enabling an observer to 'predict' portions (Attneave, 1954). Attneave (1954) suggested that the number of errors made in guessing the outline of a form could be used as a measure of figural 'goodness'. Hence, node quantity can be one of the available methods to explore in simplification.

2.4.3.2 Component Quantity

The earlier section on studies of physical phenomena had evidence to support a general principle of minimum principle (Gordon, 2004, p.22). The idea of minimum principle can be simply understood as minimum energy, minimum surfaces that the path of perception takes with the smallest amount of effort and least energy. Even though the idea of physical Gestalten had seemed more plausible as the basis of a theory of perception, this would not have solved all the problems facing the Gestalt theory. For example, when people attempt to analyse a particular pattern, how do they define its component? It is important to recognise that Köhler did not suggest that there were pictures in the head. Gestalt isomorphism is defined as existing between organised experience and processes in the brain.

The previous section (2.4.2.2) has shown that many of the Gestalt laws are useful descriptive tools for a discussion of perceptual organisation, but further literature still has some way to go to provide an adequate theory of why the principles work to how perceptual organisation is achieved. Having a set of descriptive principles is still only the starting point for the full information-processing theory of grouping processes. Biederman (1987)'s perception sequence can be applied to explain primitive elements recovered from images - edges, blobs and so on - in order to recover the potentially significant structure present. Research in artificial intelligence (A.I.), such as David Marr's works (1978, 1982), has attempted to provide such a process theory of perceptual organisation, which is much more powerful than a purely descriptive theory (Gestalt). Marr's achievement in early visual processing program implements such a process theory and extended use of Gestalt principles to achieve perceptual organisation.

During the 1960s and 1970s, many researcher approaches to grouping in artificial intelligence attempted to solve the segmentation problem (Bruce and Green, 1985, p.119). This research focused on how to divide up a visual scene into a number of distinct objects. Figure 2.47 shows an outline of a collection of objects which consisted of just straight lines in a variety of orientations. People's spontaneous perception of such a scene is more likely to be of a collection of distinct objects. For instance, even though this scene is readily described as two blocks and a wedge, and the Gestalt psychologist might argue that the perception of regions a, b and c as belonging together provides a closed, simple and symmetrical interpretation, it still is not adequate to explain how such a solution is achieved by visual processing.

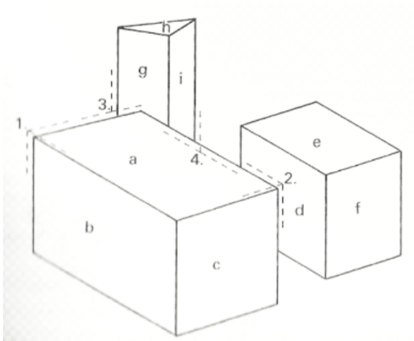


Figure 2.47: Example (Bruce and Green, 1985, p.119).

This problem was tackled by Guzman and Clowes (1968, 1971 cited in Bruce and Green, 1985, p.120), who tried to write computer programs which could see objects from collections of lines. The common rule in their work was the consideration of the junctions. A junction could be understood as a point where two or more lines meet; therefore, different junction types have different implications for the possible arrangement of surfaces within the picture. Guzman (1968 cited in Bruce and Green, 1985, p.120) addressed that the presence of an arrow junction would generally imply that the edges which formed the fins of the arrow belonged to a single body, while a ‘T’ shape junction generally implied that the shaft and the cross-bar of the T belonged to different bodies. That is to say, most structures include breaks, seams and joints, and the parts defined by the structure itself. A cut in the middle will produce a subdivision that fits the shape of the whole; hence, the difference between sections and parts will occur. In more detail, when a line shows sufficiently strong breaks or turns, the sections segregated by the corners or turning points will be its parts. Then, the part is a section of a whole that under the given conditions shows some measure of separation from its environment.

However, Guzman’s program lost some important pieces which only considered the junctions. Clowes (1971 cited in Bruce and Green, 1985, p.120) depicted the problem of junctions more systematically and specifically. The work addressed by Clowes employed a sophisticated notion of how different junction types in the image relate to the organisation of objects in the scene. In general, junction lines could be represented as the edge and intersection line in the natural world. Edges may be convex, concave or occluding form, in detail. Bruce and Green (1985, p.120) addressed that only certain combinations of edge types are compatible with a particular configuration of lines at a junction based on Clowes' program (Figure 2.48). It was able to interpret pictures successfully provided that no more than three lines met at a single junction and also able to reject certain pictures such as impossible objects.

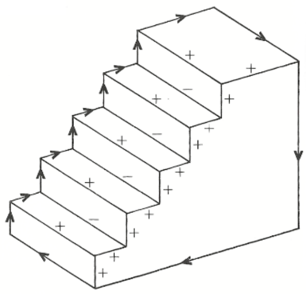


Figure 2.48: Convex (+), concave (-) and occluding form (>) (Bruce and Green, 1985, p.120).

While understanding how to determine junctions and the way of dividing them into sections, another task is how to manage those small 'elements' in a more organised way. The illustration on the left in Figure 2.49 is a set of simple shapes that are hardly describable and readable as an organised figure. In the right box (Figure 2.49) the shapes have been organised in a certain way into a face. The face would not have emerged without the shapes, but now the shapes themselves are seen differently such as a circle become eyes; a line becomes a mouth and nose. The parts form the whole, but the whole changes the parts. The simple shapes when assembled in a certain manner become organised into a recognisable and readable pattern.

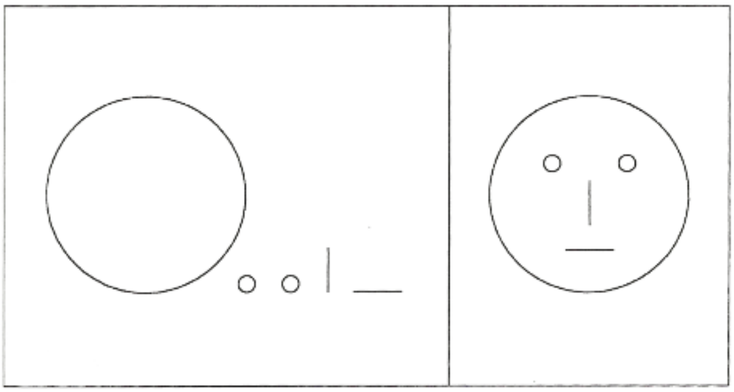


Figure 2.49: The mutual interaction of parts and wholes (Gordon, 2004, p.19).

"Objects can be identified far more rapidly if they are presented in views that clearly reveal the connections between component parts" (Ware, 2008, p.111). The phenomenon of object identification in daily life provides strong limitations on possible models of recognition. Basically, an object can be recognised quickly under the conditions of: viewed from novel orientations, with less visual noise, and parts which have been occluded (Biederman, 1987, p.117). Biederman (1987) proposed the preceding phenomenon affects theorising about object description in: (1) The process of object recognition should not be dependent on judgements of quantitative detail (2) Partial matches should be systemised. Based on the above descriptions, the human ability to identify can be accounted for.

However, after the definition of the terminology 'parts', what rules or mechanisms determine the division of shapes into parts? Hoffman and Richards (1984 cited in Barenholtz and Feldman, 2003) proposed an influential advice that the visual system pares object contours at the extrema of concave curvature referred to as 'minima rule.' Minima rule provides the basic idea of segmenting boundaries; nevertheless, not every contour and curvature segment with high curvature, is perceived as a part boundary; only concave curvature are so treated (Bareanholtz, 2003, p.1656). In Figure 2.50, the minima rule as the extrema of negative curvature (A) are interpreted as part boundaries which can divide the shape into two separate parts effectively. On the contrary, positive extrema (B) of the same curvature are not interpreted as part boundaries.

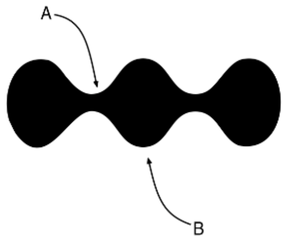


Figure 2.50: Minima rule (Barenholtz and Feldman, 2003).

Thus, after reviewing the initial concept and methods of distinguishing 'part,' the next section is going to review the component base theory and experiment for further evaluation.

2.4.3.2.1 Computation theory

Of more interest to the discussion above is a processing model which can recover structures from natural images of everyday objects and surfaces despite the internal marking, texture and shadow. Marr's (1976, 1982 cited in Bruce and Green, 1985, p.121) early visual processing programme found occluding and internal contours from images. Marr's (1976 cited in Bruce et al. , 2003, p.164) programme indicated how an object's occluding contour and internal marking could be assembled from a collection of more primitive descriptions comprising the raw primal sketch, and further used to segment a complex occluding contour into different "part" components. Hoffman and Richards (1984 cited in Bruce et al., 2003, p.164) argued for an analysis of the role played by concavities in contour segmentation. They showed transversality regularity: distinct parts of objects intersect in a contour of concave discontinuity of their tangent planes. At any point around this intersection, a tangent to the surface of one part creates a concave cusp with the tangent to the surface of the other part. Concave implies that it points into the object rather than into the background (Figure 2.51). Transversality regularity contends that in an image of a complex shape, "concavities" mark the divisions between the contours of distinct parts. Concavities can be recognised in the contour of smooth shapes through seeking places where there is greatest negative curvature (Bruce, Green and Georgeson, 2003, p.164).

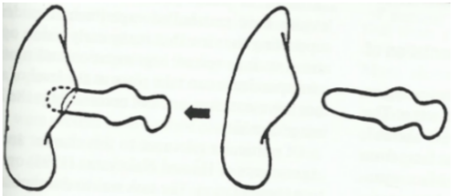


Figure 2.51: Transversality regularity (Hoffman and Richards, 1984 cited in Bruce, Green and Georgeson, 2003, p.165).

Marr (1982) assumed that three visual representations of increasing complexity were formed during visual perception (Figure 2.52).

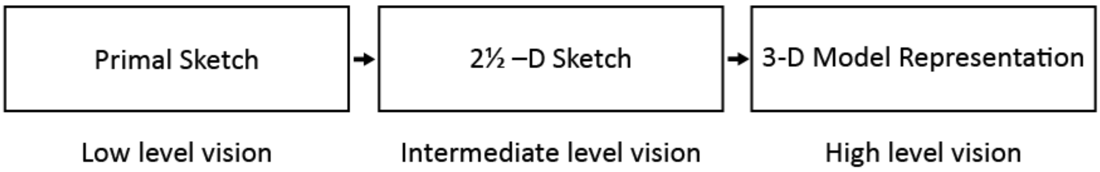


Figure 2.52: Three steps of computation theory.

The first representation – the primal sketch – comprises edges, contours and blobs. The primal sketch includes information about light-intensity changes in the visual scene, and furthermore, it utilises the information from the raw sketch to identify the number and outline shapes of the visual object (Marr, 1982, p.52). Secondly, the primal sketch is applied to form a second representation named the 2½–D sketch that is more detailed than the primal sketch, and contains information about the depth and orientation of visible surfaces. The argument is that the 2½–D sketch contains more distinct information about the image such as depth, orientation of visible surface and contours than the early visual processes. This formulation averts all the difficulties associated with the terms figure and ground, region and object, and the difficulties inherent in the image segmentation approach (Marr, 1982, p.279). The 2½–D sketch is a viewer point-centred representation which means that the visual information depends on the precise angle from which the object is viewed. The main elements applied in changing the primal sketch into the 2½–D sketch include shading, motion, texture, shape and binocular disparity (Eysenck, 2001, p.73). Shown in Figure 2.53.

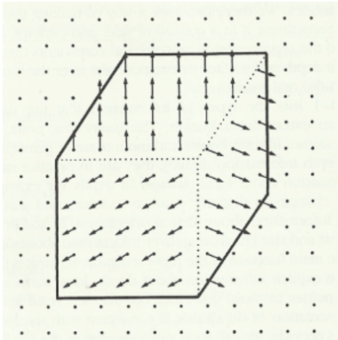


Figure 2.53: Example of 2½-D sketch (the surface orientation is represented by arrows, occluding contours are shown with full lines and surface orientation discontinuities with dotted lines)(Marr, 1982, p.278).

Thirdly, the 3-D model representation is a complete representation without the limitation of the 2½–D sketch. This model combines a three-dimensional representation so that viewers are able to decide the viewpoint independently. That is to say, this representation stays the same regardless of the viewing angle (Eysenck, 2001, p.73). In addition, Marr and Nishihara (1978) also indicated that concavities (areas where the contour points into the object) are identified first, and then segmented into several smaller components. In spite of a single 3-D model being a simple structure, it can be divided into several geometric shapes and details (Marr, 1982, p.306). Eysenck (2001, p.74) explained the Marr and Nishihara's example as follows: human form consists of a concave area in each armpit. These concavities are applied to segment the visual image into several parts such as arms, forearm and hand (Figure 2.54).

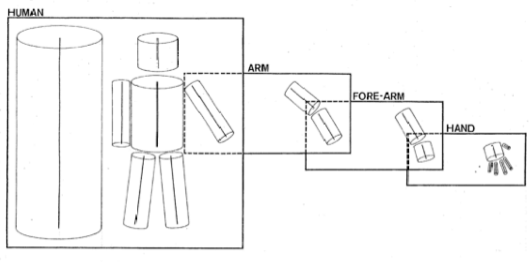


Figure 2.54: The organisation of 3-D model description (Marr and Nishihara, 1978, p.13).

Marr and Nishihara (1978) obtained the component axes from an image of a donkey (Figure 2.55). From this initial outline, convex and concave segments were labelled and used to separate the donkey into smaller sections. The axis is derived for each of these sections separately, and then these component axes are related together to form a stick representation for the entire figure. Figure 2.55 has six diagrams which reveal the concept of components: (a) the outline of a toy donkey; (b) convex (+) and concave (-) sections; (c) strong segmentation points; (d) the outline is divided into a set of smaller segments making use of the points found at (c) and rules for connecting these to other points on the contour; (e) the component axis is found for each segment; (f) the axes are related to one another (thin lines). (This section is referenced for Chapter 5.)

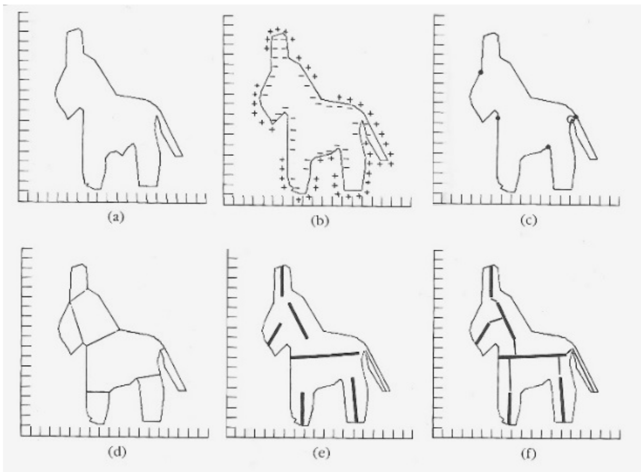


Figure 2.55: The programme derived the component axes from an image of a toy donkey (Marr, 1982, p.315).

The success of Marr's early visual processing programme can be evaluated by its ability to recover the occluding contours from the image of a teddy bear (Figure 2.56), and to reveal the internal contour of the bear which corresponds to eyes, nose and other detail outlines. Marr's theory of early visual processing thus contrasts strongly with some computer models or more general theories of visual perception where expectations and object-hypotheses guide every stage of perceptual analysis (Bruce and Green, 1985, pp.127).

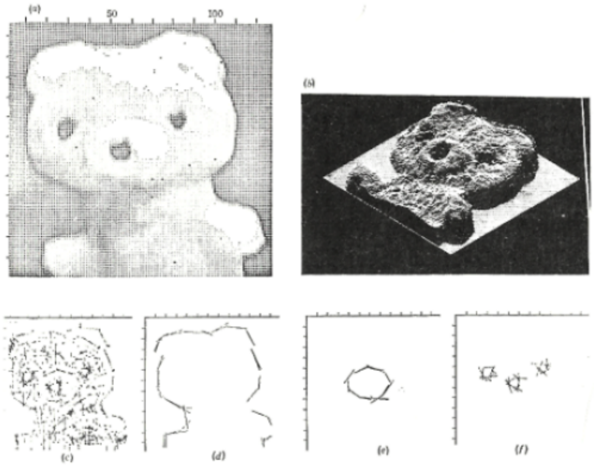


Figure 2.56: the image of a teddy bear is printed in (a), and shown as an intensity map at (b). At (c) is shown the location of all the small edge segments in the raw primal sketch. The structures which emerge after grouping operations are shown at (d), (e) and (f). Reproduced by Bruce and Green (1985, p.126).

The Gestalt psychologists, through the study of simple pattern perception, gave an insight into the organisational principles which may apply to this concept of the world. However, Marr (1982 cited in Bruce and Green, 1985, p.128) hadn't yet solved the figure-ground or segmentation problem. The achievement of early visual processing is not to recover the objects present within a scene - for the division of a scene into component objects is an arbitrary and ambiguous affair, at least at this stage; it is there to describe the surfaces present in the image.

2.4.3.2.2 Recognition by components (RBC)

Even though the concept of Gestalt psychology offered masses of literature about simplicity, it still seems to be the basis of a theory of perception. The simple question is: when people attempt to analyse a particular pattern, how do they define or what do they say about its components? Hoffman and Sign (1997, p.32) depicted the concept 'salience' of an inferred shape part which means that it has to have ''good'' parts and be able to provide better retrieval cues for recalling shapes (Bower and Glass, 1976) and easily identified in mental images (Reed, 1974). According to Marr's (1982) theoretical approach, Biederman (1987) proposed a theory of object recognition describing objects as consisting of basic shapes or simple components (Eysenck, 2001, p.74; Biederman, 1987, p.118); hence, for the recognition of an object the edge-based contour is extracted first, then decomposed and then comes the parsing or segmenting of its parts at regions of deep concavity into geons. This idea explains that there are mechanisms in the brain to recognise 3-D structural components of objects. Geons are 3-D shapes that can be curved or straight and in addition the geon components of objects are stored information in the brain, and combine with a structure skeleton which is a description of the way they are connected (Ware, 2008, p.110).

An experimental work by Biederman and Cooper (1992 cited Ware, 2004, p.229) suggests that the optimal size for recognising a visual object is about 4-6 degrees of visual angle where humans can best see the visual patterns contained in them. In addition, a structure-based approach proposes that form is analysed in terms of original 3D shapes and the structural interrelationship between them. Figure 2.57 provides a somewhat simplified overview of a neural-network model of structural object perception, developed by Hummel and Biederman (1992 cited in Ware, 2004, p.233). This theory proposes an order of processing steps leading to object recognition. It is firstly divided into edges, and secondly into component axes, oriented blobs, and vertices (Ware, 2004, p.233).

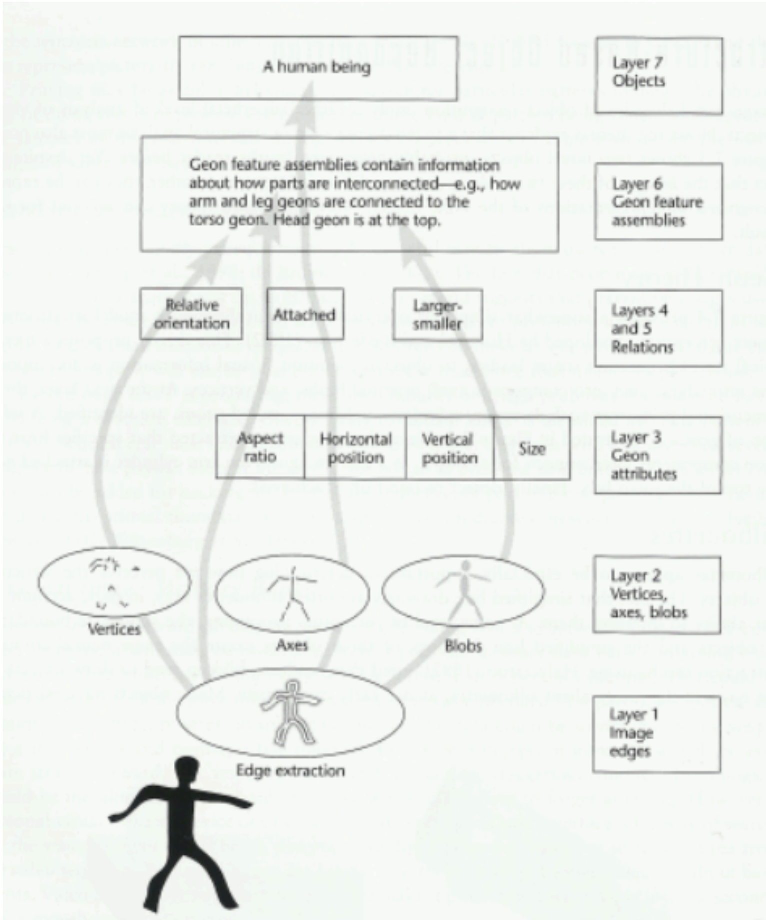


Figure 2.57: A simplified view of Biederman's (Ware, 2004, p.234) neural-network model of form perception.

In the first phase of processing, Biederman (1987, p.117) argued that "an early edge extraction stage, responsive to differences in surface characteristics - namely, luminance, texture or colour, provides a line drawing description of the object." The second phase is to explain how a visual object should be segmented to establish the number of its parts. The concave parts of an object's contour are of particular value in this task (Eysenck, 2001, p.75). RBC theory implies that the representation of images can be segmented into separate regions at points of deep concavity, especially at cusps where there are discontinuities in curvature (Marr & Nishihara, 1978; Biederman, 1987, p.117). Based on the theory of Biederman (1987, p.115; Eysenck, 2001, p.75), five detectable properties of edges in a 2-D image are as follows: (1) curvature: points on a curve; (2) co-linearity: points in a straight line; (3) symmetry: versus asymmetry; (4) parallelism: sets of points in parallel and (5) cotermination: edges terminating at a common point. Otherwise, he argued that 36 different geon scans can be arranged in almost endlessly different ways. Shown in Figure 2.58.

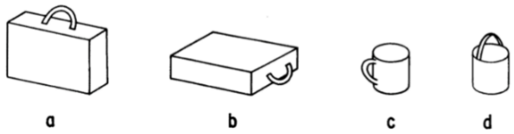


Figure 2.58: Different arrangements of the same components (Biederman, 1987, p.119).

Biederman (1987) and Eysenck (2001, p.76) explained the human ability to achieve object recognition when viewing conditions are incomplete: (1) the invariant properties, such as curvature of parallel lines, can be recognised even when only parts of edges are shown; (2) the outline of objects can be recognised when concavities of a contour are provided, because there are mechanisms helping the missing parts of a contour to be restored; (3) there is normally much redundant information available for recognising complex objects, for example, a giraffe could be identified from its neck alone.

Even when some of the geons are missing, Biederman (1985) has argued that complex objects can be recognised. In his experiment, when only three or four of the components were present, participants recognised the object 90% of the time. Biederman (1987) and Eysenck (2001, p.76) proposed a study in which degraded line drawings of objects were presented (Figure 2.59). The object was more difficult to recognise when parts of the concavities were missing than when other parts of the contour were deleted. Hence, information about concavities is crucial for object recognition, as predicted by the theory.

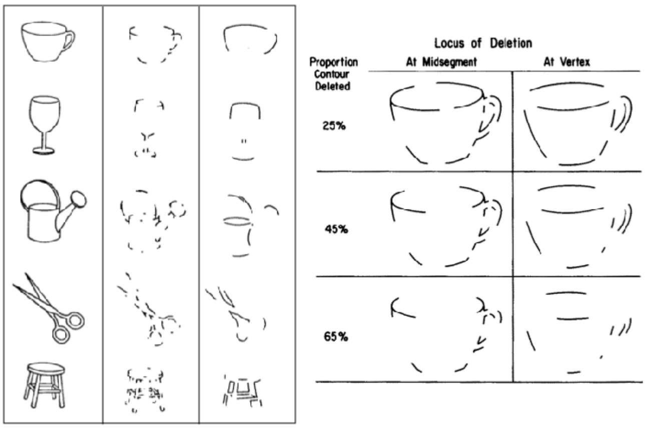


Figure 2.59: Example of five objects in Biederman's experiment (Biederman, 1987).

According to Biederman's theory, the ability of object recognition is based on edge information compared to surface information. Therefore, Biederman (1987) proposed that the input image is initially organised into its constituent parts or geons, with geons forming the building blocks of object recognition. However, Eysenck (2001, p.77) has suggested there is a limitation to Biederman's RBC theory. Firstly, the edge-based extraction processes addressed by Biederman (1987) already supply enough details to permit object recognition. Hence, line drawings are idealised versions of the original edge information and, for instance, the irrelevant edges of the object are often omitted (Eysenck, 2001, p.77).

Secondly, Biederman recommended a viewpoint-invariant theory, according to which ease of object recognition is unaffected by the viewpoint of the observer. This part of Biederman's theory resembles Marr's (1982) viewpoint-invariant 3-D model representation. This approach can be contrasted with view-point-dependent theories (Tarr and Bulthoff, 1998), which addressed that viewpoint changing decreases the speed and accuracy of object recognition. Tarr and Bulthoff (1998) indicated that the speed and accuracy of object-naming depended on the familiarity of the viewpoint, which is in line with viewpoint-dependent theories (Eysenck, 2001, p.78). Based on the theory of Hayward and Williams (2000, p.11 cited in Eysenck, 2001, p.79) they pointed out that "under some circumstances, shape differences may be large enough, distinctive enough, or overlearned enough to support viewpoint-invariant recognition (e.g., distinguishing a square from a line drawing of a car could surely be done in a viewpoint-invariant manner)". Furthermore, Biederman's theory de-emphasises the role played by context. Palmer (1975) proposed that pictures of objects were easier to be identified when showed briefly.

The RBC theory assumes organisational phenomena as object recognition. As the previous section mentioned, generating geons through the Gestalt principles, particularly the law of simplicity, helps to determine the individual geons rather than the whole object (Biederman, 1987). More specifically, component match should be countable. Biederman's research is able to explain the human ability to identify such things as the object (a chair, for example). A chair can be partially occluded by other furniture, or when a leg is missing. In addition the RBC theory explored the relationship between the reaction time of object recognition and the process of component reduction. Biederman (1987) indicated that the limited number of components should retain at least 3-4 geons (Figure 2.60).

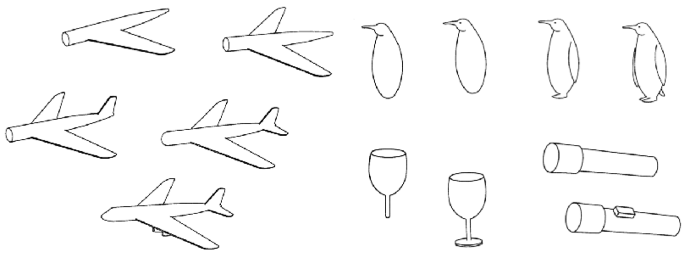


Figure 2.60: Illustration of 2 nine-component (airplane and penguin) and 2 three-components objects (the glass and flashlight) (Biederman, 1987).

Biederman (1987) also argued about the relationship between errors in object recognition and the nature of contour deletion. The result reveals that even deleting some components, retaining 3-4 nodes of the main elements of the object allows it to be recognised successfully.

2.4.4 Shape analysis

As stated by Arnheim (1969, p.37), "shape is one of the essential characteristics of objects grasped by the eyes." This section is going to determine the characteristic of shape which is possible to influence 'simple' judgement. After reviewing previous methods of how to simplify an object, node quantity and component quantity experiments have already given significant results of limitation of nodes and numbers of components. This can be translated as numbers of angles and number of components in this study. Moreover, apart from these experiments mentioned above, what other features, or characteristics should be concerned in shape analysis? Although the Gestalt theory of 'simplicity' or 'good figure' can be applied to geometric figures, some investigations have disproved the Gestalt psychologist hypotheses. Helson and Fehrer (1932, p.82) claimed the inadequacy of the Gestalt concept of 'simplicity'. For instance, according to the Gestalt psychology concept the circle is the simplest figure and for this reason should be identified more easily than other forms. However, Helson and Fehrer (1932) found that the circle ranked after the rectangle and triangle in perceptibility.

Are regular figures more easily remembered than irregular ones simply because they contain less information to be remembered, or does their priority persist even when information is held constant? In other words, what is remembered more accurately — a large, well-organised figure, or a small, poorly-organised figure containing the same amount of information? Therefore, an experimental investigation of this problem is analysed in this chapter. Shape analysis in this chapter aims to figure out which characteristics or factors might be an influence on shape recognition and legibility.

Humans perceive and identify simple forms immediately in normal conditions; however, Vernon (1970, p.32) indicated that in low illumination, brief exposure or exposure at a distance, perception is delayed; and it is then possible to invert the comparative ease of perception and identification of even very simple forms such as the circle, square and triangle, etc. Hochberg (1948 cited in Vernon, 1970, p.33) presented silhouette forms, and found that the threshold for recognition was lowest with the simplest form, the circle; then for a rectangle and then for a cross. Bitterman et al. (1954) also found the lowest threshold for the circle, and then, in order, triangle, T-shape, square and diamond, cross. Nine different forms were selected in Bitterman's experiment (circle, square, diamond, equilateral triangle, cross, *L*-shape, *X*-shape, *T*-

shape *and H*-shape) based on simple forms shown in Figure 2.61. This experiment illustrated a really interesting result for referencing. While removing colours, background and other variables, simple form itself still has its own simplicity levels. Thus, these shapes will be categorised as forms for further experiments in this study.

Figure 2.61: The forms used in Bitterman's experiment (Bitterman et al., 1954, p.212).

Understanding the outline of shape as either open or closed, another task of the human visual system is to derive shape information about the shape segmentation from topological analysis (Hecht and Bader, 1998). Based on computational theory which was addressed by Marr in 1982, the task proposed by Hecht (1998) was to classify patterns/shape by combining three topological properties - connections, components and inclusions (Figure 2.62). Comparison between objects with connected parts and disconnected ones, the reaction time of the former one is quicker than the object with a small gap (disconnected) from which could be concluded that a high degree of representational unity was captured by the reaction time of the object with connected contour (closed) rather than the one with small gap contour (open) (Hecht and Bader, 1998).

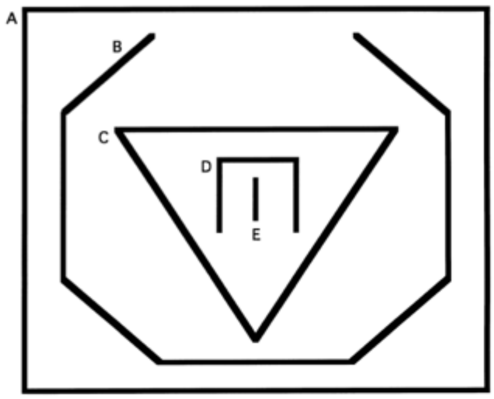


Figure 2.62: The number of components, inclusion relationship and connections (Hecht and Bader, 1998).

The concept of symmetry has been mentioned in Gestalt theory in the previous chapter. According to the previous basic explanation of symmetry features, order can be seen as a characteristic of symmetry stated non-randomness, with everything in a logical, systematic sequence and seemingly adhering to a plan (Hann, 2012, p.72). The term symmetry is nowadays applied to a form which exhibits two equal parts, each a reflection of the other which can be also determined as bilateral symmetry, a characteristic of the majority of designed objects and constructions. Hann (2012, p.73) states that symmetry is a product of a transitional process involving the interplay often of identical components continuously mapping on to one another. Symmetry involves regularity, equality, order and repetition, whereas the opposite term 'asymmetry' is a characteristic of irregularity and disorder. Furthermore, symmetry, especially regularly repeating designs, is considered invariable in terms of the design's underlying geometry and the various symmetry operations. Therefore, Hann (2012, p.74) addressed four of these, relevant to two-dimensional design: rotation, reflection, translation and glide reflection (Figure 2.63).

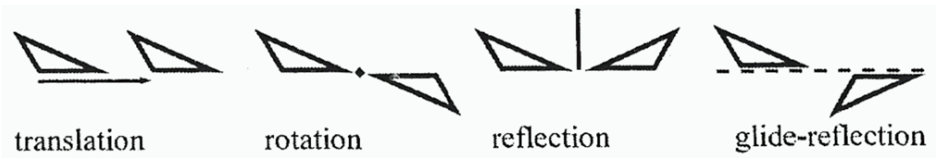


Figure 2.63: The types of symmetry (Hann, 2012, p.74).

Distinguishing the line as straight or curved is a simple task for an adult. This ability starts at ages four to five years where some distinction appears between circular and straight-line figures; and at five to six years the square, circle and triangle emerge clearly; however, the diamond cannot be reproduced accurately until over six years of age (Vernon, 1970, p.30). The experiment addressed by Barenholtz and Feldman (2003) aimed to find out whether there is a measurement of curvature segment, when a judgement must be made about two regions of a shape separated by a negative minimum of curvature along the contour. Barenholtz and Feldman (2003) displayed the sample containing both negative minima (concave) and positive maxima (convex) of curvature that are identical in terms of local geometry (Figure 2.64). Once the degree of curvature is higher, it will be seen as split components.

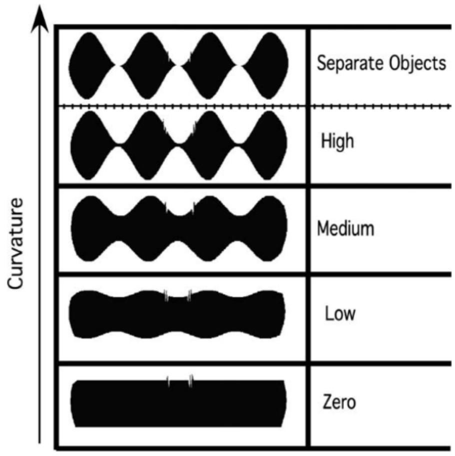


Figure 2.64: Example of levels of curvature (Barenholtz and Feldman, 2003).

On the other hand, another feature-analysis approach in letters was addressed by Gibson (1969, cited in Matlin, 2009, p.40). It proposed that letters differ from each other with respect to the distinctive features of the letter itself. Figure 2.65 shows whether a letter of the alphabet contains any of the following features: (1) Straight; (2) Closed-curved; (3) Intersection and (4) Symmetry. Therefore, this method of letter feature analysis will also be applied into shape feature-analysis for further experiments.

Features	A	E	F	H	I	L	V	W	X	Y	Z	B	C	D	G	J	O	P	R	Q
Straight																				
horizontal	+	+	+	+		+					+				+					
vertical		+	+	+	+	+				+		+		+				+	+	
diagonal/	+						+	+	+	+	+									
diagonal\	+						+	+	+	+									+	+
Closed Curve												+		+			+	+	+	+
Intersection	+	+	+	+					+			+						+	+	+
Symmetry	+	+		+	+		+	+	+	+		+	+	+			+			

Figure 2.65: A feature-analysis approach (Matlin, 2009, p.40).

Certain characteristics of shape were systematically assessed by Graham et al. (1960, p.352). Eight factors were categorised as (1) form; (2) open-closed; (3) straight-curved; (4) number of parts; (5) organisation; (6) orientation; (7) size and; (8) angles. Also, shape and direction seemed to influence weight; a regular shape, as it is found in simple geometric forms, is probably heavier than an irregular shape (Arnheim, 1967, p.13). These elements might provide some principle of simplicity of shape recognition. Moreover, the result of experiments based on the seven elements above might offer further ideas: (1) a choice of the kind of redundancy, or regularity, to be varied; and (2) a decision as to the variety of recognition that would be measured. As stated before, node and component quantity will be seen as the characteristics of number of angles and number of components. Form, open-closed, straight-curved, symmetry, weight have also been widely discussed as shape features. Overall, the following chapters will examine these features as the key criteria of simplification judgement.

2.4.5 Summary of graphic simplification

This section examined four parts of graphic simplification to understand the process of applying it in a graphic legibility experiment. First of all, with regards to the way humans perceive an object, information processing has been widely discussed in cognitive psychology and the visual perception area. An important theory of defining how people tend to organise simplification was addressed by Gestalt psychology which first addressed the idea of perception. Some laws of describing how humans organise an object or image lead to more questions about this phenomenon. In the 1970s, the definition of 'simple' shape was broadly discussed by Arnheim, and indicated that when things are arranged with simplicity, humans can easily imagine and easily remember them.

The review of cognitive psychology presented in this study is to deliver the process of how people think, represent and process information. To review the evolution of cognition psychology, it delivers concrete information to prove there is a 'way' to minimise or shorten people's perception process. Structuralism aims to analyse the conscious into constituent components, and functionalism further emphasises mental operations and the practical use of consciousness. Associationism and behaviourism are addressed in the study of observable emitted behaviour. The studies above triggered and developed the concept of Gestaltism and cognitivism. Thus, to demonstrate how people perceive information enables the determination of the ‘principles of perception’.

The central idea of Gestalt psychology leads to the determining principles proposing a number of rules that they called “laws of perceptual organisation”: (1. law of Prägnanz; 2. law of closure; 3. law of proximity; 4. law of similarity; 5. law of continuity and 6. law of symmetry). This summary delivers important information for researchers and designers, that an ‘economic/efficient’ way of information perception is possible and enables the application of this theory in practical use.

While reviewing the literature of visual perception, the idea of what ‘simple’ is and how it works was addressed. However, some practical experiments also examined the possibilities of graphic simplification. Even though previous sections have described some ideas about what ‘simple’ is, some further experiments were undertaken by Attneave (1951), Marr (1976) and Biederman (1987). In former experiments, the object was simplified and tested in node quantity, making the subjective judgement into a systematic judgement. Numbers of nodes are definitely countable and can show exactly which one is simpler than another. Similarly, component experiments divided the object into several pieces and allowed it to be countable as well. These two experiments provided the fundamental knowledge for judging simplification by objective methods. Both nodes and components quantity methods were tried to determine the numeric explanation to calculate the ‘simplicity’ level through either the numbers of graphic outline nodes or the numbers of graphic parts combination. This section provides the possibility for evaluating the level of simplicity through analysing the characteristics of shape. For both researchers and designers, this information tells one that the potential solution of graphic simplification starts from shape analysis.

In shape analysis, some features have been briefly mentioned such as form, open-closed, straight-curved, symmetry, and weight. These features are the fundamental criteria when forming a design work. Thus, this study will further examine the relationship between simplicity and shape criteria. Overall, combined with the previous experiments, seven shape criteria were decided upon to be analysed in further experiments in this study.

2.5 Chapter summary

As mentioned in the introduction section, the aim of this study is app icon legibility enhancement using graphic simplification guidelines. To solve this issue, some essential areas in secondary research are required. Therefore, this chapter has examined four parts: (1) Design thinking; (2) Logo and app icon design evolution; (3) Graphic legibility and (4) Graphic simplification.

As stated in section 2.2, design is defined as a tool to solve a current issue; thus, the role of the designer is as the subject, using a tool (design) to solve the goals (objective). In the practical design process, designers commonly start a project from define, research, ideate, prototype, select until implementation. In the theoretical design process, design researchers` work is about seeking and concreting subjective ideas to generate objective principles/theories. Moreover, the outcome of the principles will combine and evaluate the practical design process again. Thus, the process in this study will run with the design research process from experiments (Chapter 4 to Chapter 6), generating a guideline of simplification and be further applied in a design practical process (ideate) for testing how this theory works in practical use.

Secondary research in section 2.3 describes the trend of logo and app icon modification, as well as the categories of sample selections. As stated in the aim, legibility of app icon is the problem issue which might be improved. Reviewing both cases of logo evolution and app icon trend, it keeps changing because of various reasons. The trend of logo design evolution was gradual, from a realistic, elaborate style to simple design. In addition, the trend of the app icon is also modified from Skeuomorphic design to Flat design. Apart from the change in the aesthetic sense, legibility is the new issue requiring to be solved for both logo and app icon design due to the limitation display for the app icon. Therefore, scalability is the key role needed for further consideration. Thus, the trend of both logo and app icon modification can be predicted as ‘simplicity’ for its current evolution. In addition, when categorising logo types for sample selection, this study will focus on grey-scale, abstract, non-typeface logo as the stimuli.

Graphic legibility is the core issue of this study; thus, in reviewing the applications, methods of legibility experiments are essential in section 2.4. Overviewing some previous experiments, the judgement of evaluating legibility enhancement in this study is based on reaction time and accuracy. According to previous experiments, accuracy was based on the percentage of recognition errors made by participants: the higher the participant accuracy, the more legible. During the process of answering, reaction is recorded: the shortest, the most legible. In addition, some previous results of legibility tests also revealed some hints of legibility enhancement. Font features such as bold and serif as well as shape features such as details, open-closed and weight have high potential to influence graphic legibility. When stating the methods of legibility enhancement, of all the features mentioned above, simplicity is one of the most powerful tools to solve this issue.

Graphic simplification has been mentioned in graphic user interface studies many times where it indicated that it can help to reduce the time of visual perception (see section 2.4). When discussing the core of visual perception, Gestalt psychology addressed the fundamental laws of explaining how humans tend to organise objects and images. Two important experiments transferred the subjective ‘simple’ judgement into objective ‘numbers’; the concept of node quantity and component quantity experiments are the basis of graphic simplification methods in this study. In addition, other shape features such as form, open-closed, straight-curved, symmetry and weight are also the possible criteria which influence the judgement of simplicity.

Overall, concluding all the design processes both from a practical and theoretical perspective, current logo and app icon issues and requirements, methods of graphic legibility and the methods of simplification, a further step is needed to evaluate how each shape criteria influences judgement of simplification. This result aims to generate a guideline for designers to modify their app icon design with greater legibility. In the final conformation, a legibility enhancement test will compare the enhancement via two categories of samples (original and modified with guidelines). This study expects that the simplification guidelines which was generated from experiments is able to fill in the current design process gap.

Chapter 3: Case studies: Logo Evolution

When running a new design project, some phases of the graphic design process are required to be followed in order to achieve logical results. App icon and logo design are always undoubtedly the most challenging task for maintaining brand identity. They are, by far, two of the most common graphic user interfaces currently being used within smart devices. Both of them are facing a big challenge nowadays, which is how to put their design onto a small display. Apart from previous logo design tips such as uniqueness or aesthetics, designers undoubtedly have to consider a more rational problem – legibility. There are already many suggestions for designers to follow. The design process is commonly understood as - gathering information such as research background, target users; creating an outline such as developing the content; harnessing creativity; sketches and wireframes; designing multiple versions and revisions. This section is going to explore how the current design process applies to app icon and logo modification.

3.1 Logo redesign evolution

Logo evolution history has been discussed in previous research. As a symbol representing the company and brand, logos are periodically redesigned during business expansion (Vlugt, 2012, p.104), to follow the trend of a modern look (Henderson and Cote, 1998, p.15), using computing techniques and also a new consideration – legibility. A recent case is Google, “the web giant’s principal justification for its redesign was legibility, reinforcing a century-old assumption that sans serif fonts are intrinsically easier to read” (Self, 2015). Unfortunately, even though the issue of logo evolution has been discussed for a while, with previous logo research commonly categorising the types of symbol such as monograms or pictograms; letters or numbers; circular or triangular with colour combination, etc., there has been a lack of studies examining how shape characteristics influence legibility. Therefore, this section aims to study logo evolution by shape analysis. This section takes three cases as examples to evaluate the characteristics of logo modification in each company. Since first appearing in the early 1900s, a typical example of logo modification trend - the Shell pecten logo, which has become increasingly stylised, reflecting the trend towards simplicity in graphic design over the past several decades. Today, the newest version is with bold shape and distinctive colours. Undoubtedly, this new version can work in any size and in any medium, whether it is a small patch stitched on a serviceman's cap or a mural-sized icon painted on an oil tanker; even without the brand name, the logo of Shell is one of the best-recognised logos in the world (Vlugt, 2012, p. 81) as shown in Figure 3.1.

Figure 3.1: Shell pectin logo (Silver, 2001).

This study aims to explore the trend of logo redesign in current years. This section will briefly explore the evolution of logo redesign in order to understand the logo redesign trend and reasons. Secondly, it will analyse the elements of logo comprisal, briefly categorised into three types (descriptive, symbolic and typographic). However, this research explores logo redesign issues which do not include typeface logo design, specifically focusing on symbolic (non-descriptive) logos. The first objective of this study aims to categorise logos into symbolic (non-descriptive) and object (descriptive) logos in order to decrease the variation in the experiment.

There are various techniques of logo modification. The description of a logo can be divided into two parts. Firstly, it can be described by its general characteristics such as colour, 2D or 3D, font or symbol, rotation and scaling. Secondly, logo description can focus on its shape details such as corner point, shape number, symmetry, etc. To analyse the shape of a logo, the description of its characteristics can be broadly categorised into boundary-based methods and region-based methods (Mehtre et al., 1997, p.322). An overview of boundary-based methods uses only the contour or outline of the logo.

Recognition of a shape by its boundary is the process of comparing and recognising shapes by analysing the boundary (Mehtre et al., 1997, p.322). On the other hand, the region-based method focuses on the inside parts such as number of components and contour segments. However, even though these two methods can provide a brief description of logo modification trend, they cannot cover all modification types. Some other common elements such as colour changes and 3D effect will be included in a short discussion. This chapter aims to discuss the characteristics of logo modification in both overview and detailed shape analysis.

3.1.1 Google

3.1.1.1 Background information

Google, best known for its popular search engine, was founded by Stanford University students in 1998. The first name of this company is derived from the word 'googol' and is the starting point of their logo visualisation design. Several primitive logos created around 1996 until the company was founded are shown in Figure 3.2.

Figure 3.2: Google logo in 1996 (left) and in 1997 (right) (Vlugt, 2012, p. 137).

However, up to 2015 (i.e. during the past 17 years), Google has changed its logo many times. Since the first official Google logo in 1998, created by a graphics-editing program and modified in another edition a few months later, inspired by the Yahoo! logo, the concept of the logo was finally defined as a playful search engine by using joyful colours (Figure 3.3).

Figure 3.3: Google logo inspired by Yahoo! (Vlugt, 2012, p.137).

In 1999, although not revolutionary, a development of the logo based on Gustav Jaeger's Catull typeface was applied to Google`s new logo design (Vlugt, 2012, p.137). This logo was not modified again until 2010 with an official introduction, with the same typeface and colour combination but more sophisticated use of letter shading and shadow which created a 3D effect (Figure 3.4).

Figure 3.4: Google logo used between 1999 until early 2015.

The newest Google logo was announced in September 2015, which modified both typeface and colour combination. The typeface changed from serif to sans-serif making it bolder than previously. With regards to colour, the four-colour combination was maintained but was lighter and more lively (Figure 3.5).

Figure 3.5: Google logo in 2015 (Google, 2016).

Based on the previous introduction to Google's logo history, this section aims to analyse the characteristics of logo modification. Since the introduction of the first Google logo in 1996, the visualisation logo trend has become simpler and neater for communication, information, and entertainment especially with rapid developments in the digital world.

3.1.1.2 Characteristics of logo modification in overview

Comparing the trends in the Google logo, it seems like a big evolution from the first one published in 1996 to 1997. It changed from a photographic depiction of Larry Page's own hand with Google's predecessor known as Backrub, to using a graphics editing program with 'Google' typeface. It developed from photo to letter only, with lighter colour to represent a joyful phenomenon. However, the original of the modern logo was begun in 1998. It rotated the logo into a clear 2D point of view and with serif font, and a few months later published a new one with a new colour order and shadowing which was inspired by Yahoo!. However, the Google logo maintained the same typeface for around fifteen years from 1999 with a lighter typeface compared to previous logos before 1998. The Google logo was published in

1999 with a sharper and neater shadow effect compared to 1998; however, it was decided to delete the shadow in 2010. The modern one published in 2015 involves a big change again by altering the typeface into sans-serif with lighter colour selection, deleting all 3D lighting or shadowing techniques. Shown in Figure 3.6.

1996	1997	1998	1998	1999	2010	2015
BackRub		Google	Google!	Google	Google	Google
Font	✓	✓		✓		✓
Font<->Symbol	✓					
3D<->2D			✓		✓	✓
Scaling						
Rotation	✓	✓				
Colour	✓	✓	✓			✓

Figure 3.6: Logo characteristics diagram.

3.1.1.3 Characteristics of logo modification in shape

Apart from a characteristics and techniques comparison, this section provides another diagram to discuss the shape of logo in detail. According to previous literature which mentioned shape analysis based on outside boundary and inside components, this section will compare the common skills of logo modification by taking the Google logo evolution as an example. A big evolution from 1996 to 1997 changed from photo with typeface to white background with company name only. The Google logo consisted of six flattened letters in 1997 and was rotated to a 2D image with straightened line and serif font (Figure 3.7). In 1998 there was a small modification to the Google logo by reorganising the colour combination with an exclamation mark.

Figure 3.7: Logo comparison between 1997-1998.

Google modified its logo again in 1999; it changed from bold font into a lighter and sharper typeface, with added shadow and lighting effect and removed the punctuation again. In 2010, Google decided to take the shadow off but still maintain the exact typeface. However, the big jump is the one published in 2015. Google abandoned the typeface and classic colours it had used for almost fifteen years. Google decided to create a new font with bold and neat style without any other extra corner points and sharp angles. This flat design is the simplest logo Google has ever published. Shown in Figure 3.8.

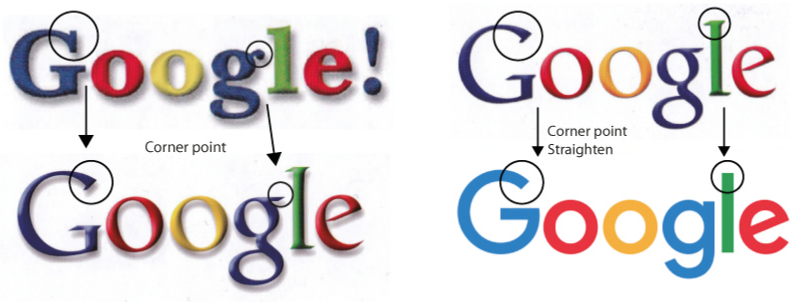


Figure 3.8: Logo comparison from 1998 to 2015.

In general terms, Google has modified its logo corner points four times, its shape number three times; its big outline compactness and area changed from 1996 to 1997, and the logo typeface line was clearly straightened in 1998 and 2015 (Figure 3.9).

1996	1997	1998	1998	1999	2010	2015
		Google	Google!	Google	Google	Google
Corner point	✓	✓		✓		✓
Shape number	✓		✓	✓		
Compactness	✓					
Area	✓	✓				
Straighten		✓				✓
Symmetry						

Figure 3.9: Logo modification details diagram.

3.1.1.4 Summary

In conclusion, this example took Google as an example to briefly reveal how a logo may be modified. In outline evaluation, font and colour change are the major modifying methods deployed during Google's logo history from 1996 to

2015. The 3D effect which uses shadow and light has been in common use from 1998 until 2010. In logo details, the trend has obviously moved towards simplicity. Since the first ‘Google’ logo was published, the typeface that Google has applied is where the font corner point has become less sharp and smoother. The newest logo furthermore abandons the serif font in favour of a bold non-serif font which increases the clarity. The shape number has just increased the one time by adding punctuation, and the surface area has removed the photo background, simply keeping the brand name as logo. Another element for judging simplicity is the straight and curved lines which Google has applied particularly in its 2015 logo.

3.1.2 Delta Airlines

3.1.2.1 Background information

Delta Airlines` first logo, nicknamed ‘Huffer Puffer’, featured Thor, and symbolised the fight against the boll weevil infestation in the cotton fields (Vlugt, 2012, p.104). The most significant symbol of Delta Airlines – the triangular shield — came from the Greek letter delta, or Δ (Vlugt, 2012, p.104). A few years later, Delta Airlines expanded its business to mail services and started operating passenger flights in 1929 (Vlugt, 2012, p.104). The core values focusing on speed, safety and comfort were taken into the logo design criteria. Therefore, the figure used in Delta Airlines changed from Thor to Mercury with the winged helmet, depicting the god of travel and commerce (Vlugt, 2012, p.104). However, a lack of mail contracts triggered the company to develop its passenger service in 1934, with a new image using a winged triangle inside a bigger triangle as its logo. However, it was soon replaced in the same year by a simplified edition with a smaller triangle surrounded by a blue circle. Another new idea came up in 1945 when Delta Airlines started to use its company name as the major part of the logo. The first letter ‘D’ of Delta was designed with a flying wing in 1945 with modified colour and outline of an oval shape until 1955. It was slightly redesigned in 1959, when Delta Airlines took off the ‘Flying D’ logo and removed the oval background and only kept the triangle as the focus symbol. The logo published in 1959 was the beginning of a trend towards simplicity. Even though Delta Airlines tried different combinations of font, colour, circle and triangle, no extra new elements or effects were included during the years 1959 to 1995. In a big change in 2000, Delta Airlines decided to keep only the simple triangle and Delta typeface in its logo. This slightly changed between 2000 and 2007 with just its serif font and curved line in a triangle. The newest logo in 2007 applied a non-serif font with red and sharp triangle as its modern logo.

3.1.2.2 Characteristics of logo modification in overview

Since Delta Airlines` first logo published in 1928 took the triangle as its main visual identity, the outline of the logo was maintained until 1945. The content of the triangle logo was modified due to the expansion of the business; however, it maintained its outline and changed the vivid colours into three basic colours (black, red and white). In 1934, in a slight restyling, the major visual identity – the triangle — was surrounded by a blue circle which was the first time Delta Airlines tried a new combination. A dramatic change in 1945 saw Delta Airlines give up the triangle shape and modify its font into black and white with shadow effect. This typeface was retained until 1959 but revised in many editions by colour modification. The one published in 1959 is the closest one compared to the modern Delta Airlines logo. In 1959, Delta Airlines decided to remove the shadow effect, scaling it into a smaller size with two colours remaining. Even though Delta Airlines returned to the oval outline in the short period between 1962 and 1963, it was modified into just the triangle visual identity and company name until 2007. During this period, the Delta Airlines logo was modified only slightly by colour and font combination (Figure 3.10 and Figure 3.11).

1928	1929	1934	1934	1945	1947	1953	1955
Font		✓	✓	✓			
Font<->Symbol				✓			
3D<->2D				✓			✓
Scaling			✓				
Rotation							
Colour	✓		✓	✓	✓	✓	✓

Figure 3.10: Logo characteristics diagram.

1959	1962	1963	1987	1995	2000	2004	2007
DELTA	DELTA AIR LINES	DELTA AIR LINES	DELTA AIR LINES	Delta Air Lines	Delta	Delta	DELTA
✓			✓	✓			✓
✓	✓	✓	✓				
✓	✓	✓					
	✓						
		✓	✓	✓	✓		✓

Figure 3.11: Logo characteristics diagram.

3.1.2.3 Characteristics of logo modification in shape

Apart from a general outline comparison, many details have been modified in the Delta Airlines logo history. In 1928, it began with a solid triangle surrounded by the company name. In 1929, Delta Airlines redesigned its logo, placed the company name inside the triangle and in 1934 took off a wing on the left side to make its logo visually symmetrical.

However, in another edition also published in the same year, a red wing was surrounded by a blue circle which modified the outline corner point into a smooth circle, added other elements and also focused concentration onto the middle; furthermore, it looked smaller and more compact by its scaling. In 1945, Delta Airlines decided to redesign its logo as the company name with a ‘Flying D’ which modified almost all the elements in this big change. Two years later, the outline of the logo was surrounded by a shape again and solidified the content into an oval. This font and oval design was maintained until 1959, when the triangle shape became the major visual again but was much simpler than previously. This big change was the starting point of the trend to make Delta Airlines look simpler and more modern. It deleted almost all other extra effects and only kept the key visual identity shape – the triangle and its company name.

Even though during 1962 and 1963 it tried to turn the logo back to an oval outline design, it only retained the triangle and company name after 1987. An interesting point during this period is that the logo redesign of Delta Airlines simply deletes elements rather than adding other new stuff. By deleting the word ‘airline’, the logo area became smaller and more delicate. In 2000, it changed the angle into a slight curve inside the triangle. In the final updated logo, Delta Airlines logo keeps all the sharp and neat line details with the non-serif font ‘DELTA’ (Figure 3.12 and Figure 3.13).

1928	1929	1934	1934	1945	1947	1953	1955
Corner point	✓	✓	✓	✓	✓		
Shape number			✓	✓	✓		
Compactness			✓	✓	✓		
Area			✓	✓	✓		
Straighten				✓	✓		
Symmetry		✓	✓	✓			

Figure 3.12: Logo characteristics diagram.

1959	1962	1963	1987	1995	2000	2004	2007
✓	✓	✓	✓		✓		✓
✓	✓	✓	✓		✓		
✓	✓	✓	✓		✓		✓
✓	✓	✓	✓		✓		
✓	✓	✓		✓	✓	✓	✓

Figure 3.13: Logo characteristics diagram.

3.1.2.4 Summary

In conclusion, the logo evolution of Delta Airlines involved various processes; from a business perspective, the logo was modified by changing the key image from Thor to Mercury – God of travel and commerce; from a design perspective, this logo narrowed down vivid colours into a maximum of three and exchanged font to symbol on either side during the logo revolution. During this time, Delta Airlines modified its logo by changing the font around five times, and changing colours with new combinations more than ten times. Furthermore, taking shape details into the analysis, the corner point and shape number of Delta Airlines was modified frequently between 1928 and

1963 when both triangle and oval shapes were considered as its visual identity. Logo compactness and area were modified many times as well due to the combination of placing company name either inside or outside of the shape. Logo outlines have been changed between curved and straight quite often created by the selection of font and visual identity shape. The element of symmetry has been applied as a modification method when analysed without typeface consideration. Generally speaking, the logo modification trend of Delta Airlines is a great example that covers various types of modification elements especially the evolution of the triangle simplification process.

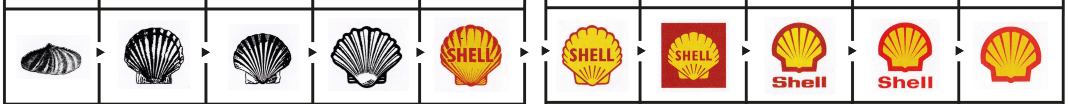
3.1.3 Shell

3.1.3.1 Background information

"Since first appearing in the early 1900s, the Shell pecten logo has become increasingly stylised, reflecting the trend towards simplicity in graphic design over the past several decades" (Silver, 2001, p.30). The name 'Shell' first appeared in 1891 as a trademark with a mussel shell. It was changed to a pecten shell in 1904 but both of these initial logos were designed realistically (Vlugt, 2012, p.254). Once Shell was chosen to be the brand name with the pecten as its symbol, the shape of the pecten changed gradually over the years. It started to add colour in 1915 with red and yellow when Shell built its first service stations in California. Red and yellow are really stand-out colours and also the colours of Spain and were used in the hope that it created an emotional bond with customers (Silver, 2001, p.30). The first time Shell designed its logo to include the company name was 1948 and this tradition continued until 1995. However, during this period, the effect of the shell shape was modified at various times; 1955 was the first edition to take off ridges or simply straighten the realistic ridges into lines. Today, with its bold shape and significant colour combination, the Shell logo works on any size and in any medium (Silver, 2001, p.30) with a good legibility level.

3.1.3.2 Characteristics of logo modification in overview

In the beginning, the Shell logo depicted a realistic rendering of a pecten in black and white. A few years later, it rotated into a straight 2D view on a bigger scale; the shell was rescaled with a slightly bolder outline in 1930. A dramatic redesign in 1948 started to add colour as part of its important visual identity and also to make the red part as the shadow of the shell. Maintaining the same elements as 1948, a new edition in 1955 took the shell's ridges off and kept the clear company's name inside the shell; this was the starting point of the flat design. Although during a short period around 1961 a red square was added as the outline background, it returned to the shell icon only again in 1971 but placed the company name with a new font at the bottom of the shell. A small change occurred in 1995 with simply an applied smooth typeface. The latest one published in 1999 deleted all other elements and only kept the shell shape itself with bold outline and two significant colours (Figure 3.14 and Figure 3.15).



1900	1904	1909	1930	1948	1955	1961	1971	1995	1999
Font							✓		
Font<->Symbol									✓
3D<->2D	✓			✓	✓				
Scaling	✓	✓	✓			✓			
Rotation	✓								
Colour				✓					

Figure 3.14 and 3.15: Logo characteristics diagram.

3.1.3.3 Characteristics of logo modification in shape

Reviewing the overview of the Shell logo evolution, the modified history of Shell is really impressive as well. It is quite common to apply a realistic object or sketch as a trademark in the early logo history around the 1900s. Shell is the classic case to explain how to modify a historical logo into a modern one based on the simplicity trend. The Shell sketch image was applied between 1900 and 1930; however, the basic shell image started in 1904 with many details and shadows designed but a little more symmetry compared to the original logo in the new version. A slight difference occurred between 1904 and 1909 with just different scaling. In 1930, it was restyled to make it more like an illustration rather than just simply a sketch by making the outline bolder but still maintaining those details inside. However, the outline of the Shell logo tended to be smoother from 1948 adding the company name as one more component inside the shell. A significant evolution took place in 1955 where the Shell logo deleted all the shadow effects for a neat and symmetrical outline. Although in 1961, there was a short period where a red square as background was added, it returned to its shell shape again in 1971. The key point of the logo published in 1971 was its design style which was between realistic and abstract. A bolder outline and few sharp straight lines represented the ridges of the shell; moreover, the outline corner points were simplified to a curved circular shape with reflection symmetry. This design is used worldwide now and has become so recognisable even without the company's name to identify it after 1999 (Figure 3.16 and Figure 3.17).

1900	1904	1909	1930	1948	1955	1961	1971	1995	1999
				SHELL	SHELL	SHELL	Shell	Shell	
Corner point	✓		✓	✓	✓	✓	✓		
Shape number				✓		✓	✓		✓
Compactness						✓			
Area	✓	✓				✓	✓		
Straighten	✓					✓			
Symmetry	✓			✓	✓		✓		✓

Figure 3.16 and 3.17: Logo characteristics diagram.

2.3.1.4 Summary

In summary, the trend of the Shell logo evolution case is a classic example of a design trend – less is more. An original design always inspired by a real object and developed into an abstract style depends on the aesthetic trend. From an overview perspective, the logo modification of Shell tried 3D and 2D effects by shadowing, and only one time of colour change but has maintained its significant characteristics up to the present day. From a shape perspective, the logo developed its corner points sharper and neater for six times out of ten, shape numbers were only increased and decreased by adding the company's name, the solid outline with red background was used once and the balance of symmetry was always a consideration. In general, the evolution of the Shell logo is a trend of the descriptive to the abstract which is a common technique applied in other logos as well. The process from the descriptive to the abstract of Shell is a classic example to analyse the simplification method. Corner point, shape numbers and colour are all key elements to make this logo distinctive.

3.2 App icon design and evolution

An icon can be defined as a graphical representation of concepts that symbolise computer actions; furthermore, a definition of good icon design should be simple and clear (Ware, 2004 cited in Gatsou, Politis, Zevgolis, 2012). Studies have found that the visual and cognitive features of icons significantly influence an icon's effectiveness (Blattner et al., 1989; Familant and Detweiler, 1993). In user interface, normally three types of icon are included in one device system – template icons, Home screen icons and app icon.

"An app icon needs to work at multiple resolutions retaining the legibility of the concept across the range of sizes" (Flarup, 2015). To maintain graphic legibility, it is essential to make sure the image/icon is scalable. As the template published on the Apple official website, every app needs an app icon and a launch file or image; also, some of them furthermore require custom icons to represent app-specific content, functions, or modes in navigation bars, toolbars, tab bars, and other areas. App icons are shown in the listing sizes (Figure 3.18) which are required for these custom icons and images. App icons will be displayed a bit larger in the App store page; however, they get smaller on the home screen and even smaller in the notification centre and in groups. Therefore, to make sure the image that the company selects for icons can be reduced really well and be clear at any size, scalability for logos is highly recommended.

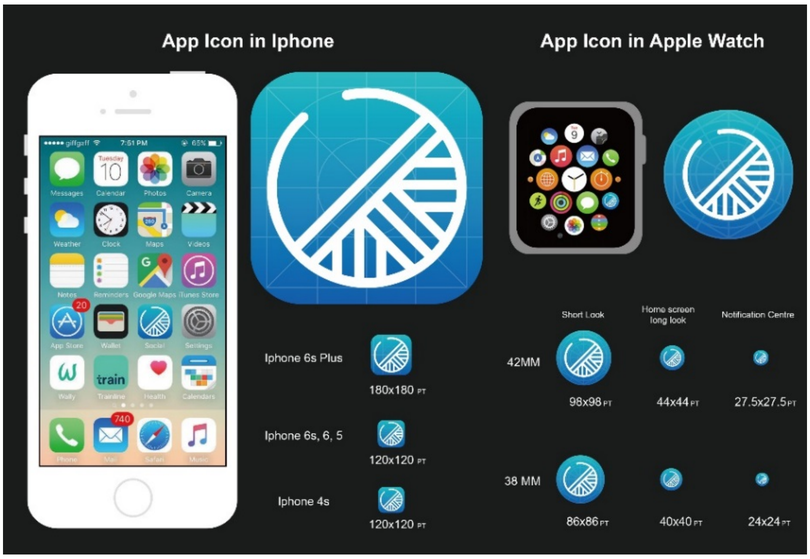


Figure 3.18: App icons in various display sizes.

Even though traditional brand logos may be elaborate, when applying them into app icon design, the risk of illegibility will increase. To increase the legibility on small displays, in user interface design, a common error related to simplicity can usually be attributed to poor planning, poorly communicated structure, or attempting to go beyond the scope of a coherent, focused design. Some general techniques can be used to simplify a design solution: (1) reduction - determine the essential qualities; (2) regularising - use regular geometric forms, simplified contours and (3) leverage – combine redundant elements into a single, simpler unit (Mullet and Sano, 1995, p.37).

As mentioned in previous sections, an app icon is not equal to logo design. The app icon and logo design have different aspects. However, many companies tend to run their business in apps by using their logo in order to maintain brand identity. Therefore, even though logo modification is always processed due to various reasons, many companies try to take scalability as the core of their next logo modification step in order to improve their logo legibility in app icon display. An app icon is a visual anchor for the product which can be understood as a tiny piece of branding that not only needs to look attractive but ideally also communicates the core essence of application (Flarup, 2015). It is not the same as a logo even though both of them certainly share branding-like qualities but not under the same restrictions. As stated in section 3.1, even though many logos are modified all the time by various factors, the core issue is concerned with how to adapt the logo into an app icon.

Flarup (2015) suggested some important elements which need to be considered. The list of five core aspects that are essential to creating a proper app icon are (1) Scalability; (2) Recognisability; (3) Consistency; (4) Uniqueness; (5) No words used. Furthermore, according to Flarup (2015) scalability is the most important aspect of an icon above everything. The app icon is going to be shown in several places throughout the platform, and at several sizes, so it is important the work created maintains legibility as the core issue. Figure 3.19 shows the various app icon size requirements in the iPhone. Following from this, it needs to be legible on the App Store, on retina devices and setting panel. Certainly, overly complicated icons often fail for bad scalability. Thus, the major part of the conceptual stages of app icon design should be dedicated to thinking about whether any given design scales gracefully.

Figure 3.19: The example of scalability (Andriuleviciute, 2015).

Compared to logo evolution history, app icon evolution history is much shorter. The reasons for logo redesign varies: new leadership, financial reasons, prospective analysis of the market or mergers (Thomas, 2000, p.15). Therefore, following on from this, the logo has been redesigned over decades. As mentioned in the previous section, current logo redesign has been faced with a new challenge issue – legibility on small screens. The following section will explore app icon evolution from three perspectives – iOS icon evolution, App icon evolution, App icon in smartphone and smart watch comparison.

3.2.1 iOS icon evolution

Icons are used widely in the human-computer interaction field. The purpose of app icon design undoubtedly requires functionality and ease to allow users to identify it in a short time. App icons are the most important objects at first glance. When discussing the trend of app icon legibility enhancement, one of the typical examples looked at is Apple's iOS Home screen. It has changed over the years since the announcement of iOS 1 in 2007. Since the release of the iOS 1, Apple has developed their system steadily every year from iOS 1, 2, 3, 4, 5, 6, 7, 8 until the current iOS 9. However, iOS 7 marked a radical aesthetic departure (Williams, 2015) (Figure 3.20). The new 'flattened design' user interface started an aesthetic trend.

Figure 3.20: Apple iOS 6, 7, 8 user interfaces evolution (Williams, 2015).

Different from other app icons in the App store, Home screen icons are shown in every version of the iOS system. As Figure 2.33 above shows, there was a significant evolution from iOS 6 to iOS 7 which was defined as Flat design. As usually mentioned in design principles, minimalistic design is the most important element to emphasise usability, and the Flat design is part of this discipline. The features of this discipline are clean, open space, two-dimensional and flat illustration. The purpose of this discipline is to create quick-to-grasp information. A simple image is undoubtedly more quickly recognised than an elaborate illustration. Therefore, Flat design is understood as being a back-to-basics design as a functional tool.

So, what is the transformation of this trend between the iOS 6 and iOS 7 systems? Apple announced it would scrap the ‘traditional’ look of its mobile apps which mimicked real-world objects — named as ‘Skeuomorphic design’ (Judah, 2013). The Apple design team believed that the computer should be able to be simple to use and require a design style in which digital elements resembled real-world objects that anyone could recognise. In the early days of graphic user interfaces, designers employed familiar devices, such as folders, trash cans and photos. Figure 3.21 below depicts the difference between skeuomorphism and flat design. Skeuomorphic design means a physical design on an object made to resemble other materials on a user interface design. As expected, iOS 7 removed texture, 3D shading and reflection, and opted for a simpler design style instead. Today’s smartphone users are able to deal with simple icons that indicate what things do, and no longer need on-screen controls that painstakingly mimic physical objects (The Economist, 2013). As shown in Figure 3.21 below, even though the new design no longer employs the familiar real object, the Flat design edition of Photo app icon displays in iOS 7 still has been widely accepted by users nowadays.

Figure 3.21: Skeuomorphism and Flat design comparison.

Comparing the difference between iOS 6 and iOS 7 user interface design, it obviously shows that all shadows and drops have been removed. To put it simply, it looks like a 3D effect reduced to a 2D design. Moreover, apart from these design features, what other elements should be considered in design? The Apple official website lists some strategies for designing iOS user interfaces for maintaining the legibility of the Home screen app icon. An app icon needs to be shown clearly at many different sizes and on different backgrounds with details that might enrich the flexibility of an icon at either larger or smaller sizes of display. Using universal imagery avoids confusion (Figure 3.22). For instance, the Mail app icon uses an envelope which is already known to the majority of users. Embracing simplicity, in particular, avoids cramming lots of different images into the icon design. In this case, the suggestion by Apple was to test the appearance of the app icon at small sizes, moving it into a folder on the Home screen — even better, moving several app icons into a folder to check if it still remains distinctive. Designers should make sure that when creating different sizes of the app icon, it is all applicable on all devices.

Figure 3.22: Home screen app icons (Apple, 2015).

Following on from the evolution mentioned above, it is no surprise that the trend of app icon designs was transformed from Skeuomorphism to Flat design. The example of the Flat design trend was announced by Apple when it released iOS 7. As a result of the high-resolution smartphone and limited space on the screen, the requirements of the app icons kept increasing. It is possible to predict that logo design which has to be adopted in app icons will be much simpler than ever before. To maintain the legibility in such various sizes of display, this new challenge requires a wide knowledge of recognition psychology, human-computer interaction, and graphic user interface to be researched.

3.2.2 App icon evolution

A famous case of app icon evolution is the photo sharing app - Instagram. A big jump from a retro-looking camera, and one of the most recognisable tech logos out there, has been replaced by a background swirl of sunset colours (orange, yellow, pink and purple) and a white outline of a camera (Parkinson, 2016). App icons of Instagram are shown in Figure 3.23. When a new version of Instagram was released, feedback of users tended to give negative comments. Most of the feedback was for the previous version of the Instagram icon which was felt to be more nostalgic, pretty, with strong recognition ability.

Figure 3.23: Instagram app icon evolution (Parkinson, 2016).

However, the new app icon was announced on May 11, 2016 via a blog post from the head of design at Instagram, Ian Spalter, explaining the process of logo modification. When Instagram was founded, it was a place to easily edit and share photos. However, now Instagram has a deeper responsibility, the Instagram icon and design are required to reflect a community image as their new challenge. Therefore, they refreshed the user interface with a simpler, more consistent design. The original icon’s style had the benefit of making it feel tangible, and their initial explorations involved trying to modernise it as it was, starting with the basics, removing ornamentation and flattening the icon. In this step, actually, due to the wide use of Instagram, many Instagram redesign works had already been published on the website as designers’ personal practice. Thus, is flattening the original icon the only way to achieve this? Would they feel the need to do this again in a year`s time? Furthermore, since the flattening explorations lacked the visual weight of the original, the focus turned to figuring out exactly what key visual elements of the original icon were required. The final survey of Instagram key visual elements are rainbow, lens and viewfinder. Some sketches are shown in Figure 3.24.

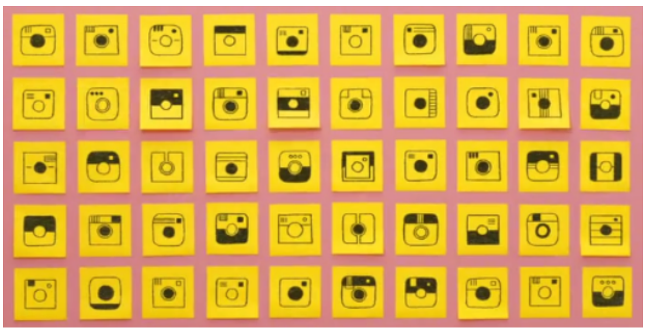


Figure 3.24: Sketches of the Instagram app icon (Spalter, 2016).

Concluding the challenge and design briefs, these elements were translated into a more modern app icon that strikes a balance between recognition and versatility. Here is the solution from the Instagram design team. The rainbow and camera lens are as a bridge for the new icon design. From a colour perspective, if the lens is a bridge into the bolder, simpler glyph, the rainbow is a bridge into the colourful gradient with minimal options, but ultimately involving warmth and energy to complement the glyph. From the glyph point of view, the Instagram design team decided to get a flexible, scalable glyph, but the previous glyph proved to be a weak basis for an icon. Similar to the idea of simplification, the design team had to figure out how to give the new design more character while also removing what was unnecessary. If the new design is too abstract, the glyph does not feel tied to the history and soul of Instagram. If the new design is too literal, it is hard to justify the previous one. Therefore, after a lot of refinement, the final glyph still maintains a camera, but also sets the groundwork for years to come.

After the brief background of the Instagram app icon evolution, how does it work in the real world? Evaluating this from the simplification study point of view, the outline of this new app icon design is quite successful. It almost challenges the simplest way of representing the camera icon. Some other designers suggested redesigns or modifications to the original Instagram icon. It is quite common to see a flat design with the shadow part of the original app icon simply removed. The risks of adjusting the original design by merely flattening it is that this design technique simply adapted the trend to ‘flatten’ without any other additions. No doubt the flat design is one of the techniques which enhanced legibility, but once everyone redesigned an original icon by simply ‘flattening’ the true function was lost and became just like following a design trend without reason. The current application of the Instagram icon is shown in Figure 3.25.

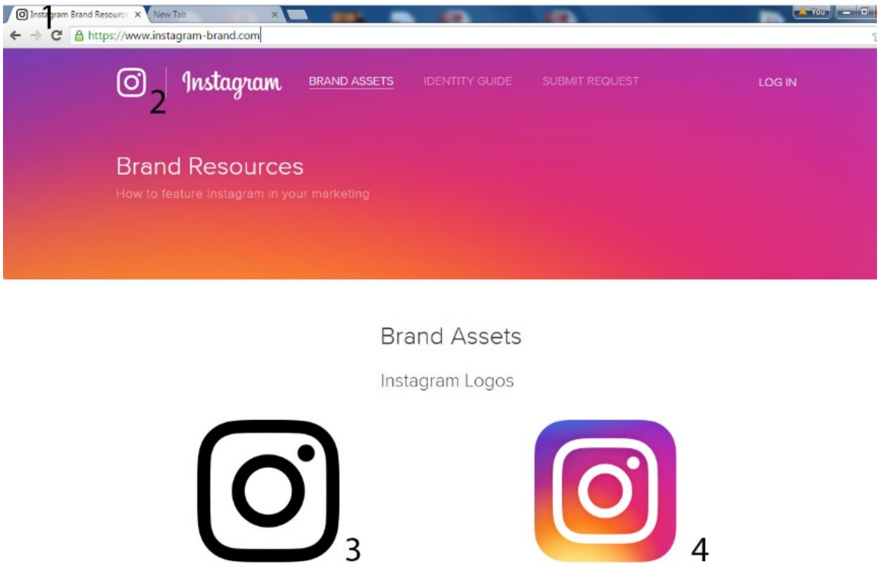


Figure 3.25: Instagram official website (Instagram, 2016).

Considering the versatility that this app icon must show in various places, scalability is always the priority in the app icon redesign. As shown above (Figure 3.25), four different sizes of app icon are shown on one page. In this case, the new design of the Instagram app icon has great legibility when presented in a black outline. If adopting the previous app icon, the results will show as follows (Figure 3.26).

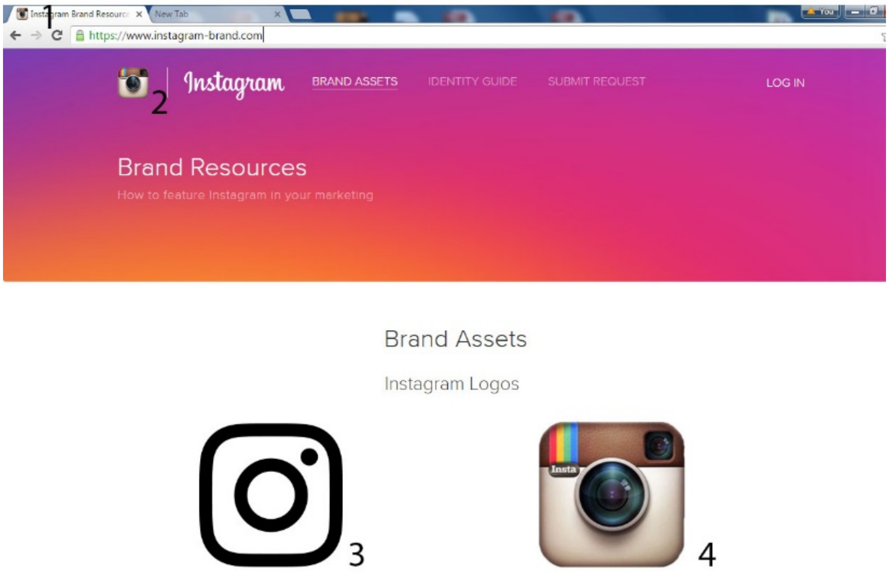


Figure 3.26: Instagram app icons comparison (reproduced from Instagram official website).

Obviously the new design, even with only an outline of a camera, is much more legible than previous ones when applied at different sizes. As shown in label number 1, the smallest icon is the Windows banner: the details of the previous design have almost disappeared. Imagine that the original app icon is adopted on various screen sizes (Figure 3.27 left), is it still legible as a new design (Figure 3.27 right)?

Figure 3.27: App icons comparison.

Overall, as the aim of this study is to evaluate this case from a graphic legibility point of view, it is undoubtedly an excellent example. Simplicity is not a trend of contemporary aesthetic preference, but is also based on the original functional aspect. According to many previous academic papers and books, simplicity is known as the core of making a design easier to use. Therefore, even though the opinions of Instagram app icon redesign from users are mixed, the core of design problem- versatility and legibility, are successfully enhanced.

3.2.3 App icon in Smart phone and smart watch

Apart from the requirement of square canvas app icons, the Apple Watch has an even smaller screen than other smart devices. Since the new challenge of the Apple Watch, there are obviously some new requirements for UI design on the device. Similar to smartphones, there are two types of icons used on the Apple Watch. The first app icon is mainly used for identification, location and launching an application; furthermore, there are Menu icons which are icons that appear in context menus within an app. As suggested before, an app icon in either iPhone or iPad is better when not accompanied by text. It is strongly recommended to avoid texts in app icon design on the Apple Watch with its more limited small screen size. This means that the app icon will need to be legible and unique enough to distinguish it from other apps and be highly recognisable. In the Apple Watch case, a minimum of four types of icon sizes have to be considered - Home Screen, Short-looks, Long-looks and Setting icons (Figure 3.28).

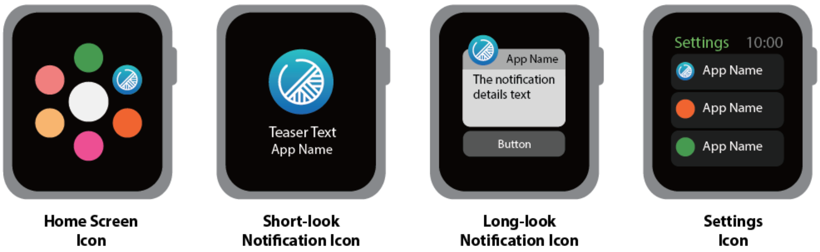


Figure 3.28: Examples of app icons shown in the Apple Watch.

Differing from the iPhone square canvas, the Apple Watch app icon is determined as a circular canvas. Home screen icons are displayed with no accompanying text (Figure 3.29). Some rules published on Apple official websites mentioned how to create Home screen icons in an appropriate way: (1) Embrace simplicity – which recommends finding a single, recognisable shape that uniquely captures the essence of the app; (2) Maintain some similarity between each device – which suggests using a similar appearance and colour palette to create an association between the two icons (3) Avoid text in icons - because text in icons is often too small to read and is rarely needed.

Figure 3.29: Example of displaying icons in Apple smart devices.

Recently designers of smartphone interfaces have been using logos to represent the functionality of the app required by users to purchase the accurate one in the App store. The most challenging one is app icon design, which requires the delivery of two types of information- functionality and brand identity in one. Many companies nowadays develop their own app in order to give a better and faster service to their customers. Not only new social media companies like Facebook and Twitter, but also airline and train companies which offer digital tickets use their logos as a symbol to announce to passengers; for example, Air Canada simplified their logo as a maple leaf.

Media such as newspapers or magazines like The Economist also simplified their logo into their capital letter alphabet. Traditional coffee shops such as Starbucks also designed their app directly by using their own logo (Figure 3.30).

Figure 3.30: Example of company apps that applied their logos as an App design.

A guideline suggested by Lewis (2015) states that shapes that are more-or-less symmetrical in every direction, such as triangles, squares, polygons, and circles, will rest more comfortably than elongated rectangles inside the circle of the icon (Figure 3.31). Many brands following this recommendation found that their logos which used their brand name as an app icon in the iPhone faced more challenges in adapting the same design to the Apple Watch.

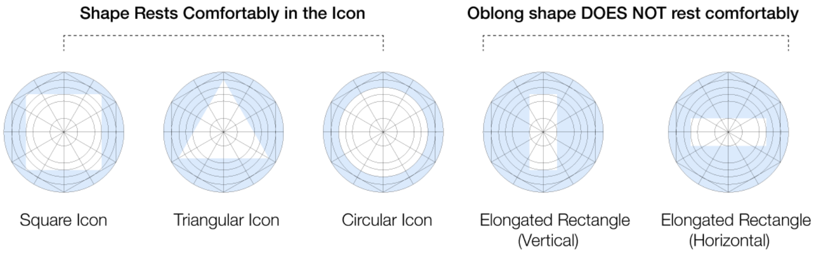


Figure 3.31: Guideline for Apple Watch app icon design (Lewis, 2015).

Figure 3.32 is the example of an app icon in the iPhone, iPad and Apple Watch - Trainline. As shown below, the app icon in the square canvas can still include the brand name in it; however, only the first letter of the alphabet was selected in the Apple Watch circular canvas. This is one of the examples which shows the difficulties in maintaining legibility.

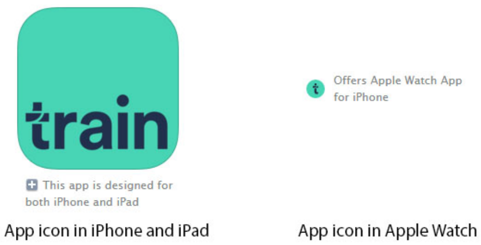


Figure 3.32: Same app icon shown in both devices.

Overall, in app icon design it is strongly recommended to consider two types of canvas (circle and rounded square). As shown in Figure 3.32, even though the design limitation of the square canvas in the smartphone has been noticed for a while, the more challenging issues are (1) How to design an app icon which is able to display in both square and circle canvas; (2) How to design an app icon which is able to display in both sizes of small screen. Smart watches have much more limited screen size as opposed to that of smartphones; more awareness is required to avoid confusion of app icon designs.

3.2.4 Sample selection based on logo/app icon categories

When products and services are difficult to differentiate, a symbol can be the central element of brand equity and the key differentiating characteristic of a brand as it can create awareness, associations and liking or feelings which in turn can affect loyalty and perceived quality (Aaker, 1991, p.197). A symbol rich in association will contribute much more, and become an important asset for the firm when included in logos, packages, cartoon characters, etc. Designers use corporate visual identity systems (CVIS) to widen the communication mix through name, symbol and/or logo, typography, colour and slogan; it helps transmit a company's visual identity through fixed assets (Melewar and Saunders, 2000). The trademark is a name, word, or symbol that is protected by law and is aimed at identifying the source of the product and to guarantee consistency of quality (Morgan, 1986). The logo is a graphic mark that is applied by companies to aid public recognition and identification (Wheeler, 2009). Overviewing the requirements of both logo and app icon evolution, sample selection should narrow with specific conditions. Thomas (2000, p.19) addressed three categories of logo types: (1) typographic - letterforms which includes some graphic organisation or addition to its content for enhancing; (2) abstract/symbolic – takes the descriptive mark one step further, literally incorporating a figurative element, in order to communicate the intangible or abstract; (3) descriptive - uses visual imagery relating to the clients product or service (Figure 3.33).

Figure 3.33: Logo types (reproduced from Thomas, 2000, p.19)

In general, logo designs are of two basic types, typographic logos and symbolic/iconic logos. Typographic logos are clearly understood as a logo design with company name, alphabet or any kind of typeface transformation (Thomas, 2000). On the other hand, symbolic logos can also be divided into two sub-categories: descriptive logos and abstract logos. Here is the description of two types of logo: (1) Descriptive – which utilises a symbol of the product or is strongly suggestive of the products or company name, apart from any relationship created through promotion; (2) Non-descriptive – cluster of initials, abstract designs and similar forms which would appear to have no visual connection with a company's products, services, or name other than that relationship developed through promotional effort over time (Block, 1969, p.401). In its simplest terms, a descriptive logo means it is a design with a direct correlation between the visual message and company products and services which often represents an actual product. Differing from a descriptive logo, a non-descriptive logo tends to express its message through figurative elements of design that relate to the company's overall business and/or vision. Since the 1970s, Zusne (p.295) classified the degrees of recognition as when random shapes, never seen before, remind one of some well-known, previously experienced objects. Thus, sample selections should also be aware of the level of recognition; for example, logos which have high recognition value such as Apple or Starbucks will not be one of the samples in further experiments.

As mentioned before, the conditions of graphic legibility are limited as grey-scale, non-typeface logos in order to decrease the variables for experiments. The first condition, typeface logo is out of selection because the text description might influence recognition. Furthermore, the symbolic/iconic logo is divided into two types: descriptive or abstract. Therefore, the following paragraphs provide some samples of abstract (non-descriptive) and object (descriptive) logo types as the reference of sample selection based on Hyland and Bateman in 2011. First of all, non-descriptive logo types were categorised as the following figures (Figure 3.34 to Figure 3.44).

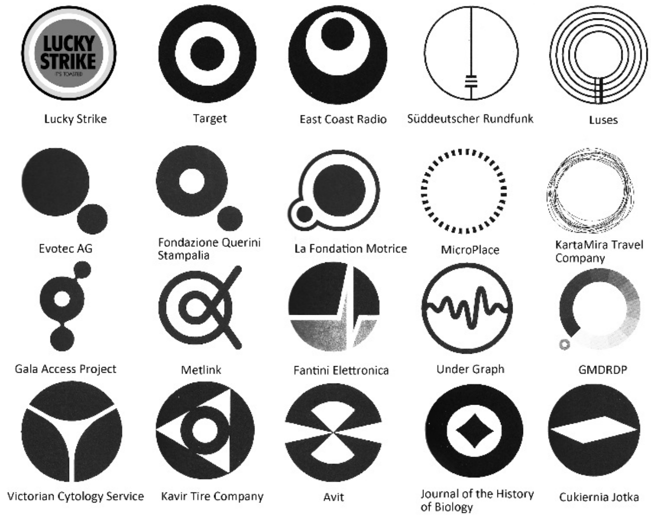


Figure 3.34: Circles (reproduced from Hyland and Bateman, 2011).

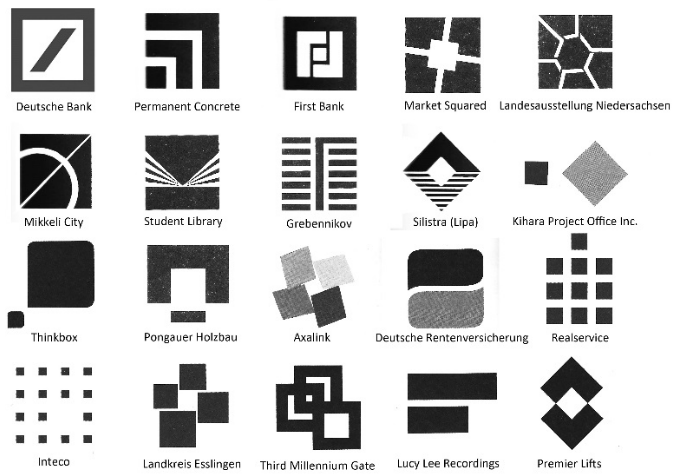


Figure 3.35: Rectangles (reproduced from Hyland and Bateman, 2011).

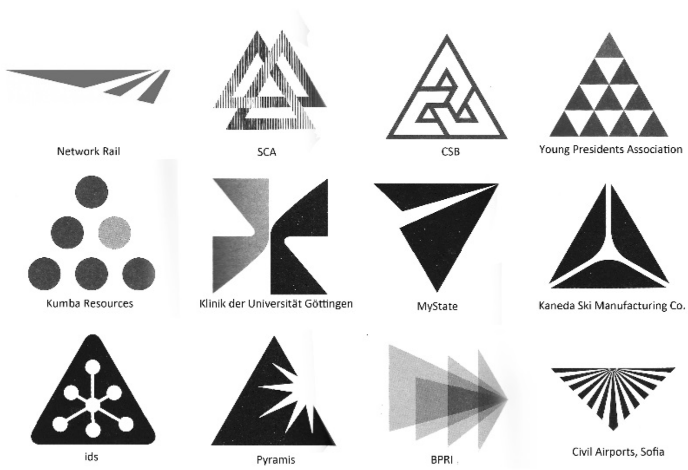


Figure 3.36: Triangles (reproduced from Hyland and Bateman, 2011).

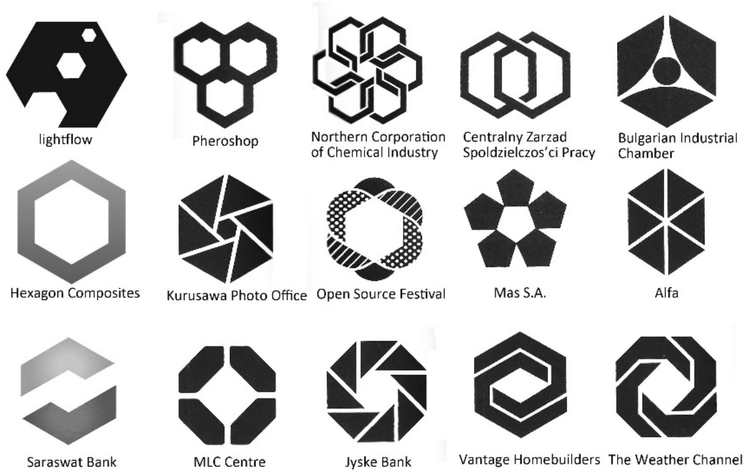


Figure 3.37: Polygons (reproduced from Hyland and Bateman, 2011).

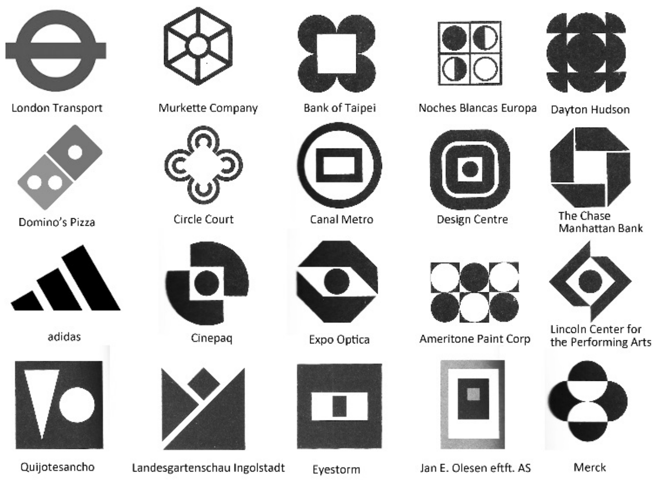


Figure 3.38: Geometric combination (reproduced from Hyland and Bateman, 2011).

Figure 3.39: Rhombi (reproduced from Hyland and Bateman, 2011).

Figure 3.40: Curves (reproduced from Hyland and Bateman, 2011).

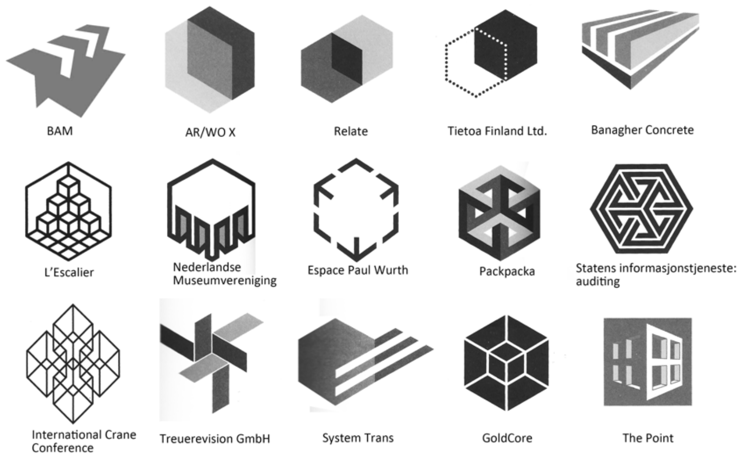


Figure 3.41: Cubes (reproduced from Hyland and Bateman, 2011).

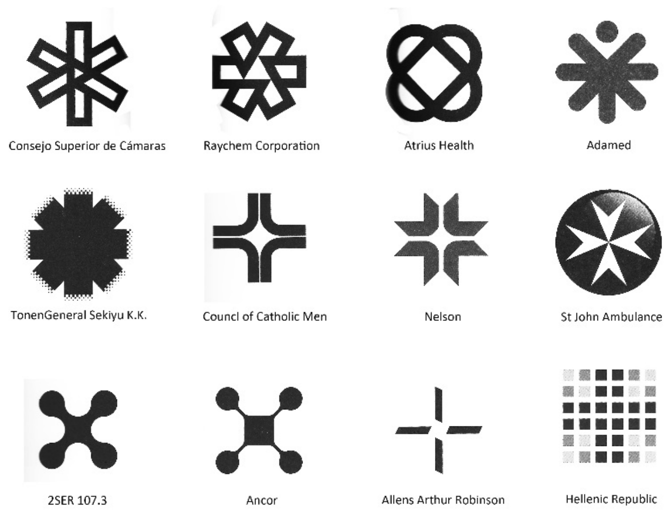


Figure 3.42: Crosses (reproduced from Hyland and Bateman, 2011).

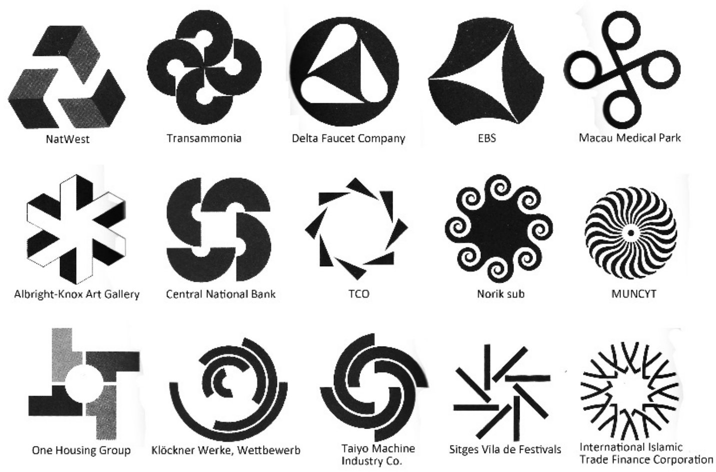


Figure 3.43: Rotary (reproduced from Hyland and Bateman, 2011).

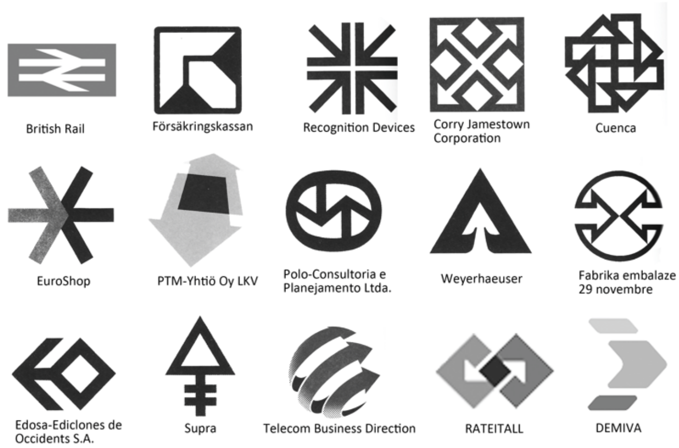


Figure 3.44: Arrows (reproduced from Hyland and Bateman, 2011).

Secondly, different from the non-descriptive logo, descriptive logo means the image references specific objects. Descriptive logos were also categorised by Hyland and Bateman in 2011 as in the following figures (Figure 3.45 to Figure 3.53).

Figure 3.45: Liquid (reproduced from Hyland and Bateman, 2011).

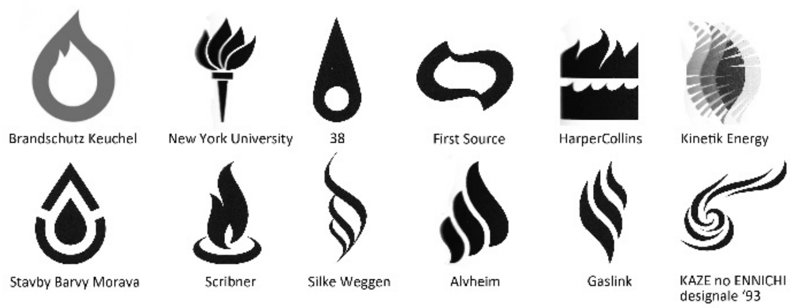


Figure 3.46: Fire (reproduced from Hyland and Bateman, 2011).

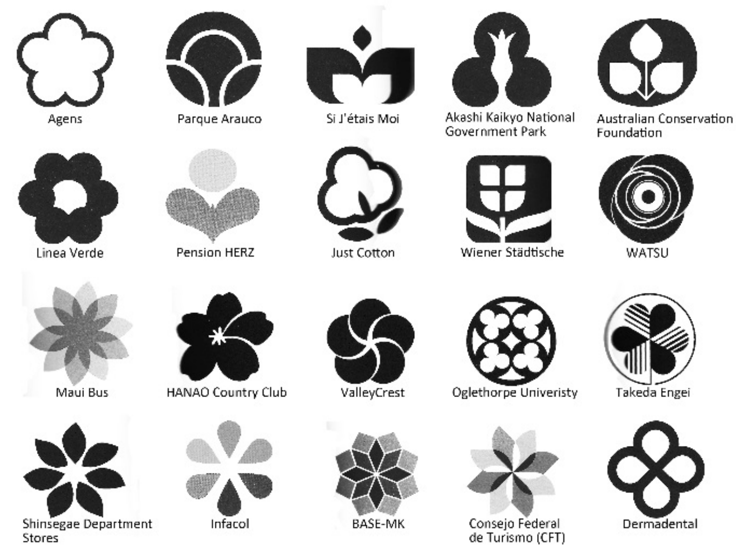


Figure 3.47: Flower (reproduced from Hyland and Bateman, 2011).

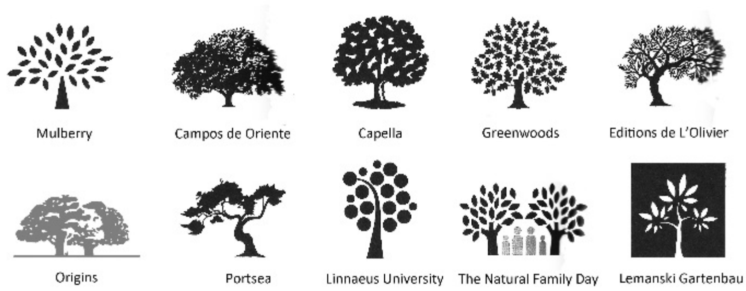


Figure 3.48: Trees (reproduced from Hyland and Bateman, 2011).

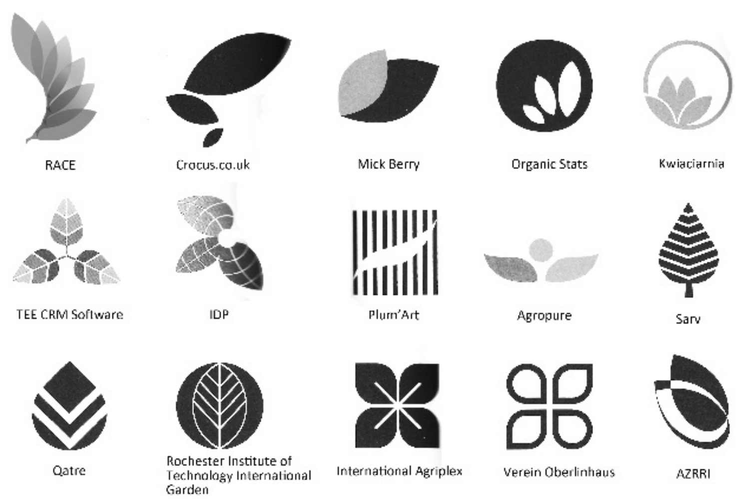


Figure 3.49: Leaves (reproduced from Hyland and Bateman, 2011).

Figure 3.50: Animals (reproduced from Hyland and Bateman, 2011).

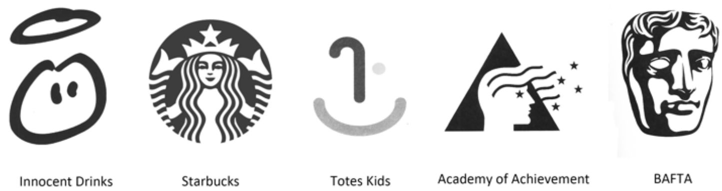


Figure 3.51: Faces (reproduced from Hyland and Bateman, 2011).

Figure 3.52: Transport (reproduced from Hyland and Bateman, 2011).

Figure 3.53: Architecture (reproduced from Hyland and Bateman, 2011).

Considering the variable of recognition and memory, descriptive logos tend to be easier for memorising, whereas non-descriptive logos have fewer variables and more rational conditions. Therefore, comparing both non-descriptive and descriptive logos, this study will apply non-descriptive logos for the experiment sample.

3.3 Summary of logo and app icon evolution

Overviewing the evolution of logo redesign and app icons, it clearly delivers the importance of legibility design issue and simplification trend. Since the 20th century, logos have been redesigned because of changes to the leadership of a company, financial reasons, prospective analysis of the market, or company mergers. However, a new challenge in the 21st century is the smart device invention. App icon and logo designs are undoubtedly always the most challenging task for maintaining brand identity. Nowadays, both of these face the challenge of maintaining legibility on a small scale. Apart from previous logo design tips such as uniqueness or the aesthetic, designers have to consider a more rational problem – legibility.

Reviewing some cases of logo evolutionary trend, it was changed for the following main reasons - (1) the need for a new image (new leadership, financial reasons, prospective analysis of the market or mergers); and (2) the need for technical function (legibility, modern, aesthetic). Generally speaking, the logo modification trend is unpredictable but depends on what is the new requirement. As mentioned above, legibility is the new issue requiring to be solved. The trend of logo modification can be predicted when ‘simplicity’ is the major factor for consideration. It has taken place in many different kinds of situations and requirements over a long period of time; however, with the invention of the smartphone, recognition and confusion have become the major tasks to solve in the logo redesign area. Techniques to consider in designing a logo include touching and overlapping letters and, for short names, open spacing. Thus, the trend of current logo modification will tend to be simple design.

Reviewing the requirements of an app icon, it has to work at multiple resolutions retaining the legibility of the concept across the range of sizes. For maintaining the legibility on the small screen, scalability is the core of their next logo modification. These new logo modifications will have a high possibility of being adopted for use as app icons directly, and to be shown in several places throughout the platform, and at several sizes. Certainly, overly complicated icons often fail due to bad scalability. Thus, the major part of the conceptual stages of app icon design should be dedicated to thinking about whether any given design scales gracefully.

To understand the trend and requirements of logo and app icons, some brief ideas of methods were suggested as follows: (1) reduction- determine the essential qualities; (2) regularising- use regular geometric forms, simplified contours and (3) leverage – combine redundant elements into a single, simpler unit. Previous studies mention many key words for awareness; however, what principles are involved to make it simple? Which level of simplicity is good enough to maintain legibility? Therefore, overall, some essential key words for achieving the aim – logo and app icon legibility enhancement, will be discussed in the following chapters.

Chapter 4: Research methodology

4.1 Introduction

Graphic design has existed long enough for its role in society to be understood; however, unlike other subjects such as literature, mathematics or fine arts, it has developed without much theoretical reflection. Three useful models of graphic design research were adapted by Noble and Bestley (2005, p.10) based on the following themes: 1) Research about design; 2) Research into design; 3) Research through design. The concept of research about design is the study of design history, styles, influence, models and approaches, in order to develop new knowledge; generally speaking the aim is to understand design as a subject. The concept of research into design is the exploration of design methods and practices, including visual testing and experimentation, which centres on both understanding the process of design and developing new design actions, artefacts or methods. However, the concept of research through design involves the development of new artefacts of which the goal is to communicate visually new knowledge that is not the centre of the whole research process. The role of research through design is to use graphic design as an instrument for investigating other subject areas, for instance, mapping, information design and editorial approaches to visualising and categorising data. Based on the definition of design research addressed by Noble and Bestley (2005, p.10), this study is determined as research into design, which aims to understand the design process of logo design and improvement of legibility through visual testing and experimentation research methods. This study will involve both quantitative and qualitative research methods to achieve its aim.

This chapter outlines the methodological approach and determines the selection and justification of the methodology for answering the research question in this study. In general, this study aims to improve legibility via graphic simplification research. This study comprises five phases: (1) defining simplicity by scale methodology; (2) determining the principle of simplicity judgement by ranking methodology; (3) simplicity criteria comparison by image-matching; (4) simplicity criteria application – drawing; (5) legibility. To adopt appropriate research methodologies for approaching these five phases in this research was crucial. A logical structure of this research argument was organised by an inductive-deductive philosophy of research.

In a philosophy research structure, two broad types of reasoning are categorised as deductive and inductive (Trochim and Donnelly, 2008, p.17) (Figure 4.1). Generally, deductive works from the more general to the more specific which means that it starts research from a theory. Therefore, sometimes it is known informally as a top-down approach. Following from the deductive approach, a study might begin by thinking up a theory about a topic of interest as a first step and then narrow it down into more specific hypotheses for testing. Moreover, observation collection may narrow down the theory further in order to address the hypotheses. This ultimately allows the study to be able to test the hypotheses with specific data – a confirmation of original theories.

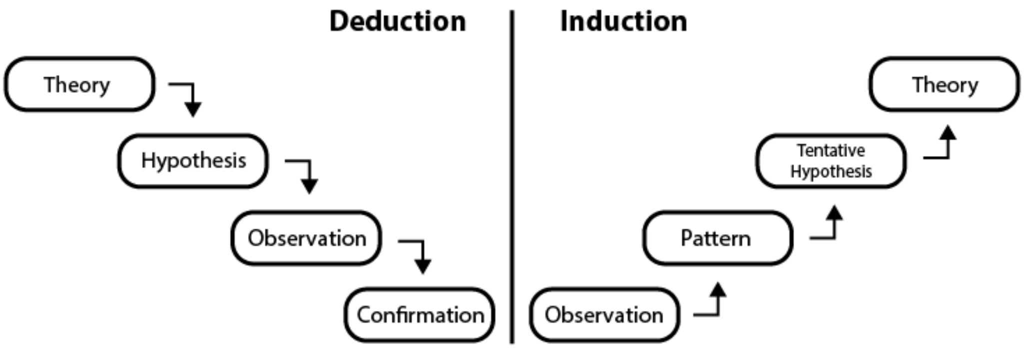


Figure 4.1: Deduction and induction reasoning (reproduced from Trochim and Donnelly, 2008, p.17).

On the other hand, an inductive approach begins with specific observations and measures and ends up as general theory (Trochim and Donnelly, 2008, p.17). In contrast to the deductive, inductive reasoning works the other way from specific observations to broader generalisations and theories. It is opposite to deductive, being known informally as a bottom-up approach. Inductive reasoning begins with specific observations and measures, detects patterns and then formulates some tentative hypotheses, and finally ends up developing some general conclusions or theories.

These two approaches have different processes when conducting research. Inductive reasoning is more open-ended and exploratory, especially at the beginning. However, deductive reasoning is narrower in nature and is concerned with testing or confirming hypotheses. Even though some particular studies may look like purely deductive or inductive reasoning, most social research involves both reasoning processes at some time in the project. This study aims for legibility improvement via simplicity modification. Thus, the structure of the research methodology will start from what simplicity is and how to apply it into design practice with the confirmation of legibility improvement. Therefore, both deductive and inductive reasoning research methods are applied in this study, as shown in Figure 4.2.

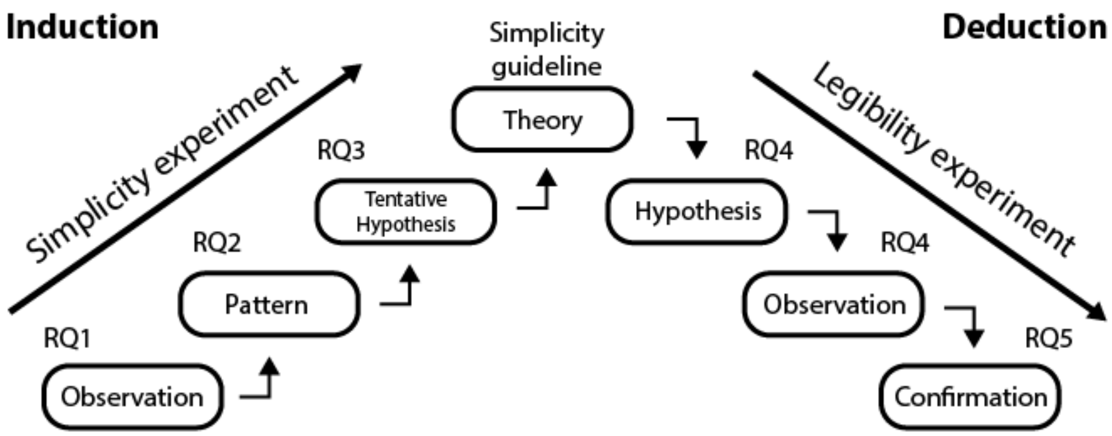


Figure 4.2: Research structure.

The research structure of this study started with induction which explored the definition of simplicity (Research question 1) and the agreement of simplicity (Research question 2). Next, applying the data given from Research questions 1 and 2, a tentative hypothesis was produced and tested in Research question 3. Summarising these simplicity experiments from Research questions 1, 2 and 3, a guideline theory of simplicity was generated. Therefore, the whole process of inductive reasoning was completed for the understanding of simplicity. As mentioned above, deductive reasoning works from theory to confirmation, and this study will continue the application of simplicity guidelines and legibility improvement experiment by following deductive reasoning processes. After a simplification theory was produced, Research question 4 aimed to know whether it is applicable or not and how it works. Therefore, examining hypotheses is once again essential in deduction reasoning and the observation step is for understanding how the guidelines work. In the last phase, the legibility improvement experiment (Research question 5) concluded all the data analysis results, examining whether simplification is an accurate method to decrease image legibility reaction time and increase accuracy. This last step of confirmation is the conclusion of this research which indicates the relationship between simplicity and legibility in a logical research structure.

4.2 Research question

As mentioned above, the aim of this study is to improve legibility via graphic simplification research. To achieve this, appropriate research questions are undoubtedly the key process to confirm a logical series of hypotheses. Five suggestions for carrying out good research questions are classified as (a) clear - they are unambiguous and easily understood; (b) specific - they are sufficiently specific for it to be clear what constitutes an answer; (c) answerable - we can see what data are needed to answer them and how those data will be collected; (d) interconnected - the questions are related in some meaningful way, forming a coherent whole; and (e) substantively relevant - they are worthwhile, non-trivial questions worthy of the research effort to be expended (Punch, 2005, p.46). Therefore, the five phases of this study (1) defining simplicity; (2) determining a principle of simplicity judgement; (3) simplicity criteria comparison; (4) simplicity criteria application; (5) legibility testing, were generated as the following research questions in order to achieve the aim:

- Research question 1: What is the definition of simplicity in each criterion? What would be an appropriate simplification method for a logo and how can its effectiveness be measured?
- Research question 2: Does agreement of simplicity judgement exist?
- Research question 3: Can the simplicity judgement be predictable via the data collection result from Research question 1 and Research question 2?
- Research question 4: Does the simplicity guidelines work properly? How does it work?
- Research question 5: Which level of simplicity design has legibility limitation? Do simplicity criteria improve legibility in application?

**Research question in this study will be abbreviated as RQ (i.e. Research question 1 = RQ1).*

4.3 Research purpose

After deciding the research questions above, a proper research purpose is necessary. Four classifications of the purposes of enquiry (exploratory, descriptive, explanatory and emancipatory) were addressed by Robson (2002, p.59) in the Table 4.1.

Table 4.1: Classification of research purpose and research question adoption.

Research purpose	Description	Research question adoption
Exploratory	• To find out what is happening, particularly in little-understood situations. • To seek new insights. • To ask questions. • To assess phenomena in a new light. • To generate ideas and hypotheses for future research. • Almost exclusively of flexible design.	RQ1 RQ2
Descriptive	• To portray an accurate profile of persons, events or situations. • Requires extensive previous knowledge of the situation etc. to be researched or described, so that you know appropriate aspects on which to gather information. • May be of flexible and/ or fixed design.	RQ4
Explanatory	• Seeks an explanation of a situation or problem, traditionally but not necessarily in the form of causal relationships. • To explain patterns relating to the phenomenon being researched. • To identify relationships between aspects of the phenomenon. • May be of flexible and/or fixed design.	RQ3 RQ5
Emancipatory	• To create opportunities and the will to engage in social action. • Almost exclusively of flexible design.	

The simplicity definition has been widely discussed in psychology, computing science, human-centred interaction as well as in design areas. However, the term 'simple' is still very subjective and has not yet been addressed in theoretical detail. As discussed in the literature review, the simplicity phenomenon exists but has not yet been proven in detail. Therefore, to determine what is the definition of simplicity in each criterion and the agreement of simplicity judgement, RQ 1 and 2 were intended to find out what is happening in little-understood situations, to seek insights, to assess the phenomenon in a new light, to generate ideas and hypotheses for future research of which exploratory is the most pertinent. Secondly, after the data collection from RQ 1 and 2, RQ 3 aims to explain patterns relating to the phenomenon being researched and to identify relationships between aspects of the phenomenon which is categorised as explanatory. RQ 4 is the test of simplicity guidelines application. It is appropriate to adopt a descriptive research study to portray an accurate usage by designers. In the last step, the legibility test aims to prove and seek an explanation of the problem – explanatory is adopted for RQ 5.

4.4 Research strategy

“The general principle is that the research strategy, and the methods or techniques employed, must be appropriate for the questions you want to answer” (Robson, 2002, p.80). In general, research strategy is categorised into two types - fixed design and flexible design (Robson, 2002, p.87) which determine how the enquiry is to proceed, and the method of data collection and analysis (Table 4.2). In the introduction of fixed strategy, it is suitable for a tight pre-specification before reaching the main data collection stage, the data of which are almost always presented in the form of numbers – commonly referred to as a quantitative strategy. On the other hand, flexible design evolves during data collection and is typically non-numerical, and often referred to as a qualitative strategy.

Table 4.2: Research strategy and research question adoption.

	Research strategy	Typical features	Research question adoption
Fixed design	Experimental strategy	• Selection of samples of individuals from known populations • Allocation of samples to different experimental conditions • Introduction of planned change on one or more variables • Measurement on small number of variables • Control of other variables • Usually involves hypothesis testing	RQ1 RQ2 RQ3 RQ5
	Non-experimental strategy	• Selection of samples of individuals from known populations • Allocation of samples to different experimental conditions • Measurement on small number of variables • Control of other variables • May or may not involve hypothesis testing	
Flexible design	Case study	• Selection of a single case (or a small number of related cases) of a situation, individual or group of interest or concern • Study of the case in its context • Collection of information via a range of data collection techniques including observation, interview and documentary analysis.	
	Ethnographic study	• Selection of a group, organisation or community of interest or concern • Immersion of the researcher in that setting • Use of participant observation	
	Grounded theory study	• Applicable to a wide variety of phenomena • Commonly interview-based • A systematic but flexible research strategy which provides detailed prescriptions for data analysis and theory generation.	RQ4

Generally speaking, experimental strategy and non-experimental strategy were categorised into fixed design. The usage of experimental strategy is referred to as the measuring of the effects of manipulating one variable on another variable. The details of the design are fully pre-specified before the main data collection begins (Robson, 2002, p.88). Following on from these typical features, experimental strategy is a general methodology for measuring a small number of variables and involves hypothesis testing which is appropriate for answering RQ 1, 2, 3 and 5. According to Robson (2002, p.98), "fixed designs are usually concerned with aggregates, with group properties and with general tendencies. In traditional experiments, results are reported in terms of group average rather than what individuals have done" The relative weakness of fixed research is that it cannot capture the complexities of individual human behaviour. Thus, flexible design is required in this study as well.

In flexible design, the case study is suitable for developing details, intensive knowledge about a single 'case', or of a small number of related 'cases'. The second flexible design, ethnographic study, seeks to capture, interpret and explain how a group, organisation or community lives, experiences and understands its situation, and typically tries to answer questions about specific groups of people, or about specific aspects of the life of a particular group (Bentz and Shapiro, 1998, p.117 cited in Robson, 2002, p.89). Thirdly, grounded theory study, the central aim of which is to generate theory from data collected during the study, is particularly useful in new and applied areas where there is a lack of theory and concepts to describe and explain what is going on (Robson, 2002, p.90). Thus, RQ 4 adopts this.

4.5 Data collection methods

The selection of data collection methods used depends on what kind of information is sought. The research questions to which this study seeks answers, and the overall research strategy that is appropriate for getting these answers, means that data collection methods needed to be considered. In traditional social science studies, rich data may be collected from multiple sources: questionnaires, interviewing, observations, focus groups, unobtrusive measures, secondary analysis, tests and scales (Gray, 2014, p.315, p.352, p.383; Robson, 2002, p.223, p.292; Kumar, 2013, p.239).

To identify suitable tools for this study, both social science data collection methods and design research methods were essential. This study largely involved the understanding of participants' attitude towards simplicity judgement. Due to the complexity of people's feelings and attitude agreement, tests and scales was a common data collection method which allowed details of attitude to be captured (Robson, 2002, p.292; Engeldrum, 2000). It is commonly used quantitatively in attitude measurement and enables details of scientific measurement data to be provided. Therefore, tests and scales was the appropriate method adopted for RQ 1, 2, 3 and 5 (shown in Table 4.3).

However, RQ 4 more likely needs to apply some research methods from the design area rather than general social science methods. Concept scenarios aim to explore concepts via generating short scenarios as a series of sketches, illustrations or photos to express how potential users in proposed situations will use the concept. This is shown in Table 3. It may be helpful to generate the simplicity guidelines concept from RQ1, 2 and 3; in addition, to examine how designers apply it. For instance, the first step of the concept scenario is to go through a set of already generated concepts (simplicity guidelines generated from RQ 1, 2 and 3). Secondly, to think of possible situations in which that concept will work (imagine designers involved) and examine the key interactions that this study expects. Thirdly, to rethink the concept during scenario making, modifying or enhancing the concepts (simplicity guidelines). In addition, design methods were commonly used for receiving information about user attitude and perception (Kumar, 2013, p.239). Therefore, for measuring simplicity and legibility, the concept scenario is the suitable method for data collection in RQ 4.

Table 4.3: Data collection framework (Gray, 2014, p.352, p.383; Robson, 2002, p.292; Kumar, 2013, p.239).

Methods of Data collection	Description	Research question adoption
General social science methods		
Questionnaire	a. The use of a fixed, quantitative design b. The collection of a small amount of data in standardised form from a relatively larger number of individuals. c. The selection of representative samples of individuals from known populations.	
Interview	a. The research objectives are based upon understanding experiences, opinions, attitudes, values and processes. b. There is a need to attain highly personalised data. c. Opportunities for probing are required. d. A good return rate is important. e. Respondents are not influent in the native language of the country, or where they have difficulties with written language.	
Tests and scales	a. Usually quantitatively, the individual's performance or standing on the attribute in question. b. Gain some insight into what people feel or believe about something. c. Commonly used for attitude measurement d. Enable details of measures to attitude, social desirability, stress, values etc.	RQ1 RQ2 RQ3 RQ5
Design research methods		
Concept Scenarios	a. Exploring concepts by visualising them working in the real world. b. Helps refine ideas, facilitates discussion, improves communication. c. Generates short scenarios as a series of sketches, illustrations or photos to express how that concept will be used by potential users in proposed situations.	RQ4

Following on from section 4.2, each research question indicated different aspects. Four research questions are categorised as tests and scales data collection types; thus, it is necessary to choose a proper scaling type in each research question. In general, scaling types were categorised as Likert scale, Thurstone scale and Guttman scale. The description and typical features of each scaling type is explained in Table 4.4 below.

Table 4.4: Type of scaling (Robson, 2002) and research question adoption.

Types of scaling	Description	Research question adoption
Likert scale	a. Gather a pool of items that appear to be related to or important to the issue. b. Decide on a response categorisation system. c. Ask a large number of respondents to check their attitude to the list of statements. d. Obtain a total score for each respondent. e. Select items for final scale using 'item analysis'.	RQ1 RQ2
Thurstone scale	a. Collecting a large number of statement relating to the attitude in question. b. Give the statement to 'judges.' c. Find the scale value of each statement. d. Select a number of statements spread evenly along the scale.	RQ3
Guttman scale	a. Collect a large number of apparently relevant and usable statements. b. Administer the statements to a standardization group c. Carry out a scalogram analysis of the standardisation group d. Apply the scale to respondents	RQ5

RQ 1 and 2 aim to figure out some potential criteria and agreement of simplicity judgement while asking participants to rank the given samples. In general social science, the summated rating (Likert) scale development commonly has five fixed-alternative expressions labelled as ‘strongly agree, agree, undecided, disagree and strongly disagree’ and, furthermore, asks a larger number of participants to check their attitudes to a list of statements and obtain a total score for each participant (Robson, 2002, p.294). In this study, RQ 1 and 2 applied the Likert scale but labelled the scale like a spectrum from `most simple` to `most complex` instead. The total scores obtained from participants’ ranking of ‘simple feeling’ may give the initial scientific calculation of a simplicity measurement template. Therefore, the Likert scale is an appropriate scaling type for RQ 1 and 2.

Based on the data results from RQ 1 and 2, RQ 3 aims to confirm whether the simplicity judgement can be predictable or not. It requires collecting a large number of statements relating to the attitude in question and gives the statements to participants individually. The equal-appearing interval (Thurstone) scale was designed to ask participants to rate each statement on a certain number of points scale according to the degree of favourableness (Robson, 2002, p.297) it showed towards the attitude (i.e 10 most favourable, 6 neutral and 1 most unfavourable). RQ 3 in this study applied the process of the favourableness step but transferred the statement into 7 items and with 3 to 10 different levels of scale in each, in order to examine the favourableness. Therefore, the Thurstone scale was adopted for RQ 3.

RQ 5 aimed to determine legibility limitation boundaries. Two types of element were required to evaluate it – reaction time and accuracy/errors. Therefore, the analysis was based on a substantially greater number of items. The cumulated (Guttman) scale has the same step as the Thurstone scale in number collection of apparently relevant and usable statements but also includes yes/no questions (Robson, 2002, p.299). As mentioned above, the calculation of reaction time and accuracy was the method used to evaluate legibility; this feature of the Guttman scale was adopted for calculating the total scores of accuracy/errors in RQ 5.

4.6 Data analysis

The purpose of data analysis is to help get data into shape, and to suggest how to analyse and interpret it (Blaxter, et al., 2006, p.194). Collecting the data is about using the selected methods of investigation (Robson, 2011, p.408) which means to generate it in a systematic way. After data has been collected in the experiments, it is necessary to find an appropriate procedure to analyse and interpret it. Typically data is categorised as quantitative data if it is in numerical form and qualitative if it is not (Trochim and Donnelly, 2008, p.11). As mentioned in previous sections, this study involved both quantitative and qualitative research methods. This section is going to discuss the use and selection of appropriate procedures and to discuss how the results obtained from these procedures were interpreted for each research question.

4.6.1 Analysing quantitative data

In the quantitative research method, data analysis is commonly divided into two types: (1) confirmatory – seeks to establish whether you have actually got what you expected to find and (2) exploratory – explores the data trying to find out what they tell you (Robson, 2011, p.419). As mentioned in section 3.5, much fixed-design research is exclusively quantitative. A description of types and features of data analysis is shown in Table 4.5.

Table 4.5: Types of data analysis and research question adoption.

Types of data analysis	Description	Research question adoption
Exploratory	• Explores the data trying to find out what they tell you.	RQ1 RQ2
Confirmatory	• Seeks to establish whether you have actually got what you expected to find.	RQ3 RQ5

As mentioned in section 4.3, the purposes of RQ 1 and 2 were to determine the definition of simplicity and simplicity criteria comparison. The purpose of these research questions was to explore the potential simplicity criteria; therefore, exploratory was adopted. On the other hand, the purpose of RQ 3 was to seek to establish whether the prediction of simplicity judgement or hypotheses of simplicity criteria matched the prediction or not. RQ 5 aimed to confirm the application of simplicity for legibility improvement and determine the limitation of legibility through examining the reaction time and errors. The results of the data were expected to tell the boundary of legibility limitation. Therefore, confirmatory was adopted for RQ 3 and 5.

Following on from previous sections, quantitative data is normally presented in numerical form. To generate participants' results as numerical data, a classic 'levels' of measurement process was addressed by Stevens (1946). The function of level of measurements refers to the relationship among the values that are assigned to attributes for a variable. Beginning with the idea of the variable, for instance simplicity (Figure 4.3), this variable has a number of attributes. The assumption from the literature review is that there are seven relevant attributes – form, open-closed, straight-curved, symmetry, weight, angles and components. For the purpose of analysing the results of this variable, this study arbitrarily assigned the value 1, 2, 3, 4, 5, 6 and 7 to the seven attributes. The level of measurement describes the relationship between these seven values. These numbers just represent names rather than judge the rank order. In this case, the number function may be described as nominal (Trochim, 2008, p.95).

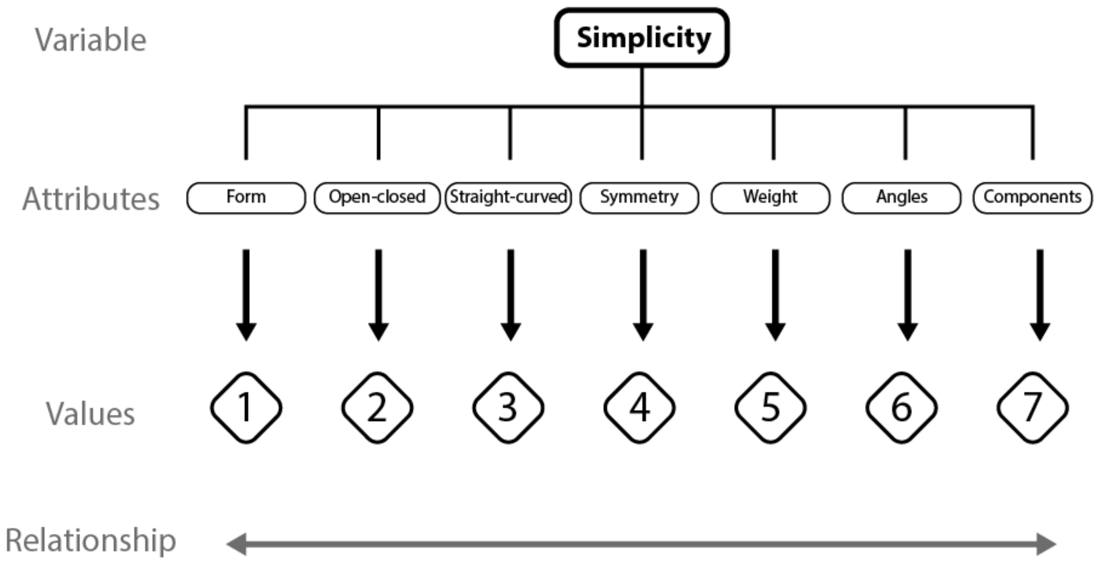


Figure 4.3: The level of measurement describes the relationship between the values associated with the attributes of a variable (reproduced from Trochim, 2008, p.95).

The summary of the levels of measurement included four phases: (1) nominal – refers to a set of categories used for classification purposes; (2) ordinal – refers to a set of categories where they can be ordered in some meaningful way; (3) interval – refers to a set of categories which are not only ordered but also have equal intervals on some measurement scale; and (4) ratio – similar to interval level but with a real or true zero (Trochim, 2008, p.95). Following on from previous sections, the purpose of RQ 1, 2 and 3 aimed to generate an agreement of simplicity theory through quantitative research methods; thus, these four phases were a suitable process for data analysis for RQ 1, 2, 3 and 5.

4.6.2 Presenting quantitative data in numbers

Following on from the decisions of data analysis methods, it is an important stage to know how to display/interpret these numbers. To present the results of data collection from each research question, an understanding of the meaning of the scores is required. Summary or descriptive statistics is a way of representing some important aspects of a set of data by a single number: (a) measures of central tendency (b) measures of variability. In central tendency measurement, the most common such measure to the layperson is the 'average', calculated by adding all of the scores together and then dividing by the number of scores.

Following on from previous sections, some types of descriptive statistics are required in this study: (1) mean score - a description of the central tendency in which you add all the values and divide by the number of values; (2) standard error - the spread of the averages around the average of averages in sampling distribution; (3) R squared - a measure of the proportion of the variance in the dependent variable which is explained by the independent variables in the equation; (4) percentage - a number or rate that is expressed as a certain number of parts of something divided into 100 parts (Trochim, 2008, p.266; Robson, 2002 p.417). Table 4.6 shows the function of each statistic below.

Table 4.6: Types of descriptive statistic and research question adoption.

Types of descriptive statistic	Description	Research question adoption
Mean score	A description of the central tendency in which you add all the values and divide by the number of values.	RQ1 RQ2 RQ3 RQ5
Standard error	The spread of the averages around the average of averages in sampling distribution.	RQ1 RQ2 RQ5
R^2	A measure of the proportion of the variance in the dependent variable which is explained by the independent variables in the equation.	RQ3
Percentage	A number or rate that is expressed as a certain number of parts of something divided into 100 parts.	RQ4 RQ5

In this study, the purposes of RQ 1 and 2 was to determine the definition of simplicity and agreement which are needed to understand the ranking of each sample. The mean score is the necessary number to display the relationship of orders. Apart from the mean score that was required for RQ 1 and 2 analysis, as mentioned in previous sections, the result of gathering an agreement of subjective attitudes may be wide. Therefore, the score of standard error also needed to be presented in RQ 1 and 2.

The data results of RQ 1 and 2 were expected to produce two aspects in numerical presentation; ranking score of simplicity criteria and tendency of simplicity. A scoring template was produced based on the ranking score of simplicity; then, the big challenge for the next step was to examine whether this scoring template (hypothesis) is applicable in the real world. Therefore, the tendency of simplicity in RQ 2 was determined as the 'aim' of the simplicity definition. RQ 3 is going to examine how good the fit is between this model (hypothesis and aim) and test how the percentage of simplicity can be predicted.

To examine the 'goodness of fit,' correlation coefficient was adopted which is a number that describes the degree of relationship between two variables (Trochim, 2008, p.268). Measures of correlation are referred to as correlation coefficient. It gives an indication of both the strength and the direction of the relationship between the variables. The commonly used coefficients assume that there is a linear relationship between the two variables. The symbol '*R*' stands for the correlation and it turns out that *R* will always be between -1.0 and +1.0 to measure the strength and the direction of a linear relationship between two variables. If the correlation coefficient was squared, a direct measure of the proportion of the variance will be explained. This is the multiple coefficient determination 'R^2' which measures the proportion of the variance of one variable (dependent) that is predictable from the other variable (independent) in the equation (Robson, 2002, p.431; Gray, 2014, p.690). While the correlation coefficient is a measure of the relationship between the variables, it is difficult to assess the strength of this relationship. Therefore, the square of the correlation coefficient (r^2) is a useful index as it corresponds to the proportion of the variation in values of one of the variables which can be predicted from the variation in the other variable (Robson, 2002, p.423). Broadly speaking, if R^2 is low (less than 0.3), then it is unlikely to be profitable to exert much further time and effort in investigating the relationship. In brief, it is a measure that allows us to determine how certain one (hypothesis) can be in making predictions from another certain model (aim). R^2 runs between 0 and 1 to represent the percentage of the data that is the closest to the line of best fit. Therefore, the R^2 score is the appropriate number to represent the result of RQ 3. The number of R square (also known as coefficient of determination) indicates using X to predict Y, and reflects the `goodness of fit`. As mentioned above, data analysis from RQ 1 and 2 (X) was needed to test the correlation in RQ 3 (Y). To test the correlation, it can be categorised into three types – positive correlation, negative correlation and no correlation. The starting point of any such analysis can be constructed and subsequently examined via a scattergram. RQ 4 aimed to understand how designers apply the simplicity guidelines, and which rules might apply the most. Thus, percentage is the clearest way to explain this.

To understand which level of simplicity design has legibility limitation and legibility improvement, two aspects of evaluation are required – reaction time and accuracy. The longer the time participants require to answer the question, the lower the legibility of the item, and vice versa. In another aspect, the higher the accuracy participants achieve, the higher the legibility of the item, and vice versa. Therefore, mean score is the appropriate calculation method to average participant reaction time for one item. The accuracy result in each item will be presented as a percentage. As mentioned above, assessing human judgement may be on a wide spectrum, standard error score will also show in RQ 5.

4.6.3 Presenting quantitative data in charts

Having analysed the data collected from previous methods, the next task is to present the findings in an appropriate way. The main purpose of using data display techniques is to make the findings clear to understand and provide extensive and comprehensive information in an effective way. Generally, there are four ways of displaying the analysed data – text, tables, graphs and statistical measures (Kumar, 2011, p.293). Several types of charts may be used for display, either frequency or percentage of the results. Generally, the appropriate use of charts and graphs of frequency data are by bar chart, pie chart, histogram, or frequency polygon (Black, 1999, cited by Gray, 2014, p.562). In addition, scatter charts and radar charts are quite common for presenting statistics. The presentation methods for statistics will be based on the features of each chart. Because of the nature and purpose of investigation in this research, these four data display methods were selected individually for each research question.

To present the result from RQ 1 - 'what is the definition of simplicity in each criterion?' the first step is to understand what criteria might influence participant judgement. As mentioned above, the experiment design for answering this research question is to divide the definition of simplicity into seven criteria and compare individually; therefore, these may be simply be presented in a table form. Table 4.7 below is the summary of selected statistics and charts presentation in each research question.

Secondly, RQ 2 – 'does an agreement of simplicity judgement exist?' – applied mixed criteria in all samples; however, the task simply asked participants to place the sequence from simple to complex one by one. To represent these numbers in graphical form, a display showed the mean values as a dot, which had an 'error bar' extending above and below it, to tell one standard deviation unit above and below the mean. These measures are suitable for exploring tendency and for displaying single variable results. Therefore, a scatter chart is the appropriate option for showing data individually.

RQ 3 - can simplicity judgement be predicted via the data collection results from RQ 1 and RQ 2? This research question aims to establish whether the hypotheses setting from RQ 1 and RQ 2 are predictable or not. A scatter chart/diagram is a graphical representation of the relationship between two variables that gives a clear picture of the nature and strength of the relationship between the variables (Robson, 2002, p.419). Both the variables must be measured either on interval or ratio scales and the data on both the variables needs to be available in absolute values for each observation. Data is taken in pairs and displayed as dots in relation to their values on both axes. Thus, a scatter chart was adopted and R^2 is the clearer option to display the gap. Secondly, a further question asks participants to indicate which simplicity criteria influenced their judgement the most and rank it in order. A radar chart is the appropriate chart to illustrate the comparison in this task.

RQ 4 mainly examines the application of simplicity guidelines used by designers; therefore, the role of statistics in this section is simply explained by the percentage of simplicity criteria comparison and displayed in a radar chart.

RQ 5 - Which level of simplicity design has legibility limitation? Do simplicity criteria improve legibility in application? These questions aim to provide an answer as to where the boundary of legibility limitation lies; therefore, a bar chart is a suitable option for displaying reaction times and accuracy.

Table 4.7: Summary of descriptive statistics and data presentation.

Types of data presentation	Types of descriptive statistic: Mean score	Standard error	R^2	Percentage
Table	RQ1	RQ1		
Scatter chart	RQ2	RQ2	RQ3	
Bar chart	RQ5	RQ5		RQ5
Radar chart	RQ3			RQ4

4.6.4 Analysing and presenting qualitative data

RQ 4 in this study aims to test the usability of the simplification guidelines. As mentioned in the previous section, a grounded theory study is adopted. As mentioned before, the aim is to generate a theory to explain what is central in the data. The challenge of grounded theory is to find a central core category which is both at a high level of abstraction and grounded in (i.e. derived from) the data you have collected and analysed. Furthermore, three kinds of data analysis process were categorised as (1) open coding – to find the categories; (2) axial coding – to recognise relationships between categories; and (3) selective coding – to integrate the categories to produce a theory, in order to establish the core category (Gray, 2014, p. 611; Corbin and Strauss, 1990). RQ 4 aims to apply the simplicity guidelines which was generated from RQ 1, 2 and 3. Generally speaking, the concept of simplicity criteria was already categorised and generated from RQ 1, 2 and 3; therefore, the task for RQ 4 is not to find the categories but to establish the core category instead. Therefore, selective coding was adopted for RQ 4.

4.7 Sampling

Using statistics to improve design seems to contradict the field's inherent freedom and creativity; however, the field of design often uses quantitative research to inform anything from practical considerations to refining theories about interactions with designed objects through the validation of exploratory research findings (Purpura, cited in Laurel, 2003, p.63). To achieve this challenge, sampling is an important role for both quantitative and qualitative research in this study.

Sampling is the process of selecting a few (a sample) from a larger group to become the basis for predicting the prevalence of an unknown piece of information, situation or outcome regarding the larger group (Kumar, 2011, p.193). The various sampling strategies in quantitative research can be categorised as random, non-random and mixed sampling design. For a design to be named as random sampling, each element in the population has an equal and independent chance of selection in the sample. Non-random sampling designs are used when the selection of elements is dependent upon other considerations. There are five commonly used non-random designs, each based on a different consideration: quota sampling, accidental sampling, judgemental sampling, expert sampling and snowball sampling (Kumar, 2011, p.199). RQ 1, 2, 3 and 5 in this study aim to gather general opinions and agreements from people without any specific limitation; thus, random sampling was adopted. As RQ 4 is the application of simplicity guidelines which limits only design background participants to be involved, thus, judgemental sampling was adopted.

Quantitative validation means to confirm what has been collected from a smaller group of people with a larger and hopefully representative group of people. The sample size determined by Purpura (cited in Laurel, 2003, p.68) was of at least 30 people. The sample size in fixed designs is a common question but not straightforward to answer as it depends on many factors (Robson, 2011, p.128). Following from Borg and Gall (1989), Mertens (2005, p.325 cited in Robson, 2011, p.128) suggested a 'rule of thumb' figure of about 15 participants for experimental design. The aim of this study is going to improve logo legibility in small devices focusing on testing simplicity, legibility and usability rather than likeability; therefore, the sample size for this study may be small (around 40 participants) which is permitted (Shown in Table 4.8).

Table 4.8: Types and size of sampling in each research question.

	RQ1	RQ2	RQ3	RQ4	RQ5
Types of sampling	Random	Random	Random	Judgemental	Random
Size of sampling	**40**	**40**	**40**	**10**	**40**

4.8 Overview of research design

Following on from previous sections, the aim of this study is to improve graphic legibility via simplification. The structure of this study is divided into three major categories of simplicity, design process and legibility. In terms of simplicity, RQ 1, 2 and 3 try to gather agreement among people through an attitude measurement scale. In terms of the design process, RQ 4 tries to examine how designers apply the simplicity guidelines (theories) via evaluating designers` work. In terms of legibility, RQ 5 aims to compare the legibility improvement between the items produced with and without simplicity guidelines via reaction time and accuracy. The structure and process of this research is described in Figure 4.4.

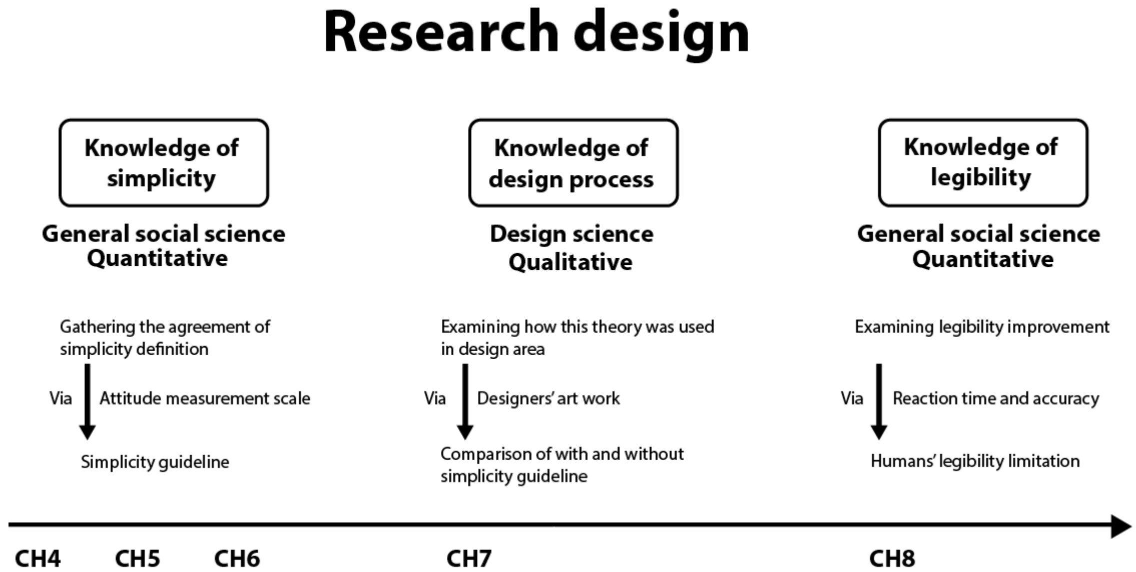


Figure 4.4: Research structure

To answer the five research questions stated in this study, Table 4.9 below summarises all the methods selected in this study.

Table 4.9: Research design and methods adoption.

	RQ1	RQ2	RQ3	RQ4	RQ5
Research paradigm	Constructivism Inductive	Constructivism Inductive	Inductive → **Theory** → Deductive	Positivism Deductive	Positivism Deductive
Research purpose	Exploratory	Exploratory	Explanatory	Descriptive	Explanatory
Research strategy	Experimental strategy	Experimental strategy	Experimental strategy	Grounded theory study	Experimental strategy
Data collection **Types of scaling**	Tests and scales Likert scale	Tests and scales Likert scale	Tests and scales Thurstone scale	Concept Scenarios	Tests and scales Guttman scale
Data analysis	Exploratory	Exploratory	Confirmatory	Selective coding	Confirmatory
Data display	Table	Scattergrams	Scattergrams Radar chart	Text Radar chart	Bar chart
Sampling	40	40	40	10	40
Research structure	Observation →	Pattern →	Tentative Hypothesis **Theory** →	Hypothesis Observation →	Confirmation

Chapter 5: Definition of simplicity

5.1 Introduction

As a graphic mark, a logo is applied by companies to aid public recognition and identification (Wheeler, 2009). Providing a recognisable and readable logo for users is undoubtedly always the aim of graphic designers. In recent years, one in fifty companies changed their names and logos for a variety of reasons; therefore, in order to adopt the changes of company name, adoption of new strategies or novelty, logos may need to be changed (Walsh et al., 2007). Logos are traditionally applied across media such as packaging, letterheads, business cards, signs and print advertisements, and in recent years in digital devices — specifically, nowadays apps in mobile devices have been popularised. There is therefore a need for brands to ensure their logo is recognisable across different media. Figure 5.1 shows some examples of how a logo of a fast-food company, Subway, appears across different media (a laptop and a smartphone display).

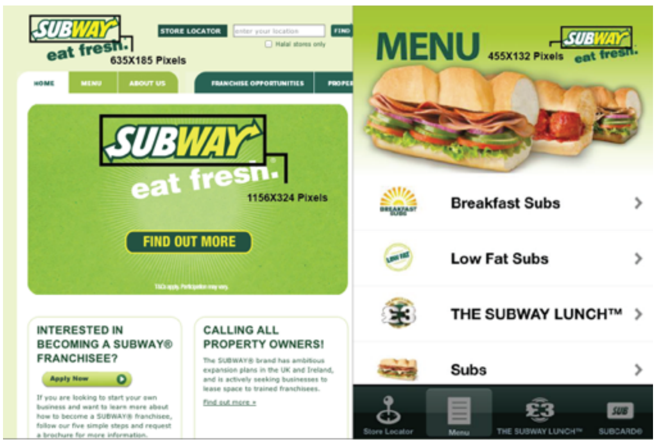


Figure 5.1: Examples of the Subway logo appearing on a laptop screen and a smartphone screen.

Some logos can be distinguished easily and obviously, while others cannot be identified or recognised by viewers. As a medium of the brand and consumers, logos must have marked ability to increase high identification and recognition. Hence, the causes behind the outcomes are a valuable issue to explore. As previous studies have mentioned (e.g. Arnheim, 1967; 1974), simplification is considered a major element in designing logos, giving the ability to increase recognition. Designers sometimes simplify objects to obtain effective communication or a unique style rather than create realistic art works, simplified objects usually can enhance the memory of the images for humans.

It seems that the response from graphic designers, when considering logo creation, is one of two types: ‘it looks visible’ or ‘it looks invisible’ may be based on consideration of a range of factors among which form, open-closed, straight-curved, symmetry, weight, angles and components are probably the most important. To achieve the concept above, this study provides a review of the shape analysis method which was known as a key role in systems for object recognition, matching and analysis. According to some previous studies, Gestalt psychologists addressed the idea that graphic simplification could be a better way to develop the ability of image recognition. Graphic simplification aims to create images that contain simple graphic elements and yet efficiently represent real objects. Maeda (2006, p.16) described the simplest way to achieve simplicity as being through thoughtful reduction, and simplifying a design is more difficult than making it complicated. Simplification means not only deleting the details of the objects, but also emphasising key points on specific details. Previous studies revealed simplification as the remarkable ability to express the characteristic of the object clearly, in addition to increasing the identity and memory (Gombrich, 1982; Arnheim, 1969; Zusne, 1970). Moreover, a good figure means to apply the least configuration to convey the identical information since the visual cognition of human beings is inclined to receive information by the most economical way (Koffka, 1935; Arnheim, 1969; 1974; Goldstein, 2010). Therefore, the initial concept of this study is to apply the simplicity method to enhance logo recognition ability. To solve this problem, the design concept starts with considering how to simplify the graphic, and whether any rule exists in subjective simple graphic decisions? This study aims to figure out and explain a more systematic method to evaluate the level of simplicity. Therefore, the aim is to answer the questions: What would be an appropriate simplification method for a logo and how can its effectiveness be measured?

5.2 Research methodology

Shape can be analysed according to different criteria and function. The principle of this study focuses on recognition with the argument starting with the degree of simplicity. The definition of 'good figure' in terms of redundancy among parts raises some new questions that concern the memory and recognition of form (Attneave, 1955). For example, are regular figures better remembered than irregular ones simply because they contain less information to be remembered? Does their priority persist even when information is held constant? In other words, which is remembered more accurately: a large, well-organised figure, or a small, poorly-organised figure containing the same amount of information? Therefore, a common problem in shape research is how to evaluate the degree of simplicity. Simplicity of shape analysis is hard to be judged on one specific factor but also has to be chosen depending on the properties. The first serious attempt at understanding graphic perception and graphic simplicity was undertaken through Gestalt theory. "There is an observable bias in our perception for simple configurations, straight lines, circles and other simple orders and we will tend to see such regularities rather than random shapes in our encounter with the chaotic world outside" (Gombrich, 1979, p.4). Gestalt psychologists proposed a set of laws to explain how vision groups elements in order to recognise objects (Pelli *et al.*, 2009, p. 36).

This study reviewed some previous visual perception experiments and applied them as the degree of simplicity criteria. Hochberg's (1948 cited in Vernon, 1970, p.33) visual perception experiment presented silhouette forms, and found that the threshold for recognition was the lowest with the simplest form, the circle; then for a rectangle and then for a cross. Bitterman (1954) also firstly found the lowest threshold for the circle, and then, triangle, T-shape, square and diamond, and cross respectively. Nine different forms were selected in Bitterman's experiment (circle, square, diamond, equilateral triangle, cross, *L*-shape*, X*-shape*, T*-shape and *H*-shape) as follows.

Figure 5.2: The forms used in Bitterman's experiment (Bitterman, 1954, p.212).

Attneave (1954) suggested that the number of errors made in guessing the outline of a form could be used as a measure of figural 'goodness' which provided an initial idea of node quantity and number and size of angles. Zusne (1970) argued that the node of a polygon is the concentrated point for human vision rather than a straight line. Hence, number and size of angles can be one of the available methods to explore in simplification. Apart from the angle task, another method was taken by Marr (1982) which focused on segmentations or called ‘components’. Marr and Nishihara (1978) obtained the component axes from an image of a donkey. From this initial outline, convex and concave segments were labelled and used to separate the donkey into smaller sections. The axis is derived for each of these sections separately, and then these component axes are related together to form a stick representation for the entire figure. Figure 5.3 has six diagrams which reveal the concept of components: (a) the outline of a toy donkey; (b) convex (+) and concave (-) sections; (c) strong segmentation points; (d) the outline is divided into a set of smaller segments making use of the points found at (c) and rules for connecting these to other points on the contour; (e) the component axis is found for each segment; (f) the axes are related to one another (thin lines).

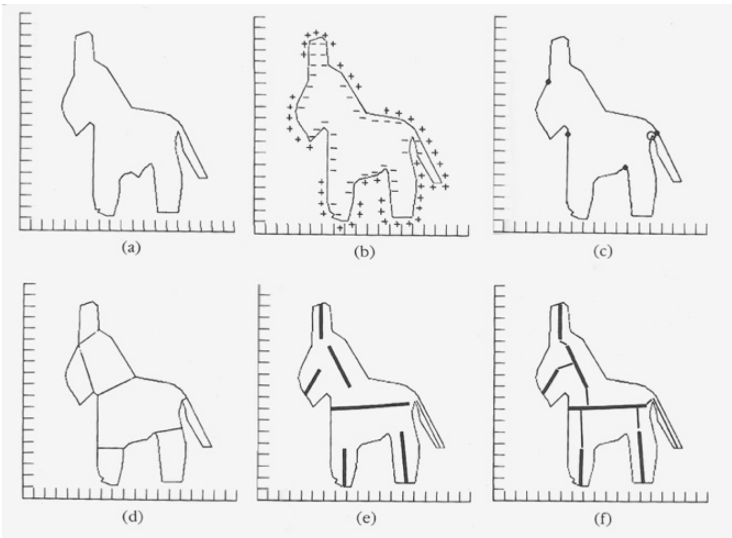


Figure 5.3: The programme derived the component axes from an image of donkey (Marr, 1982, p.315).

According to Marr’s (1982) theoretical approach, Biederman (1987) proposed a theory of object recognition describing objects as consisting of basic shapes or simple components (Eysenck, 2001, p.74; Biederman, 1987, p.118); hence, for the recognition of an object the edge-based contour is extracted first, then decomposed and then comes the parsing or segmenting of its parts at regions of deep concavity into geons. This idea explains that there are mechanisms in the brain to recognise 3-D structural components of objects. Geons are 3-D shapes that can be curved or straight and in addition the geon components of objects is stored information in the brain, and combines with a structure skeleton which is a description of the way they are connected (Ware, 2008, p.110). Biederman (1987, p.115) argued that any single object can project an infinite number of image configurations onto the retina. An object can be presented as a simplified line drawing rather than a full-coloured image. Object recognition is conceptualised to be a logical process in which the image is divided into simple geometric components (Biederman, 1987, p.115).

Another task of the human visual system is to derive shape information about the shape segmentation from topological analysis (Hecht and Bader, 1998) based on computational theory which was addressed by Marr in 1982. The task proposed by Hecht (1998) was to classify patterns/shape by combining three topological properties - connections, components and inclusions (Figure 5.4). Comparison between objects with connected parts and disconnected ones, the reaction time of the former one is quicker than the object with small gap (disconnected) from which could be concluded that a high degree of representational unity was captured by the reaction time of the object with connected contour (closed) rather than the one with small gap contour (open) (Hecht and Bader, 1998).

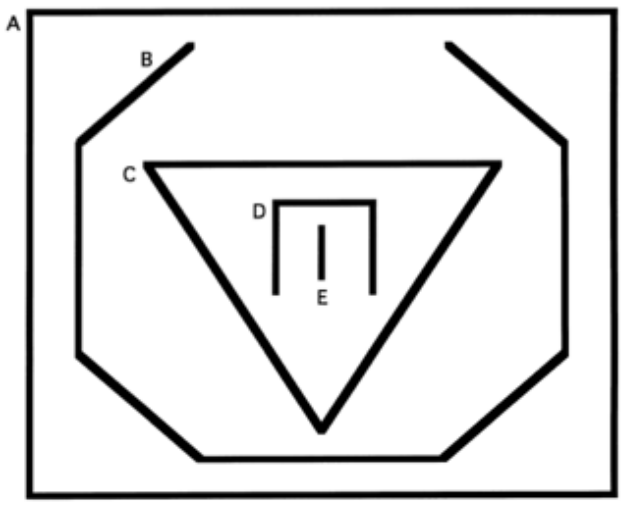


Figure 5.4: Three factors describe the topology of 2-D patterns: The number of components, inclusion relationship and connections (Hecht and Bader, 1998).

Previous research has already provided some methods of visual perception; in general, most visual perception tasks focus on reaction time as the criteria. In contrast, this experiment starts with figuring out the simplicity principle or simplicity rules; therefore, the experiment in this study will extract some part of previous research for reference and add more categories for greater comprehensive consideration. Various studies have focused on discovering underlying shape characteristics; however, the experiment in this study extracts previous concepts as part of shape analysis factors – form, open-closed contour, straight-curved line, symmetry, weight, number and size of angles, and number of components.

5.3 Research question and hypotheses

This study applied shape analysis to identify which elements can be used to measure overall simplicity and could possibly lead to better shape recognition.
Research question was stated in the following: What would be an appropriate simplification method for a logo and how can its effectiveness be measured?
The hypotheses of the study are stated in the following:

H1: Simple shape is related to fundamental form (circle, triangle, …irregular).
H2: Simple shape is related to the degree of closedness of the outline.
H3: Simple shape is related to the shape with pure straight or pure curved form.
H4: Simple shape is related to the shape with complete symmetry.
H5: Simple shape is related to the shape with lighter superficial measurement.
H6: Simple shape is related to the angle in the shape (over or under 180°).
H7: Simple shape is related to the shape with fewer components.
Based on these hypotheses each element includes different levels of simplicity.

5.4 Experiment design

5.4.1 Participants

Twenty students enrolled at the University of Leeds (5 males and 15 females) took part in the experiment with an age range between 20 and 30. Each participant carried out the experiment twice and, therefore, the total number of observation results was 40.

5.4.2 Images

Seven elements (form, open-closed, straight-curved, symmetry, weight, degree of angle and number of components) were identified by shape analysis as the samples for the experiment to develop simplification measurement.

Form

The first step in producing form simplification was to create ten different levels of image using Adobe Illustrator software, based on fundamental shapes such as circle, triangle, square, diamond, polygon and further forms used by Bitterman, Krauskopf, Hochberg (1954), L-shape, T-shape, cross and H-shape, and adding an irregular shape as one of the options.

Figure 5.5: Form selection.

Open-closed

Hypothesis two of simplicity assumes that shapes with closed outlines tend to be simple. Therefore, this experiment applied five levels of open-closed to test this. Each level was set up as a completely closed shape, 45°, 165°, 195°, 255° and open shape respectively.

Figure 5.6: Open-closed selection.

Straight-curved

The third hypothesis assumes that the pure straight, such as a line, or pure curved shape, such as a circle, tend to be more simple. This experiment applied three figures as follows.

Figure 5.7: Straight-curved selection.

Symmetry

As indicated in the literature review section, Hann (2012) depicted four different types of symmetry - translation, reflection, 2-fold rotation, and glide reflection. This experiment addressed a hypothesis that assumes that completely symmetrical shapes tend to be simple shapes, and translation, reflection, 2-fold rotation, glide reflection and asymmetry respectively.

Figure 5.8: Symmetry selection.

Weight

The fifth hypothesis assumes that lighter or thinner figures tend to be more simple. This experiment used the following figures which eliminated other variables.

Figure 5.9: Weight selection.

Degree of angle

The concept of the angle test is based on the previous study by Attneave (1954), and the first experiment in this study. According to previous results, this experiment aims to figure out the influence of convex and concave on the definition of simplicity. This experiment applied ten different degrees of broken line (90°, 120°, 108°, 135°, 128°, 45°, 55°, 40°, 50°, 60°). The result of the angle degree test may be combined with the node quantity method to develop the measurement.

Figure 5.10: Angle selection.

Number of components

The component test assumes that the figure with fewer components tends to be simple. This experiment used the following figures with the same shape and increased the numbers of it by varying transformation. This section can be compared with the previous component quantity experiment.

Figure 5.11: Component selection.

5.4.3 Experimental procedure

In the experiment participants were presented with seven sets of images in turn. Each set of images contained diagrams from one of the seven factors (form, open-closed, straight-curved, symmetry, weight, numbers of angle and numbers of component). Figure 5.12 (left) shows an example of the images presented to the participants. Images were placed at the bottom left corner of the screen and the images were placed at the red box with a random sequence. The participant instructions were given as below; for each image set, they were asked to complete the following tasks:

1. *Put all of the given images in order, from the simplest (1) to the most complicated (10). *Please do not resize the images.*
2. Please drag the images from the left hand side and place them into the numbered boxes.

There was no time limit for the experiment; generally, participants took 10-15 minutes to complete this task. Figure 5.12 (right) shows an example of the participants' results. The participant arranged the ten diagrams in sequence according to their judgement on simplicity. The participants were asked to complete the tasks, following the same instructions for all the seven sets of images.

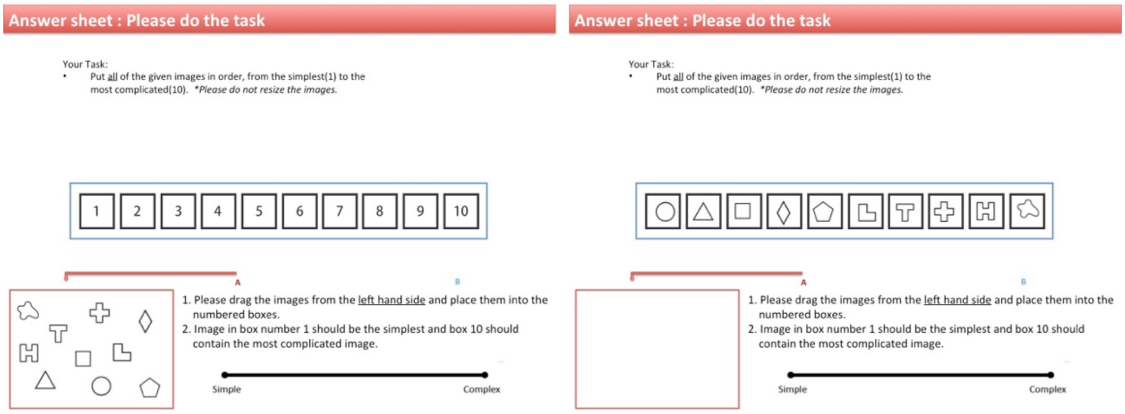


Figure 5.12: An example of images presented to the participants and participants' results.

5.5 Statistical analysis

Participants' results were converted to numeric scores. Mean scores (representing the sequence of the factor levels) and standard errors (participants' variability) were computed. In each image the ranking of the diagrams was recorded and the cumulative rank order of each diagram was averaged by the number of observations. Given each element has different levels of simplicity/complexity present, the mean results were all multiplied by a factor to fall into a range of 1-10.

Tables 5.1-5.7 show the mean score and standard errors for the simplification task. The results show the average sequence arranged by participants in each section.

The sequences of each image are placed according to participants' results illustrated by mean and standard error in the following tables. A number of interesting findings emerged from this experiment. For the form task most of the participants placed the order of simplification from simple to complex images based on the numbers of sides and angles in particular when comparing circle, triangle and square and irregular H-shape. The standard error of form results is between 0.08-0.47. This indicates the consistency of the participants' results, in particular with the circle.

Table 5.1: The result of form.

Mean	1.16	2.58	2.84	4.50	5.63	6.45	7.00	7.92	8.00	8.92
Std error	0.08	0.11	0.11	0.24	0.25	0.22	0.18	0.20	0.47	0.17

For the open-closed task all participants put the completely closed shape as the simpler shape. Apart from the pure closed shape, the result reveals that participants tend to place the angles around +45° or - 45° (45° and 255°) as the simpler shape rather than ambiguous angles that are around 180° but not accurate (165° and 195°). The standard error of open-closed results is between 0.00-0.22. This indicates no doubt that the closed shape is the simpler shape with high agreement.

Table 5.2: The result of open-closed.

Mean	1.00	3.03	3.03	3.97	4.16
Std error	0.00	0.22	0.14	0.13	0.19

Thirdly, the results for the straight-curved task show that pure curved and pure straight shapes tend to be simpler than mixed shapes. However, the mean score (1.74, 1.92) and standard error (0.12, 0.16) for both curved and straight shapes are quite close and can be grouped in the same degree of simplicity.

Table 5.3: The result of straight-curved.

Mean	1.74	1.92	2.34
Std error	0.12	0.16	0.08

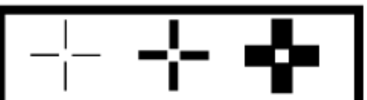
Fourthly, an interesting finding in the symmetry test emerged in this experiment indicating the different types of symmetry with different levels of simplicity influence. Generally, it can be seen that the pure symmetry shape is certainly defined as a simpler shape with mean (1.00) and standard error (0.00). The next one, translation, which could be seen as a copy and move, was placed in the second degree of simplicity with mean (2.55) and standard error (0.18). The reflection symmetry seems equal to complete symmetry and translation and gets a mean score (3.79) and standard error (0.20). However, the degree of rotation and 2-fold rotation were quite similar and seem hard for participants to categorise, remarkably getting a mean score (4.16, 4.29) and standard error (0.20, 0.16). The most complicated shape was predictable — asymmetry placed in this level by participants.

Table 5.4: The result of symmetry.

Mean	1.00	2.55	3.79	4.16	4.29	5.21
Std error	0.00	0.18	0.20	0.20	0.16	0.17

For the weight task, participants generally arranged the images in the order from lighter to heavier or thicker shapes. The standard error of weight results was with the ambiguity possibility (0.06-0.11) that might be considered to require further experiment to clarify. Nevertheless, the result still supports the hypothesis that major participants choose lighter ones as simpler shapes.

Table 5.5: The result of weight.



Mean	1.39	1.89	2.71
Std error	0.11	0.06	0.11

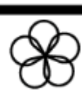
The results in the angle task clearly illustrate the relationship between angle size and simplicity. Participants indicated that the images generated by 90° were the most simple shape with high agreement (standard error 0.07). It could be generally classified into four groups (90°, >90°, 45°, <90°). Even though in the over 90° group, there does not seem to exist a particular relationship with angle size due to the order being 120°, 108°, 135° and 128° respectively, the result could still be regarded as the second level of simplicity. The demarcation of simplicity in the angle task can be depicted by 45°, the angles smaller than 90° being placed in the complicated group (55°, 40°, 50°, 60°). In the degree of angles, 180° was given the score 0 because 180° could possibly be a circle and a line without any angles. The second size of angle 90° was given the score 1.16 and the angle between 90°- 180° was scored as 4.55, the angle 45° got 6.87 and the angle between 45°-90° got a score of 8.13.

Table 5.6: The result of angle.

										
Mean	1.16	2.76	3.53	4.55	4.79	6.87	7.63	7.74	7.84	8.13
Std error	0.07	0.31	0.19	0.25	0.24	0.33	0.24	0.36	0.26	0.27

The result of the component task reveals that participants placed the order according to the number of shapes which were obtained for one, two, three, four and five components respectively. The average score increased steadily from fewer components to more components in the image. High agreement in this task was where there were fewer components, the image tended to be simpler. The majority of the participants indicated that five components was the most complicated image with a mean score 5.00 and standard error 0.00. The standard error in this task is around 0.00-0.10 which is the clearest principle in these seven tasks for defining the degree of simplicity.

Table 5.7: The result of component.

					
Mean	1.26	1.89	3.05	3.79	5.00
Std error	0.10	0.08	0.06	0.09	0.00

According to the results, a template for simplicity measurement for each factor has been created and is shown in the tables above. Not surprisingly, in the result of form, circle, triangle and rectangle are in the simplest order. An interesting finding in this result is that participants might also consider the numbers of angle with form simplicity selection started from no angle (circle), three angles (triangle), four angles (square and diamond) and more than five angles (polygon, etc.) respectively. However, the irregular shape is placed ninth which might be an ambiguous and unexpected result compared to the most complex one — H-shape. One possibility might be the number of sharp angles. Open-closed elements could be understood as two categories — over 180° and under 180° — that the former one tends to be defined as a simpler shape and the latter tends to be the least simple. The result of straight- curved, symmetry, component and weight almost match the hypotheses, and the data shows a clearer statistic about the distance between each level. The most interesting finding is that the degree of angles results suggest that sharper angles tend to be seen as the least simple shape and the flat one tend to be seen as simpler shape. The template summarises the results of each level of the elements.

5.6 The problems and limitations of this experiment

A review of simplicity analysis criteria is given in this study. Taken together, this study provides good evidence that rule of simplicity exists which could be helpful for further research - simplification measurement. The initial concept of this study was looking for an appropriate simplicity method to enhance logo recognition ability. The result of this experiment evaluates some possible factors that might be influencing simplicity decision. This result suggests a more systematic method to evaluate the level of simplicity. The paper presents summarised results from 40 observations and has been found agreement with six of the seven simplification hypotheses. Simplicity in shape analysis could be defined as (1) regular form; (2) shapes with closed outline; (3) shapes with pure straight and pure curved form; (4) symmetrical shape; (5) the shape with lighter superficial measurement; (6) angles in the shape over 180° and (7) fewer components. The results of this study indicate that it is feasible to develop a systematic measurement for scoring the degree of simplicity.

The initial recommendation in practical work such as logo design would suggest reference to the seven factors mentioned above in this study to evaluate the recognition risk before finalising design. Further research could focus on more details of shape or contour characteristics and the inside content of shape rather than shape outlines. The understanding of simplicity might be helpful for shape analysis and characteristics that could extend to broader applications such as image analysis. In addition, it plays an important role in object recognition and image-matching techniques. However, this study assumes each of the seven elements are equally important in the measurement which is one of the limitations. The hypotheses and result of this experiment provide the possible factors of simplicity decisions but the proportion of influence of each factor has not yet been found. Further work will consider the relative importance of the elements and should be factored into the template. The result of this experiment aims to provide a reliable and systematic measurement for logo recognition development in different media display; furthermore, it could enhance recognition ability and offer a pre-measurement test before the direction signs and other works are printed.

Chapter 6: Principle of simplicity judgement

6.1 Introduction

In the 20th century, simplicity is defined as the effect certain phenomena have upon the observer, and its meaning may be limited to such subjective reactions — when things are arranged with simplicity so as to represent ideas to people in a way that they can easily imagine, and as a consequence, easily remember them (Arnheim, 1967, p.37). "When a work of art is praised for `having simplicity`, it is understood to organise a wealth of meaning and form in an over-all structure that clearly defines the place and function of every detail in the whole" (Arnheim, 1967, p.38). Following on from Arnheim (1967), the concept of 'simple' shape is the starting point to raise interest in other research areas.

In recent decades the search for significant legibility-improving effects which characterise the major process of visual perception has driven this issue towards simplifying logos/icons. The simplicity phenomenon has been discussed widely in various areas such as psychology (Katz, 1951; Attneave, 1955; Arnheim, 1974; Gombrich, 1982; Chater; 1997; Eysenck; 2001), computing science (Marr, 1982; Biederman, 1987; Maeda, 2006), and visual perception (Ware, 2004). It is not a new issue in most areas; however, most studies have addressed this concept and illustrated this phenomenon without any systematic data to measure it. The term 'simple' still utilises emotion and is subjective and is hard to measure based on a rational principle. Therefore, the purpose of this experiment is planned to determine the characteristics involved in logos and whether there is an invisible agreement in the human judgement of simplicity? The result of this experiment aims to explain how people judge the level of logo simplicity.

6.2 Research methodology

Measurement is a term when people try to use some yardstick by which to determine weight, height, or some other feature of a physical object. It is possible to apply this to both physical objects and abstract concepts. However, measurement is a relatively complex and demanding task, especially when it concerns quantifiable abstract phenomena. To determine the abstract issue – simple or complex, a suitable method for measuring has to be figured out. Technically speaking, measurement can be understood as a process of mapping aspects of a domain onto other aspects of a range according to some rule of correspondence (Kothari, 2004, p.69). Scales of measurement in research can be considered in terms of their mathematical properties of which the most widely used classification of measurement scales are: (a) qualitative scales - nominal and ordinal; (b) quantitative scales - interval and ratio (Kothari, 2004, p.69; Picardi and Masick, 2014, p.15).

Following on from the above, the first step of this measurement scale is to classify the data into one or two categories, categorical or quantifiable. Categorical data cannot be quantified numerically but is used for categorising the name of the image (nominal) and also the initial sequence ranking (ordinal); in addition, quantifiable data can be measured numerically when applying interval data for data calculation (Gray, 2004, p.286). As mentioned above, the purpose of this experiment is to try to determine the principle of simplicity by ranking the sequence, stages and techniques of measurement scales required from nominal, ordinal to interval (shown in Figure 6.1). Ratio scale analysis will be included in the next chapter. This initial data may provide a clearer idea about what a simple shape should look like or what criteria should be involved.

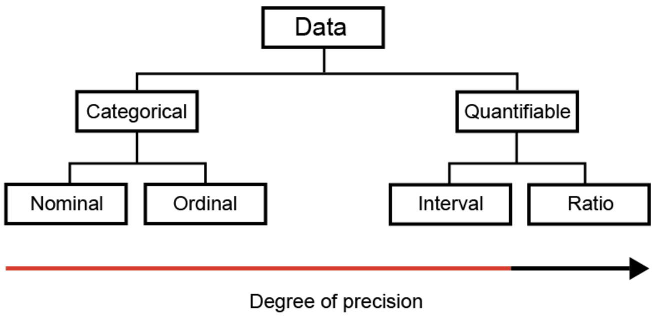


Figure 6.1: Types of categorical and quantifiable data (Gray, 2004, p.286).

Measuring subjective judgement to objective judgement, some previous academic experimenters believed that a successful design was developed based on specific principles. An experiment of visual complexity was run by Snodgrass and Vanderwart in 1980. The aim of their experiment was to test familiarity, visual complexity and image agreement. Their subjects were asked to judge the familiarity of each picture according to how usual or unusual the object was and were told to rate the concept itself. In the visual complexity test, subjects were instructed to rate the complexity of each picture on a 5-point scale in which 1 indicated very simple and 5 indicated very complex. Complexity was defined as the amount of detail or intricacy of line in the sample. In the image agreement test, subjects were asked to judge how closely each picture resembled their mental image of the object. Therefore, their research is a good example to prove a possible research method to test subjective issue judgement.

To achieve this, in the research area, one often faces a measurement problem, especially when the concepts to be measured are complex and abstract and where there is a lack of standardised measurement tools. It is hard to determine a high agreement for abstract (subjective) topics, but at least the tendency. Scaling may enable researchers to measure abstract (subjective) concepts more accurately (Kothari, 2004, p.76), thus justifying the application of scaling techniques in this study. Scaling describes the procedures of assigning numbers to various degrees of opinion, attitude and other concepts through (a) making a judgement about some characteristic of an individual and then placing it directly on a scale that has been defined in terms of these characteristics and (b) constructing questionnaires in such a way that the score of an individual's responses assigns it a place on a scale. Hence, the term 'scaling' is applied to the procedures for attempting to determine quantitative measures of subjective abstract concepts (Kothari, 2004, p.76).

Some bases of scale are broadly classified by Kothari (2004) as (a) response form – classifying the scales as categorical (rating scales) and comparative (ranking scales). Categorical scales are used when a participant scores some object without direct reference to other objects. Comparative scales are used when the participant is asked to compare two or more objects; (b) degree of the subjective – the scale data may be based on whether we measure subjective personal preferences or simply make non-preference judgements; (c) scale properties – classifying the scales as nominal (classifying without indicating order, distance), ordinal (indicating magnitude), interval (indicating both order and distance value) and ratios scales (possessing all features).

Thus, two types of ranking scale methods are presented: (1) method of paired comparison; (2) method of rank order. Firstly, the method of paired comparison is where the participants can express their attitude by making a choice between two objects, but when there are more than two stimuli to judge, the number of judgements required in a paired comparison is given by the formula: $N=\frac{n(n-1)}{2}$, where N = number of judgements and n = number of samples or images to be judged. For instance, as this experiment included 25 images for judging, there are 600 paired comparisons that can be made with them. Secondly, rank order is a method of comparative scaling which asks participants to rank their choices. Obviously, this method is easier and faster than the method of paired comparison. For example, with 25 images it takes 600 pair comparisons to complete the task, whereas the method of rank order simply requires the ranking of 25 images only. However, there may be the problem of respondents becoming careless in assigning rank particularly when there are many (usually more than 10) samples (Kothari, 2004, p.82).

From what has been stated above and previous research method discussion (Chapter 4), it is possible to determine the level of simplicity via quantitative research and scaling techniques. This experiment design is based on ranking scales (method of rank order) and measurement scale to analyse the principle of simplicity.

6.3 Research question

In order to determine an invisible judgement of image simplicity level, the research question was stated as follows: Does the agreement of simplicity judgement exist?

6.4 Experimental design

6.4.1 Participants

Forty students and staff enrolled at the University of Leeds with an age range of between 21 and 62 took part in the experiment.

6.4.2 Images

Following the classification of logo described in Chapter 3, the images selected in this experiment were based on some criteria: (1) abstraction; (2) grey scale; and (3) without brand name. The purpose of these image selection principles was to try to ensure that simplicity judgement was only focused on shape rather than being influenced by colour and font. This setting aims to reduce the variations from various types of logo design. Based on these rules, twenty-five images were selected as shown in Figure 6.2. To achieve this, the samples were referenced from Hyland and Bateman's (2011) which also classified logos into several types. The conditions of the sample selection were based on (1) abstraction; (2) no texts, and (3) no colours. This selection rule is aimed at narrowing the variation into 'shape' as the only judgement criterion, rather than concern with other characteristics.

Figure 6.2: Samples (Hyland and Bateman, 2011).

6.4.3 Experiment procedure

This experiment was presented in PowerPoint mode. Participants were asked to rank 25 images according to their simplicity levels. An example page was shown to explain the process in advance (Figure 6.3). 25 numbered boxes were shown in the PowerPoint slide, and 25 images were placed in the right hand side red box randomly. Participants were asked to drag these 25 images into the numbered boxes following the sequence from simple to complex. The image in box number 1 should be the simplest and box number 25 should contain the most complicated image.

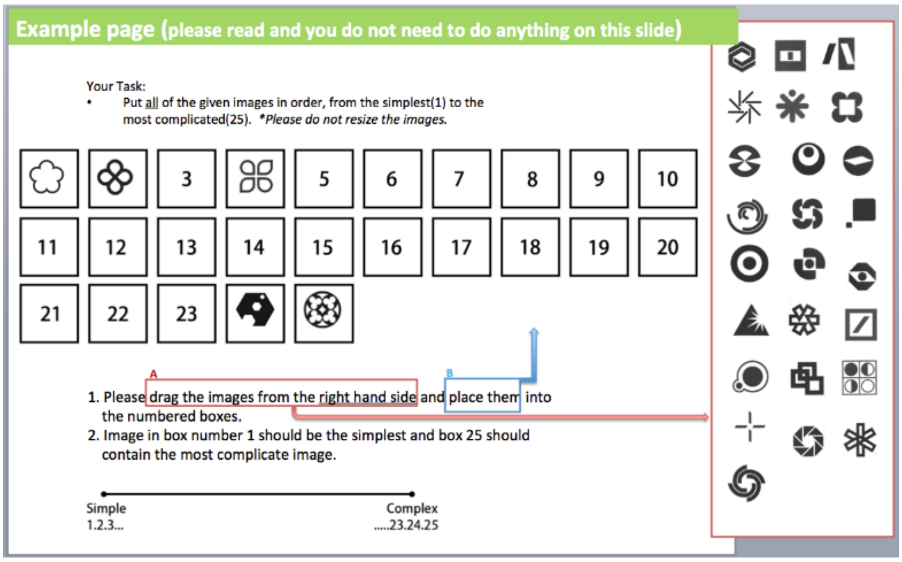


Figure 6.3: Example sheet.

Following on from the example page, the next slide is the answer sheet. Figure 6.4 shows an example of the images presented to the participants. In this experiment, participants were asked to put all of the given images in order, from simplest (box numbered 1) to the most complex (box numbered 25). As mentioned in the instructions, in order to ensure all the image conditions were the same, images were not allowed to be resized or zoomed in. This task was presented and done in normal view setting mode rather than slide show mode. Figure 6.5 shows the example of one of the participant's results. There was no time limit for this experiment; generally, participants took 20-30 minutes to complete this task.

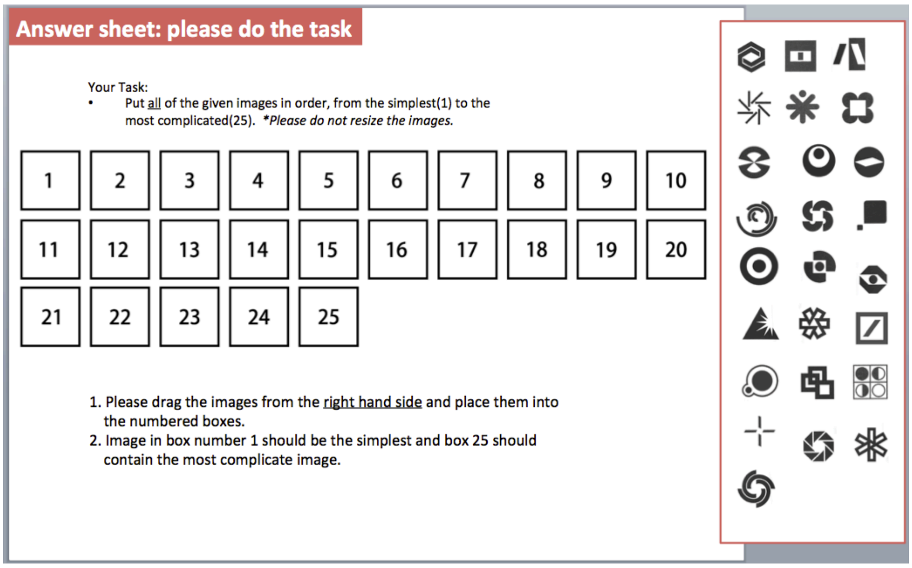


Figure 6.4: Task sheet.

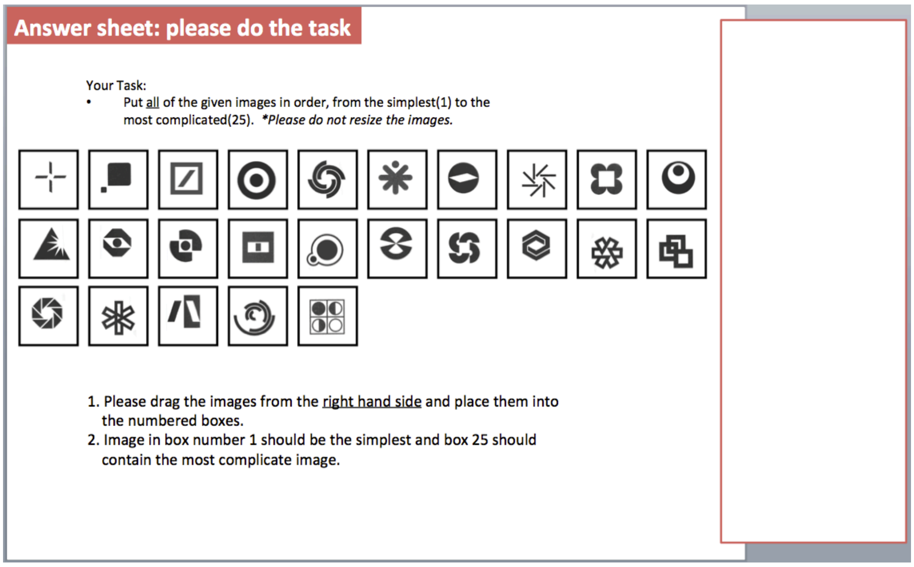


Figure 6.5: Answer sheet.

6.5 Statistical analysis

Participants' results were converted to numeric scores for simplicity ranking comparison. To generate participants' results to numerical data, a classic 'levels' of measurement process addressed by Stevens (1946) suggested four 'levels' of measurement phases as follows: (1) nominal – refers to a set of categories used for classification purposes; (2) ordinal – refers to a set of categories where they can be ordered in some meaningful way; (3) interval – refers to a set of categories which are not only ordered but also have equal intervals on some measurement scale; (4) ratio – similar to interval level but with a real or true zero. As mentioned in the previous section, data analysis in this experiment was applied with nominal, ordinal and interval for answering the research question: Does the agreement of simplicity judgement exist? Following on from the measurement scales, first of all, according to the nominal, 25 images were named alphabetically from Sample A (SA) to Sample Y (SY) as shown in the following:

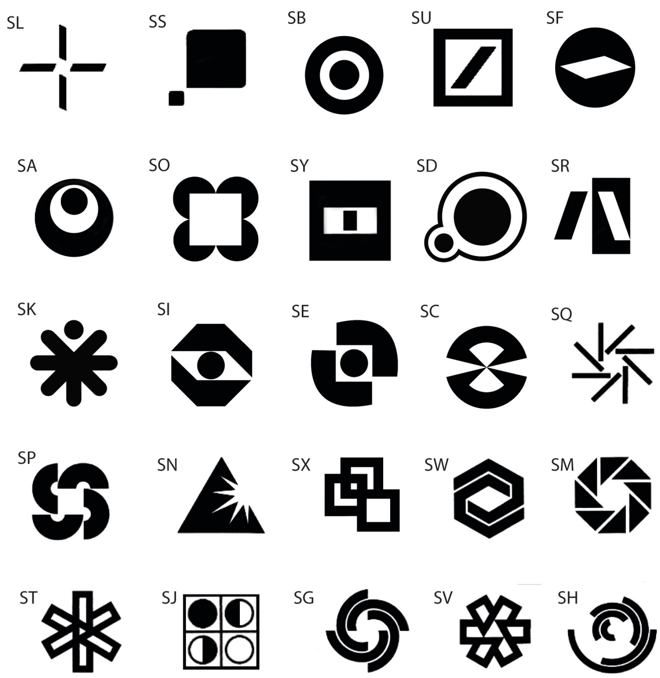


Figure 6.6: Naming samples.

Secondly, the step of ordinal was applied to convert visual data into statistical data. The mean score of each image determined its sequence in this simplicity ranking experiment. The scattergram in Figure 6.7 represents the mean score from lowest to highest. The average of each image was ranked, with the lowest score by participants meaning it tended to be simple, and the image with highest mean score representing the tendency towards complexity. The score was standardised between 0.00 and 1.00, with the mean score 0.00 representing the simplest and 1.00 representing the most complex.

Thirdly, the step of interval scale was applied to place the order in sequence from the simplest to the most complex based on the mean scores calculated in the ordinal scale. According to the result, Sample L (SL) is the simplest image, ranking as 0.08, and Sample H (SH) is the most complex, ranking as 0.93 among 40 participants' ranking average. Figure 6.7 shows the ranking scores of each sample and also the sequence of simplicity is placed according to the score of simplicity from lowest (simple) to highest (complex).

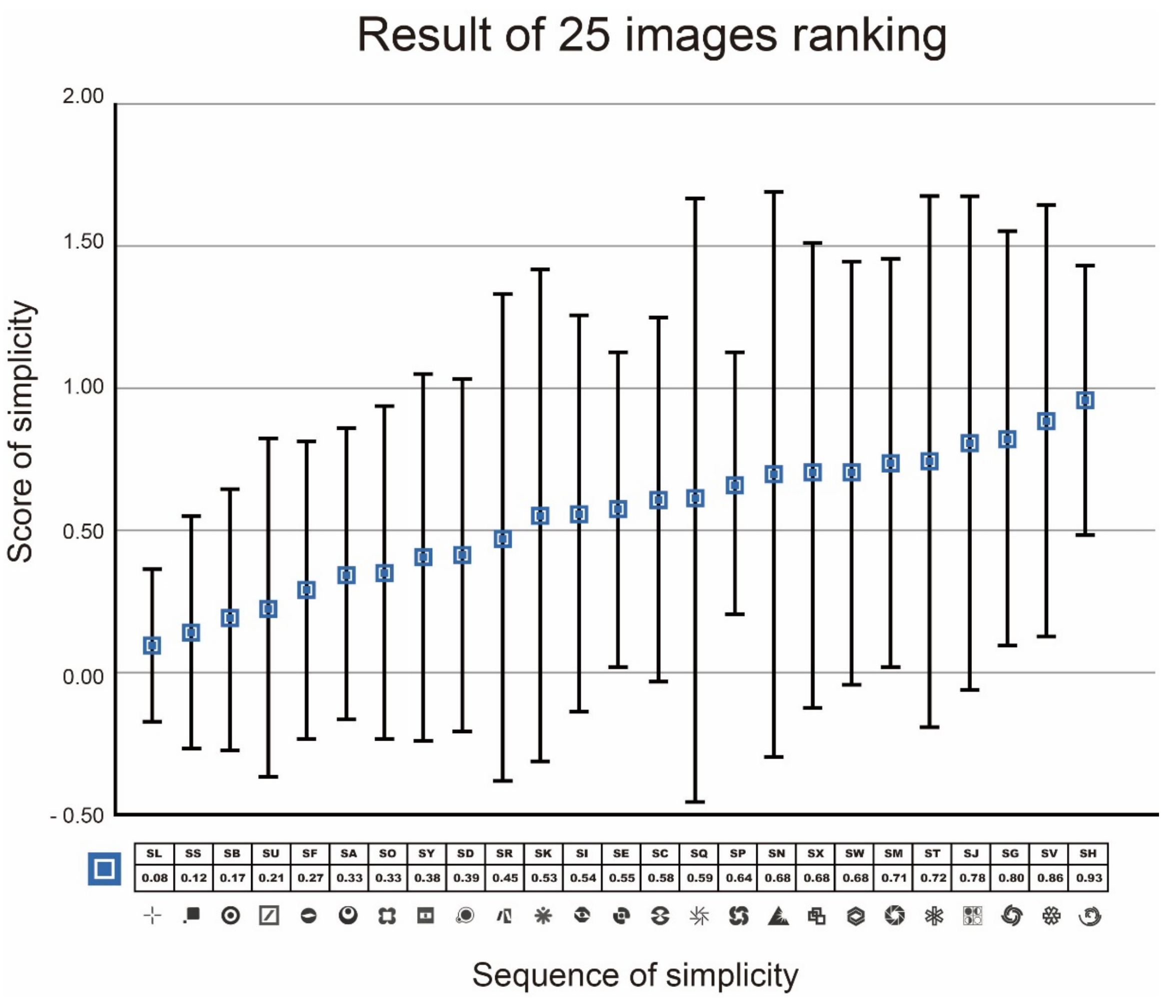


Figure 6.7: Scattergram of experiment result.

On the other hand, the standard error bar is the representation of the variability of data and indicates the range of uncertainty. It was calculated by dividing the standard deviation by the number of measurements (N=40). Therefore, the standard error of Sample L (SL) is 0.27 with the shortest bar shown in Figure 6.7 indicating that the agreement of SL sequence is the highest with least doubt. However, following from this standard error graph, the agreement of image sequence shows that following on from the increasing complexity, the variations are more uncertain. The score of standard error increases gradually especially in the middle range part of this experiment. This problem might be caused by the characteristics of those images being not distinctive enough for participants to make a judgement.

Analysing the characteristics of each sample, they can be categorised into seven criteria (form, open-closed, straight-curved, symmetry, weight, angles and components) for comparing the results in the previous experiment (Chapter 4). According to the top five simplest samples ranked by participants, it can be shown that they tended to judge 'simple' based on geometric outlines (such as circle and square). First of all, Sample SL was commonly judged as consisting of four lines which gave a light-weight impression placing it in the simplest sequence. Sample SS was easily judged as a two squares logo. Sample SB has the simplest outline in the form criterion section and has perfect symmetry. Sample SU also has a simple outline (square) which placed it fourth. Sample SF has a simple circle outline but not perfect symmetry compared to Sample SB as shown in Figure 6.8.

Figure 6.8: Top 5 simple samples.

Furthermore, the top 5 complex samples which achieved the highest score in this experiment were Samples ST, SJ, SG, SV, SH respectively. With the exception that Sample SJ is asymmetrical, Samples ST, SJ, SG were commonly shown to be rotation images with all participants. All of these samples include up to four components, more than four angles and have either medium or heavy weight. This characteristic indicates that even though rotation is one type of symmetry, asymmetry and rotation are much more complicated for people compared to pure symmetry and reflection. In addition, the component can be understood and translated as having too many details as shown in Figure 6.9.

Figure 6.9: Top 5 complex samples.

The scores of simplicity ranking are very explicit to indicate the difference between simplest and most complex. However, samples that were ranked in the medium place were a bit vague as shown in both the standard error bar in Figure 6.7 and Figure 6.10 below. Samples SA and SO were ranked in exactly the same place with both being 0.33; in addition, Samples SY and SD got 0.38 and 0.39 which only indicated a slight difference being almost insignificant. Sample SR is the only one ranking in between the 0.40-0.50 area; scores in the second row from Sample SK to Sample SQ are all located between 0.53-0.59 which is hard to distinguish the simplicity level. Samples in the third row also started from 0.64 to 0.71 with just 0.8 points difference for these five sample simplicity scores.

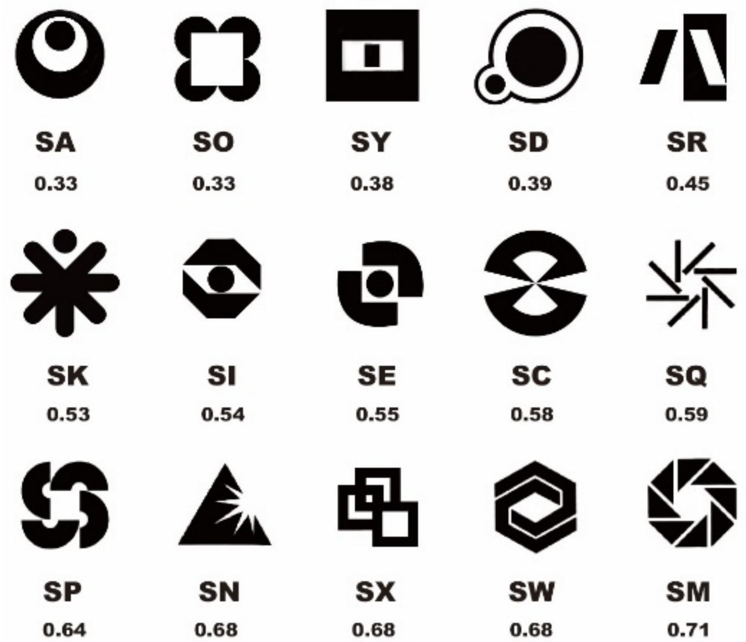


Figure 6.10: Medium place samples.

6.6 The problems and limitations of this experiment

The experiment results illustrate an initial idea about what characteristics might influence simplicity judgement and also the valuable ranking scores for further experiments. However, some limitations and problems can be considered and adjusted for future work.

In the sample selection, following on from the suggestion in the research methodology, there may be the problem of participants becoming careless in assigning rank particularly when there are many more than 10 samples. There is a bit of risk in this experiment which involves 25 samples. As shown in the statistical analysis section, the standard error bar becomes larger from samples ranked in 6th to 20th places and the range of scores gets closer in the medium placed samples. This phenomenon indicates that participants might be careless within larger data comparison. Further experiment designs have to avoid using too many samples for comparison at once.

Another possibility of leading standard error is participant sample recognition. Some participants evaluated Sample SL as consisting of four lines but some thought that it was four rectangles. This dissimilitude possibly influenced the judgement of sample weight or number of angles. The same problem is also shown in Sample SS where some participants saw it as a two square sample; however, they are squares with only one right angle but three others are curved. Therefore, the same sample might produce different judgements depending on how people think and also their awareness. Further experiments should consider the size of sample display carefully. Overall, following on from this experiment, the answer as to whether the agreement of simplicity judgement exists or not has partly been discovered. The result of this experiment provides an initial idea about how people judge samples simple or complex, and also the possible criteria which influence people's judgement. The sequence of these samples will be the initial 'principle' for further experiments. The calculation of simplicity scores in further work might reference the results of the previous experiment (Chapter 5) and this experiment.

Chapter 7: Simplicity criteria comparison

7.1 Introduction

The terminology `simple` is often considered an artistic behaviour or personal subjective judgement that is difficult to analyse rationally. Many previous studies such as Gestalt psychology, geometric and aesthetic research addressed the idea of `simple` in brief and more like a phenomenon. However, with the development of research tools, it has become more feasible to examine the perception of `simple` by quantitative research methods.

Following from the results of Experiment 1 and Experiment 2, this experiment aims to determine the appropriate measurement of logo legibility on the mobile screen. For this, in accordance with previous experiments which conclude that some criteria might influence simplicity judgement, this experiment aims to identify which criteria play the most important roles and at what level, based on observers' matching. Generally speaking, Experiment 1 gave a brief 'simple' definition of each criterion; for instance, in form, the circle, triangle and square gave people a more simple 'image'. It presented a clear definition of what `simple` was individually. In addition, Experiment 2 had a further test which mixed all criteria at the same time and asked participants to rank the level of simplicity.

Therefore, Experiment 3 is going to compare the simplicity criteria in both individual and mixed conditions. The purpose of this experiment tries to determine the gap between individual and mixed judgement criteria. All the scores applied in this experiment are referenced from Experiment 1 and Experiment 2.

7.2 Research methodology review

Many previous studies evaluated graphic simplification in both qualitative and quantitative research methodologies. To approach this experiment design, three aspects of research methodology are going to be discussed in the following paragraphs. Firstly, in order to determine the perception of simplicity, image matching is a common method to generate a subjective issue. Gathering a larger database of subjective results and transfer into objective analysis has commonly been used in the psychology area. Secondly, the research method of types of simplicity analysis is also essential. Thirdly, the quantitative research calculation method in this experiment will be the core of simplicity definition in this study. Some relevant research methodologies are going to be discussed in this section.

First of all, a method addressed by Clark and Knoll (1969, p.221) applied a matching experiment for a shape association test — the value shape association (percentage of Ss making an associate to a shape) is a strong determining factor in shape recognition research. In their experiment, the physical characteristics of shapes of high and low association value were compared. This experiment uses the same concept of the image-matching task to gather a database of general simplification judgements.

Next, another relevant research methodology was referenced in Wang and Hsu's (2007) experiment. The interval graphic simplification method stated in their research was divided into three phases: (1) the singularisation and operability of simplification of external visual perception; (2) interval measurement and (3) clear rules of operation for graphic simplification. Their study focused on how many types of simplification can be generated, namely grid simplification method, node reduction method (Attneave, 1954), geon/component reduction method (Biederman, 1987) and blur method. If assuming types of simplification methods as the horizontal axis, this experiment is the vertical axis to determine the simplicity measurement. The three phases of the simplification type research method was referenced as the logic of characteristic analysis of simplicity criteria.

Furthermore, statistical analysis in this experiment is based on level measurement that describes the nature of information within the numbers with variable elements. The best-known classification of level measurement has four scales: nominal, ordinal, interval and ratio. The purpose of these four scales aims to report quantitative estimates of sensory events which deal with (a) the various rules for assignment of numerals, (b) the mathematical properties of the resulting scales, and (c) the statistical operations applicable to measurements made with each type of scale (Stevens, 1946). Nominal scale represents the unrestricted assignment of numerals;

in brief, the numerals or type of numbers or words are used only as labels. The numbers or words of the subjects do not have numerical value or relationship. Secondly, the ordinal scale arises from the operation of ranking purpose. The method of ordinal scale allows for order ranking in which data can be sorted; however, this stage was analysed by each individual sample result rather than by comparison. Thirdly, after the nominal and ordinal scales process, the score of each subject was illustrated. The interval scale is the method of determining the distance between each subject; for example, 10 points and 20 points represents the same level gap as 80 points and 90 points. Fourthly, the ratio scale represents the percentage result within subject comparison. This method could represent the ratio of simplicity criteria influence.

Overall, the above three research methods are going to be referenced in this experiment. The experiment design applied an image-matching task to gather the simplicity judgement database. Simplicity criteria were categorised into ten levels in each section to score the sample. In the last step, statistical analysis was based on the theory of scales of measurement to build up a systematic simplicity measurement guideline.

7.3 Objective and hypothesis

This experiment aims to determine a systematic scoring method for simplicity measurement. Therefore, the goal of this result is to match the result of Experiment 2 which is the aim of this chapter. The hypothesis is stated as follows: The result of Experiment 3 (calculation template) has the same order as Experiment 2 (aim).

7.4 Experimental Design

7.4.1 Participants

Twenty students enrolled at the University of Leeds (10 with a design background and 10 without a design background) with an age range of between 20 and 30 took part in the experiment. Each observer carried out the experiment twice and, therefore, the total number of observation results was 40.

When repeating the experiment, the question order in the second round will be swapped randomly and the observers will be requested to complete it on the next day. This arrangement is to avoid (1) fluctuating data, and examining (2) reliability. This experiment aims to examine the 'simplicity criteria' matching for each graphic; thus the key point is to confirm that the observer`s selection is rational and has potential principles behind the results; thus, the ability of 'memory' is not considered as a variation in this experiment.

7.4.2 Images

Twenty-five samples as shown in Figure 7.1, each containing seven criteria (form, open-closed, straight-curved, symmetry, weight, degree of angle and number of components), were used. As mentioned in Chapter 6, the rules of sample selection are to abstract a logo with greyscale which means descriptive and text logos are not taken into consideration. These 25 samples are based on Hyland and Bateman's (2011) logo categories.

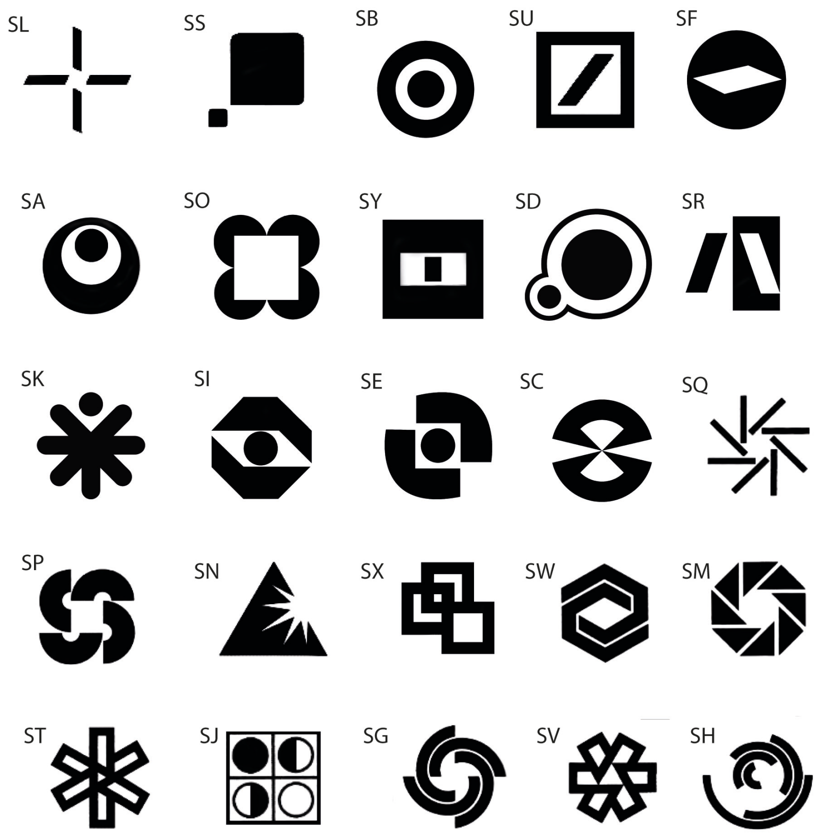


Figure 7.1: Images of 25 samples.

7.4.3 Experimental Procedure

Two tasks were included in this experiment. The first task was to test the result of Experiment 2 which accorded with the result of Experiment 1. The second task aimed to understand the level of simplicity judgement by criteria comparison. In the first task, participants were presented with twenty-five sets of images in turn. Each set of images contained diagrams with seven criteria (form, open-closed, straight-curved, symmetry, weight, number of angles and number of components) in the template. Figure 7.2 (left) shows an example of the images presented to the participants. Images were placed at the bottom left corner of the screen and the images were placed at the red box with a random sequence. The instructions for participants were given as below; for each image set, they were asked to complete the following tasks:

* Please highlight one of the options in each criterion that matches the sample presented on the top right-hand side.

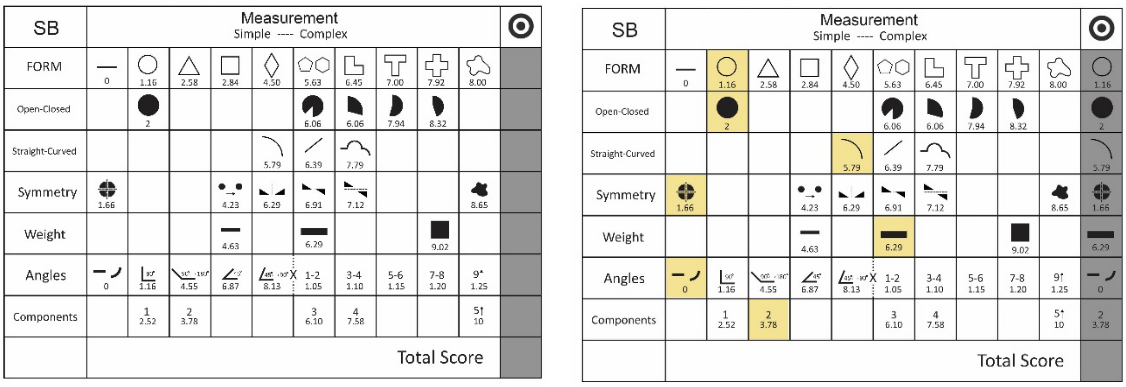


Figure 7.2: Example of experiment question sheet (left), example of experiment answer sheet (right).

The participants were asked to complete the tasks, following the same instructions for all the twenty-five sets of images. Figure 6.2 (right) shows an example of the participants' results. The participant highlights the options in each criterion (form, open-closed, symmetry, weight, angles and components) that are similar to the sample given on the top right-hand side blank. In the second task, participants were asked to rank simplicity criteria from the most influential to the least in their opinion. There was no time limit for this experiment; generally, participants took 15-35 minutes to complete this task.

7.5 Statistical analysis

Participants' results were converted to numeric scores. The process of measuring was referenced from Steven's theory of scales of measurement that categorised the four measurement processes as nominal, ordinal, interval and ratio scales. The majority of scores were computed and results presented. In each set, the selection of the options was recorded. Tables 1a-1y (in appendix) show the majority of selections for the simplification task. The results show the majority selection highlighted by observers in each section. Four steps divided this calculation method as indicated in the following paragraph. After data collection, each sample was listed in alphabetical order from SA to SY. In order to explain the calculation process, this section uses sample SL as an example. As shown in Figure 7.3, participants highlighted the options in each criteria section to indicate which one matched the sample image on the upper right. The nominal step differentiates between samples based on their names. It may be used to represent the variables but does not represent numerical value or relationship in this step.

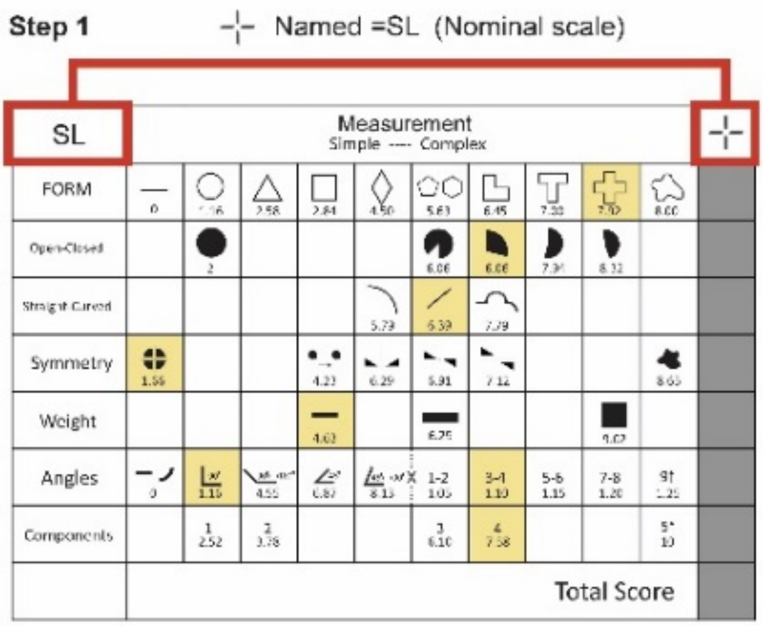


Figure 7.3: Statistical analysis step 1.

The second measurement step is to convert visual data into statistical data (Figure 7.4). The cell highlighted with red represents the highest number of participant selection in each category. This ordinal step allows for rank order by which data can be sorted, but cannot represent the relative degree of difference between them. This step aims to determine which option formed the majority of participant selection.

Take sample SL form criterion for example: selected by participants 23 times in level nine simplicity judgement.

Step 2 (Ordinal scale)

Total										
SL	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	15	0	0	2	0	0	0	0	23	0
OPEN-CLOSED	0	8	0	0	0	7	13	1	11	0
STRAIGHT-CURVED	0	0	0	0	2	38	0	0	0	0
SYMMETRY	34	0	0	1	2	1	2	0	0	0
WEIGHT	0	0	0	38	0	2	0	0	0	0
DEGREE/NUMBER OF ANGLES	6	31	2	1	1	2	30	0	1	0
COMPONENTS	0	5	3	0	0	0	32	0	0	0

Figure 7.4: Statistical analysis step 2.

Thirdly, once the calculation in each sample was completed, interval scale provided information about order (Figure 7.5). The sum of each sample calculation shows the distance between scores 1 and 2 was the same as that between 5 and 6 on our 70-point rating scale. On the right side grey bar, the summary of each selection represents the simplicity level of the sample. In detail, Sample SL got 7.92 simplicity score in the form section, 6.06 simplicity score in the open-closed section, 6.39 simplicity score in the straight-curved section, 1.66 in the symmetry section, 4.63 simplicity score in the weight section, 1.16 multiplied by 1.10 (degree of angles multiplied by number of angles) which got 1.28 simplicity score in the angle section and 7.58 simplicity score in the components section. The summary of each simplicity score indicates the simplicity level of sample. In this step, an initial simplicity ranking and the distance between each sample can be presented.

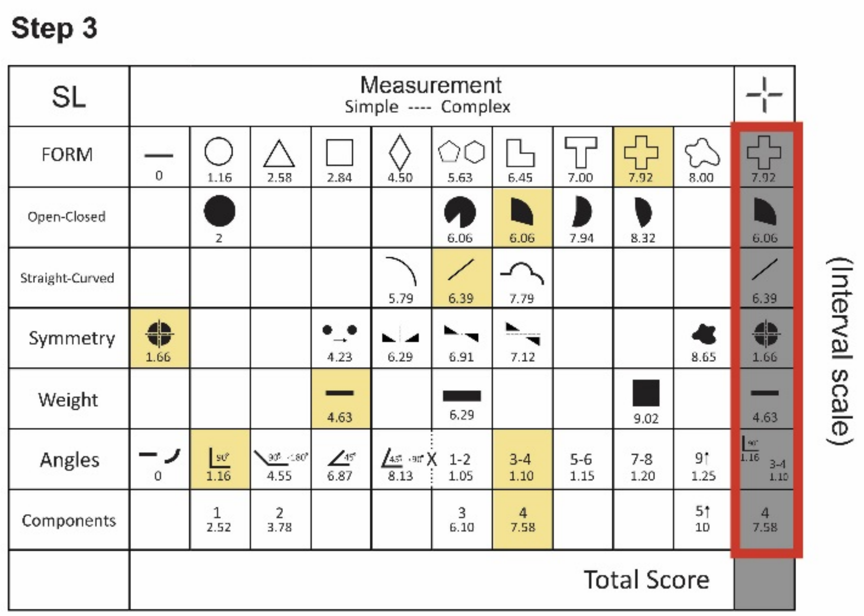


Figure 7.5: Statistical analysis step 3.

Based on interval scale, the ranking results of each sample are shown in Figure 7.6. In this step, the first task of calculation results shows the selection by participants (total score 70 without importance level multiplied) as follows.

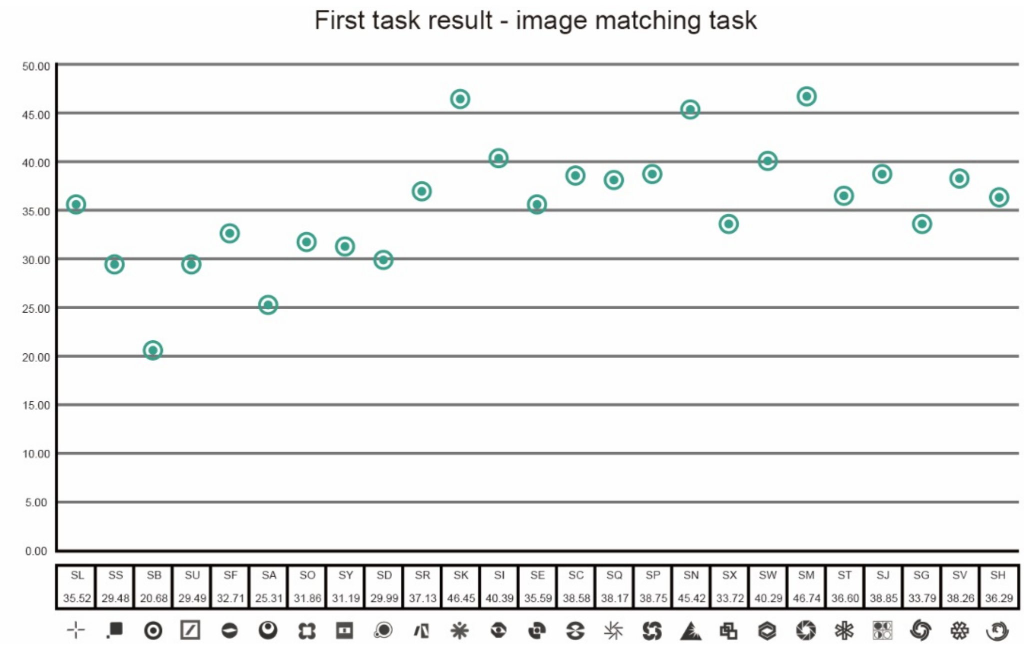


Figure 7.6: First task result.

However, the proportion of simplicity judgement in each criterion up to the third step has not been involved yet. So far, we assume that each simplicity criterion has an equal level of influence. However, according to the second task result which ranks the importance of simplicity judgement criteria by participants from a score of 7 to 1 (most to least importance), it obviously shows an agreement trend. The criterion form got an average 5.50 overall, open-closed got 3.25, straight-curved got 3.60, symmetry got 5.30, weight got 2.50, degree and number of angles got 3.00 with 4.85 in components (shown in Figure 7.7).

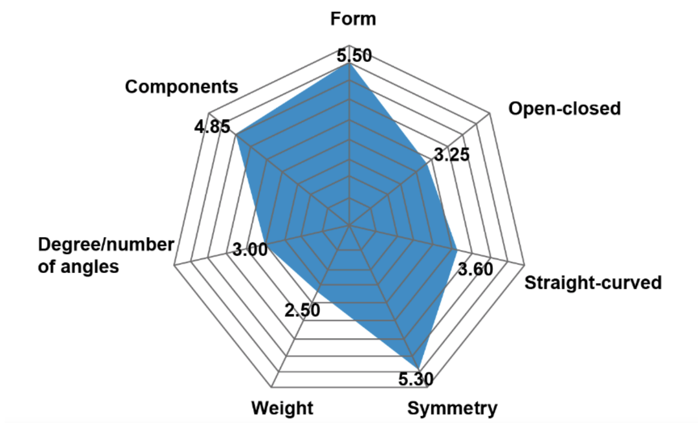


Figure 7.7: Second task result.

The last step in the calculation is to multiply the result of the first task (options in each criterion) and second task (ranking of each criterion). In the fourth step, the most important calculation is statistical adjustment. Take Sample SL for example: after the highest selection agreement in each criterion, the scores based on the first task would be multiplied with the average score from the second task. In the form section, the majority of participants selected the X-shape (which scored 7.92) multiplied by the importance of simplicity criteria judgement (average 5.50 times in form criteria); therefore, the final score of Sample SL criterion form is 43.96. The sum of all scores in each criterion after ratio scale adjustment is the final score of the sample. For instance, the final score calculation of Sample SL is 147.62 (process shown in Figure 7.8).

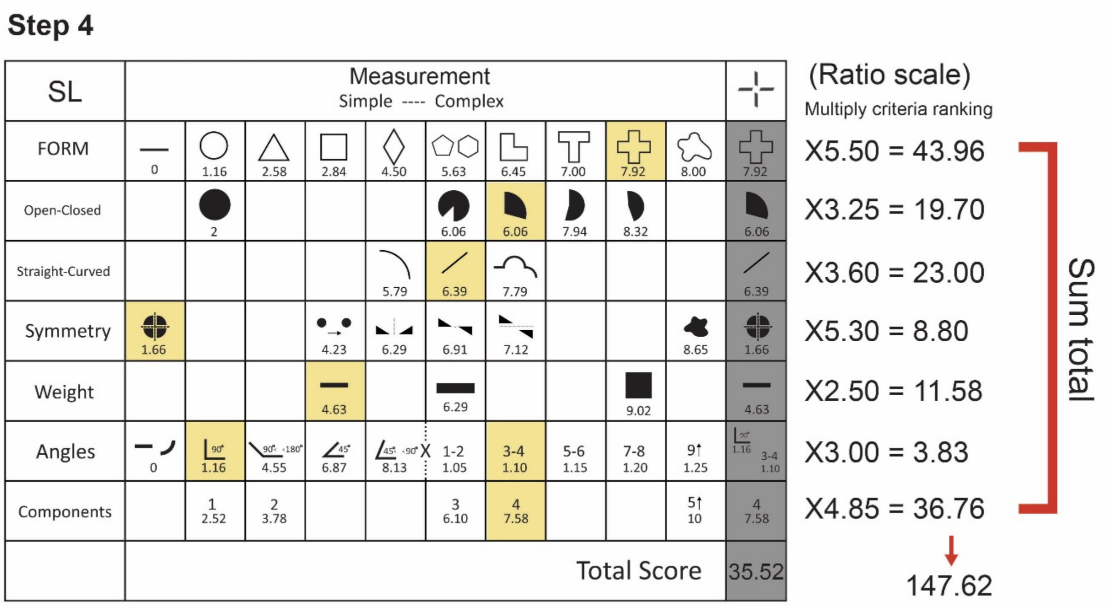


Figure 7.8: Statistical analysis step 4.

Using the calculation above, the final scores of each sample are shown as follows (Figure 7.9). This result combines the summary data analysis of Experiment 1, Experiment 2 and Experiment 3. All the numbers are referenced from previous calculation and ranking sequence. The sample orders from SL to SH are revealed in Figure 6.9. Figure 6.9 based on the sample ranking order of the Experiment 2 result. However, according to the hypothesis, the trend of the results did not seem to grow up as smoothly as the same sequence as in Experiment 2.

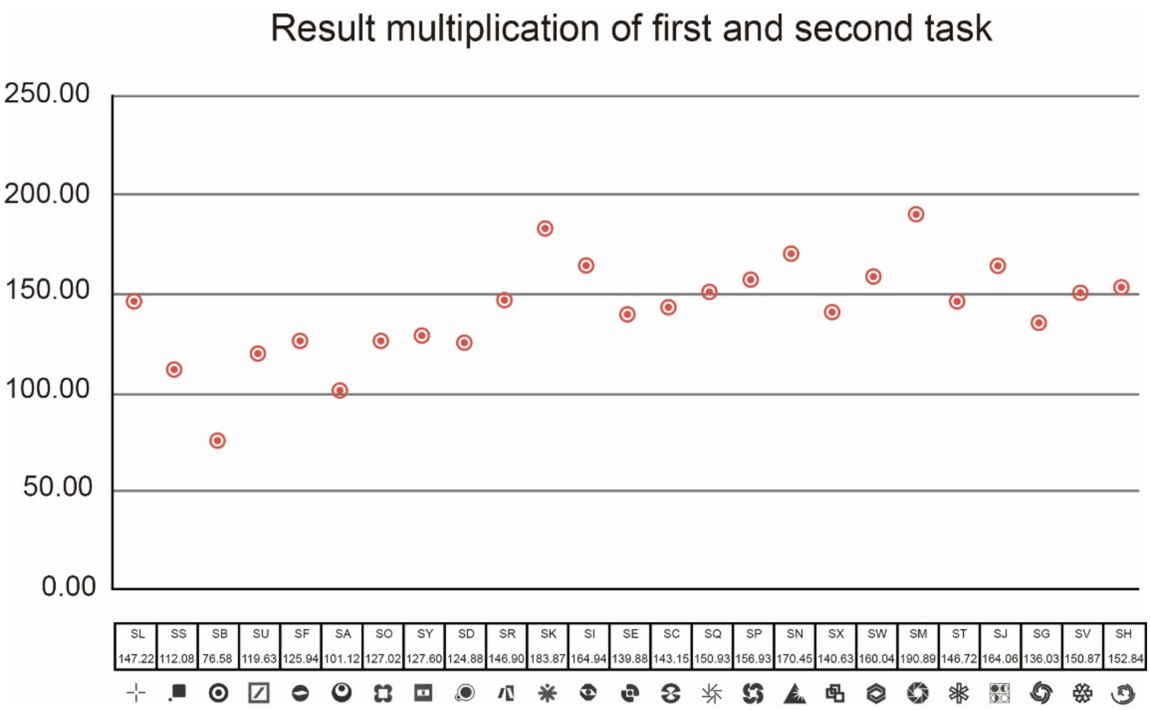


Figure 7.9: Result of Experiment 3.

Grouping five samples as a set for comparison, the top 5 simple samples and top 5 complex samples are taken for explanation (shown in Figure 7.10). In the simple set, three out of five samples have simplicity agreement. Samples SS, SB and SU highly tallied with the expectation in both Experiment 2 ranking and Experiment 3 calculation scores — an interesting finding in this result which indicates the importance of outline form. Samples SS, SB and SU were all identified as having geometric outlines (circle and square). This result also matches the result of the simplicity criteria ranking which indicates that form is the most influential criterion of all.

However, once samples become more complex, the results agree less. In the top 5 complex samples comparison, only one sample has the agreement of complexity judgement. Sample SJ was identified as a complex sample in both experiments. According to this, once the sample has greater complex criteria to influence the judgement, the variation increases as well. Therefore, to predict a simple sample is easier compared to predicting a complex sample. The square in blue represents the ranking of Experiment 2. The circle in red represents the ranking of Experiment 3.

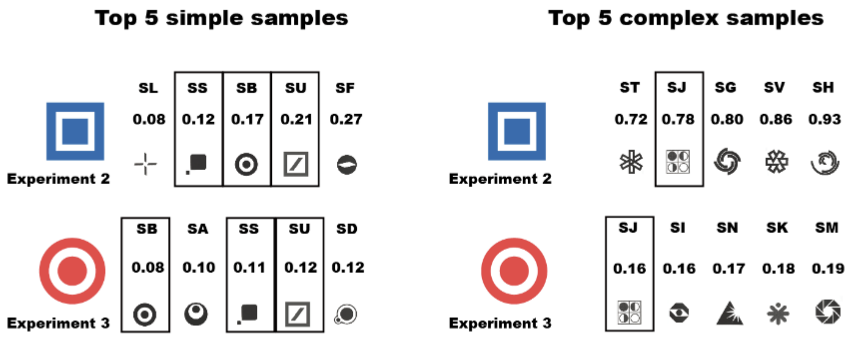
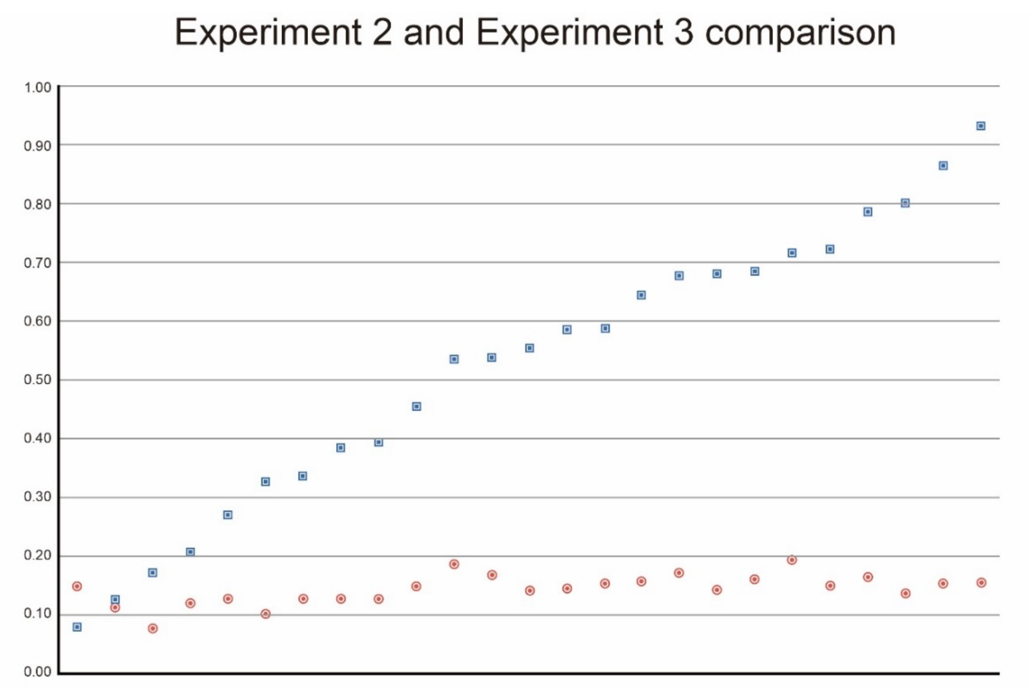


Figure 7.10: Comparison of simple and complex.

Figure 7.11 represents the relationship between the ranking results of Experiment 2 and the calculation score of Experiment 3. It shows the comparison between the visualisation results of Experiment 2 and Experiment 3. The vertical axis shows the level of simplicity scores. The horizontal axis shows the sequence of sample (sequence based on Experiment 2). The square in blue represents the sample scores of Experiment 2 average ranking. The circle in red represents the samples scores of Experiment 3 calculation. In order to compare both experiment results, the scores were standardised into a range between 0.00 - 1.00.



	SL	SS	SB	SU	SF	SA	SO	SY	SD	SR	SK	SI	SE	SC	SQ	SP	SN	SX	SW	SM	ST	SJ	SG	SV	SH
Experiment 2	0.08	0.12	0.17	0.21	0.27	0.33	0.33	0.38	0.39	0.45	0.53	0.54	0.55	0.58	0.59	0.64	0.68	0.68	0.68	0.71	0.72	0.78	0.80	0.86	0.93
Experiment 3	0.15	0.11	0.08	0.12	0.13	0.10	0.13	0.13	0.12	0.15	0.18	0.16	0.14	0.14	0.15	0.16	0.17	0.14	0.16	0.19	0.15	0.16	0.14	0.15	0.15

Figure 7.11: Comparison of hypothesis (Experiment 3) and aim (Experiment 2).

The representation of Figure 7.11 clearly depicts the trend of simplicity ranking. As mentioned in the previous section, the result of Experiment 2 was mainly to show the simplicity agreement by the average of people's ranking sequence. Therefore, the result of Experiment 2 can be assumed to be the aim target of this study. Thus, this study expects that the trend of Experiment 3 (hypothesis) is able to match Experiment 2 (aim). However, even though the scores of Experiment 3 increased as expected, the trend of growth still did not increase steadily as in Experiment 2 (Figure 7.12). This means the hypothesis did not tally properly with the aim.

To determine how well the hypothesis fits the aim, R-squared statistic can depict it clearly. R-squared is a statistical measure of the closeness of the data (hypothesis) to the fitted regression line (aim) which is always represented between 0 (0%) and 1 (100%). In general, the higher the R-squared presents, the better the model (hypothesis) fits the aim. The regression model in this experiment presents 0.4239 of the variance (shown in Figure 7.12).

In some fields, R-squared can be an entirely good fit, such as the science area; on the other hand, it commonly reveals a lower R-squared in some fields such as psychology. Any fields that attempt to predict human behaviour and emotions typically have a lower than 0.5 R-squared value. It is not surprising that human behaviour sometimes is unpredictable.

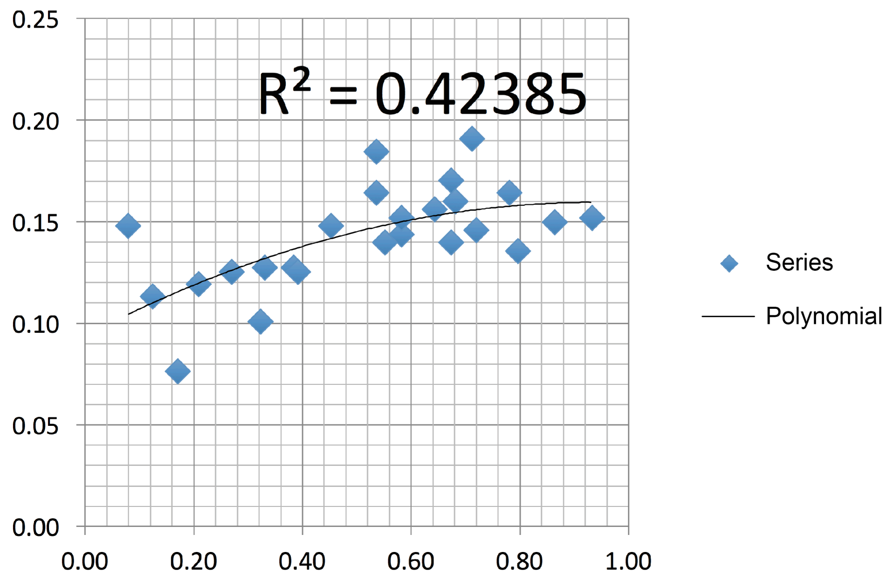


Figure 7.12: R-squared.

In overview, from the results of the analysis of Experiment 2 and Experiment 3, this study derives some simplicity judgement when participants generate both tasks. Although the calculation of this experiment has not been solved completely, the way of simplicity judgement, the method of calculation and the consideration of each criterion are all valuable data for further experiment design. The result of this experiment interprets a systematic calculation template of simplicity judgement. It provides an objective method to evaluate the term 'simplicity'. The analysis result of this experiment concludes a fundamental method of simplicity measurement that is going to apply in larger amounts of data.

7.6 The problems and limitations of this experiment

The data could be interpreted as a tentative measurement method of simplicity. Even though a fundamental database has been built up based on this experiment, there is still room for improvement. According to the R-squared result, this study needs to ensure that the explanation of the first task (image matching) has been well understood by participants and reflects the answers as expected. The instruction of the first task is to highlight one of the options in each criterion that matches the sample presented on the top right-hand side. However, one common problem in form matching is that the considerations of participants are sometimes different. When participants judge which options match the providing sample, some considered the outline of the shape, but some judged the whole sample in its totality. Another limitation in this task is that the options are single choice, even when some samples comprised many complicated elements. This might have caused difficulty in participant judgement.

The limitations of this experiment include the calculation process. According to the second step in the calculation, the final options determination was selected by the majority of participants. Take sample SL the form criterion for example: even though 23 participants selected level nine, 15 participants selected level one. Due to the rule of majority representation, the selections of these 15 are removed from consideration. Therefore, some valuable data was ignored even though it was only slightly lower than the highest selections. These ambiguous problems mentioned above might lead to low agreement in this experiment.

Chapter 8: Application of simplicity guidelines

8.1 Introduction

Designers always start their creative work after receiving the task requirements such as the given object, name or idea symbol. The design process progresses from requirement, observation, ideation, design development, prototyping up to the final solution. However, the important step between design development and prototyping hasn't yet been explored. This is the legibility test — a systematic measurement for legibility improvement via simplification guidelines. Graphic designers need to develop the ability to create visual work to support limited size of devices. According to previous research, simplicity is core to helping the achievement of legible output and production. Therefore, a systematic research method for understanding the design process is essential.

The overall study aim is to understand this from two perspectives: (1) simplification usage from the designer's point of view and (2) legibility from the user's point of view. Therefore, this chapter is going to summarise previous research results and build a clear simplification guidelines for designers to test applicability. The graphic designers who participated in Schenk's (1991) experiment were asked to describe their use of drawing during the procedures of (1) accepting and passing on briefing, (2) collecting reference material, (3) the analysis of a design problem and (4) the development of first ideas, the synthesis and development of design solutions, and the final step in preparation for production. Therefore, the graphic design process can be made up of a series of phases determined by Schenk (1991, p.180) which were categorised into the following: a) Preparation phase – accepting and passing briefing, collecting reference material; b) Main creative phase – analysis/first idea, synthesis/development, presentation/evaluation/revision; c) Production phase – commissioning artwork and preparing for production. This chapter aims to use drawing as the experiment method to examine the main creative phase from the point of view of the designer.

According to the aim and design process, the target participants of the simplification guidelines will be designers. This experiment is going to apply the qualitative research method to answer and evaluate applicability. This chapter is going to review some previous research methodologies which applied design work analysis and reference to a simplification guidelines experiment.

8.2 Research methodology review

Design has been discussed widely, especially design process analysis (Won, 2001, p.319). Design process analysis is divided into four phases: analysis, concept generation, preliminary design and detail design (Won, 2001, p.319). While there has been some methodological research about this area such as visual perception (Vernon, 1970), visual thinking (Won, 2001), creativity (Stones, 2007) and brainstorming method (Osborn, 1963 cited in Won, 2001), many researchers have proposed the importance of sketching or drawing at concept generation. In the design research area, many previous studies have used analysis artefacts as part of the qualitative research method. However, preliminary design thinking can be supported well by sketching (Stones, 2007, p.60) which is also the fastest and most effective way to visualise the thinking of designers (Won, 2001, p.319). Some previous research methods for testing design creativity had applied sketching as analysis material (Stones, 2007, p.60). Researchers often elicit information about cognitive design processes by logging the process of designing via protocol analysis or interviews and questionnaires rather than by analysing characteristics of the designs themselves (Schenk, 1991 cited in Stones, 2007, p.60). At this point, as a research method, drawing is no longer used solely as a quick notation of ideas but also for combining and modifying visual elements, and for exploring subtle variations in composition and form (Schenk, 1991, p.173). The use of drawing is commonly shown in the graphic design process especially in the creative phase stage. By focusing on an exploration of the role of drawing in the work of the graphic designer, it has been possible to examine the role of drawing as an intrinsic element in the development of the creative process (Schenk, 1991, p.180) and also to examine the process of logo modification under different disciplines.

Reviewing previous research methodologies, this experiment comprises three parts. In part one, a hypothesis is suggested; while designers generate concepts randomly before applying the simplification guidelines, the result of logo drafts will be more complex and less legible. In part two, designers were given two pages of simplification guidelines. Designers were asked to modify one of their logo drafts by referencing the simplification guidelines. The purpose of the first step was to learn how designers conducted the original logo drafts, the drawing of which were without any rules or limitations in a traditional way. Likewise, designers were asked to modify one of their own drafts but using the simplification guidelines as reference. The purpose of the second step was to use the same work, but with some rules. After these two steps were completed, the third part of the method was the analysis of the results of the simplification guidelines usability from the designers' work. The major analytical source is the visual data from the experiment, and the supporting data is the selection data of the questions that subjects were given after their drawing tasks. In other words, the author would like to understand the applicability of simplification guidelines on designers and the representations of modified designs when sketching with simplification guidelines at the concept generation stage.

8.3 Objective and research question

This experiment aims to examine the impact of simplicity principle application.
The major question of this experiment is stated as follows:
When designers use the simplicity guidelines, simplicity criteria have been used and how does it work?

8.4 Experimental design

8.4.1 Participants

Ten students enrolled at the University of Leeds in the school of design (undergraduates and postgraduates) took part in the experiment with an age range of between 21 and 35. Each participant carried out the experiment in three sets. This package was selected since they were all students with a design background; therefore, in order to avoid confusion, this experiment will use `designer` as the term to represent `participant`.

8.4.2 Images and materials

Designers were asked to draw some drafts which were inspired by three different objects – 1) eagle; 2) tree and 3) stationery as shown in Figure 8.1. These three objects were selected by the category of animal, plant and human-made objects. Designers were asked to produce some drafts inspired by object exteriority rather than object interiority, for example the association of courage or bravery from the eagle image.

Figure 8.1: Sample objects.

After the first task, they were asked to choose one of their drafts to take forward to the second task. At this stage, the task description was to ask them to read a two-page simplicity design guidelines and apply it to their original draft work. The simplification guidelines sheet was given as follows:

Legible Design Guidelines

Defining what constitutes a 'legible' logo depends on the situation and the objectives for that logo. Traditionally, a good logo is recognisable and meaningful. Legible logos also include the scientific elements of simplicity, neatness and clarity. For a company that needs to promote its logo such as an app or the place where it is provided/has a limited space for each logo, visual identity definitely has to make legibility play a key role in logo redesign consideration. Therefore, the following are seven different strategic objectives for logo modification that achieve legibility enhancement:

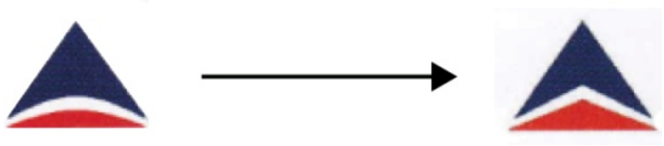
A. Form: Regular form as outline (circular, triangular, rectangular, polygon etc.)
According to some previous cases studies, one logo modification method commonly restyles the outline shape as a regular geometric shape or adds a regular shape as the surrounding outline to frame the focus of the company name and symbol. A regular geometric shape as the outline could give the impression of being simple and neat.

<u>*Please take regular shape as logo outline base.</u>

B. Straight-curved: Straight/Curved outline

Some logos include both straight lines and curved lines; however, previous experiments have shown that if only one element (either straight or curve) is kept, then it could slightly improve the simplicity. For example, most people regard circles (only curved lines) and square (only straight lines) to be simpler than semi-circles (both).

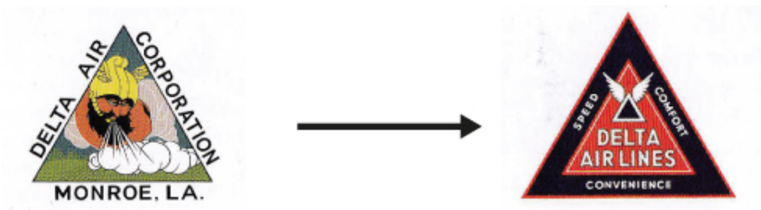
<u>*Please take either straight line only or curved line only in a logo.</u>



C. Open-closed: Complete outline node/point

One of the modification methods could be gathering components into the centre within a completed outline. This method could be helpful for people to concentrate on a specific area. The outline of the logo shape would be more concentrated with a completed outline rather than with a broken gap.

<u>* Please complete the broken gap outline.</u>



D. Symmetry: Symmetrise

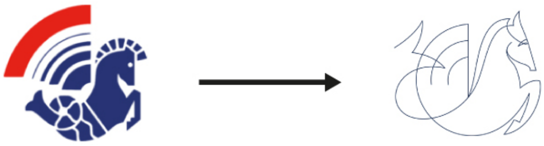
A well-balanced logo might increase simplicity, at the stage of redesigning the original logo, where some symmetry types could be considered as modification methods. Reflection and rotation logos might be simpler than an asymmetrical one.

<u>*Please choose any types of symmetry for logo modification.</u>

E. Weight: Lighten the shape

From research, many logos try to add a contrasting colour as their symbol background to make their logo distinctive; however, it also possible to narrow the flexibility of colour application on some occasions, making the image heavy. Removing the background or figure-ground techniques could be considered to redesign it.

Please use lighter/thinner line for logo modification.



F. Number/size of angles: Delete extra angle/point.

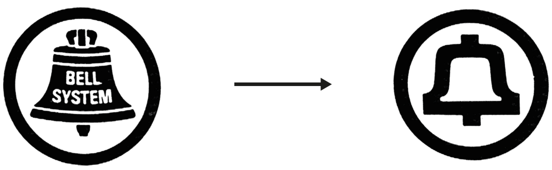
Elaboration logos tend to include extra details to decorate their image; however, to make it legible, these complicated outline details should be made straighter and smoother.

Please smoothen and straighten outline for deleting extra details.

G. Components: Minimise the amounts of components

Some logos apply extra components to emphasise specifics effect and decorate it with elaborate lines. Take into consideration the removal of extra components which are just for adding effect and retain the essential components.

Please minimise the amounts of components for keeping key visual.



8.4.3 Experiment procedure

This experiment was designed in five steps. First of all, a reference sample object was presented on A4 paper; designers were asked to reference the sample object and draw some logo drafts. They were also told that the drafts should be inspired by the sample object appearance rather than association and meaning; for instance, the eagle appearance and elements rather than the association with courage or other meanings. Secondly, designers could pick one of their own drafts for the next step. Thirdly they were given a two- page simplicity guidelines to read in detail. Fourthly, they referenced the guidelines sheet, and refined their draft in the boxes below in three simplification variations. The final steps involved selecting simplicity criteria from the guidelines which they chose for simplification consideration. Introduction pages were given in advance to explain the above steps clearly (shown in Figure 8.2 and Figure 8.3). The sample object was shown in grey scale without a background.

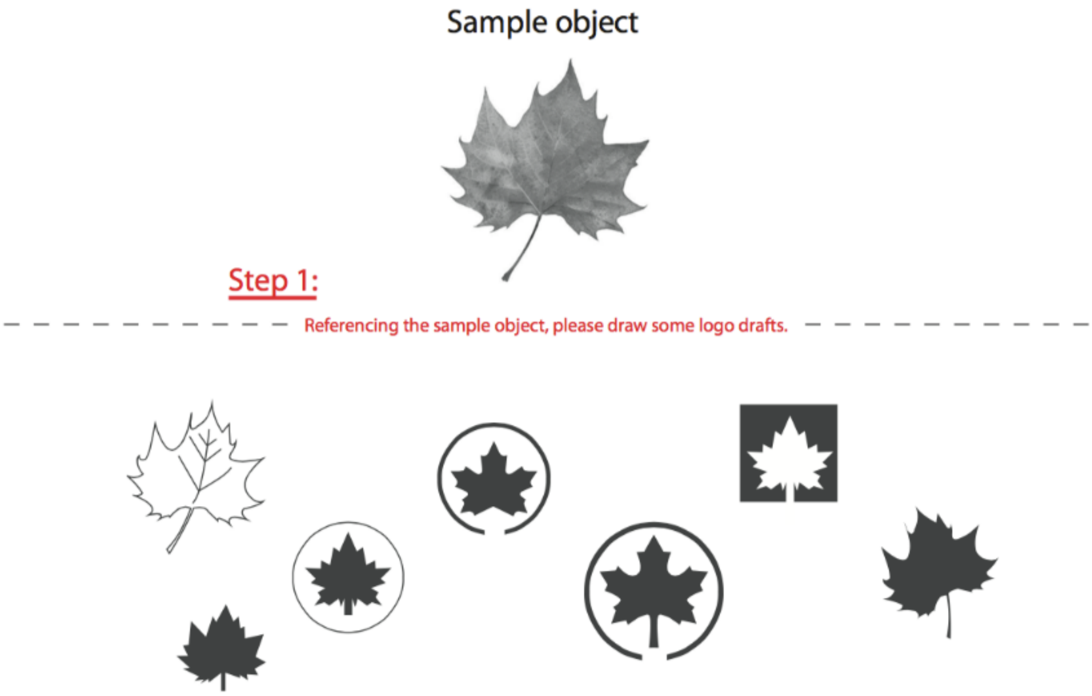


Figure 8.2: Explanation page 1.

After viewing the explanation page, designers were asked to draw some drafts which were inspired by three different objects – 1) eagle; 2) tree and 3) stationery. Secondly, they were asked to pick up one of their logo drafts and read the simplification guidelines sheet. Referencing the guidelines sheet, they were asked to refine their original draft to three simplification variations and circle the criteria they applied for simplification consideration.

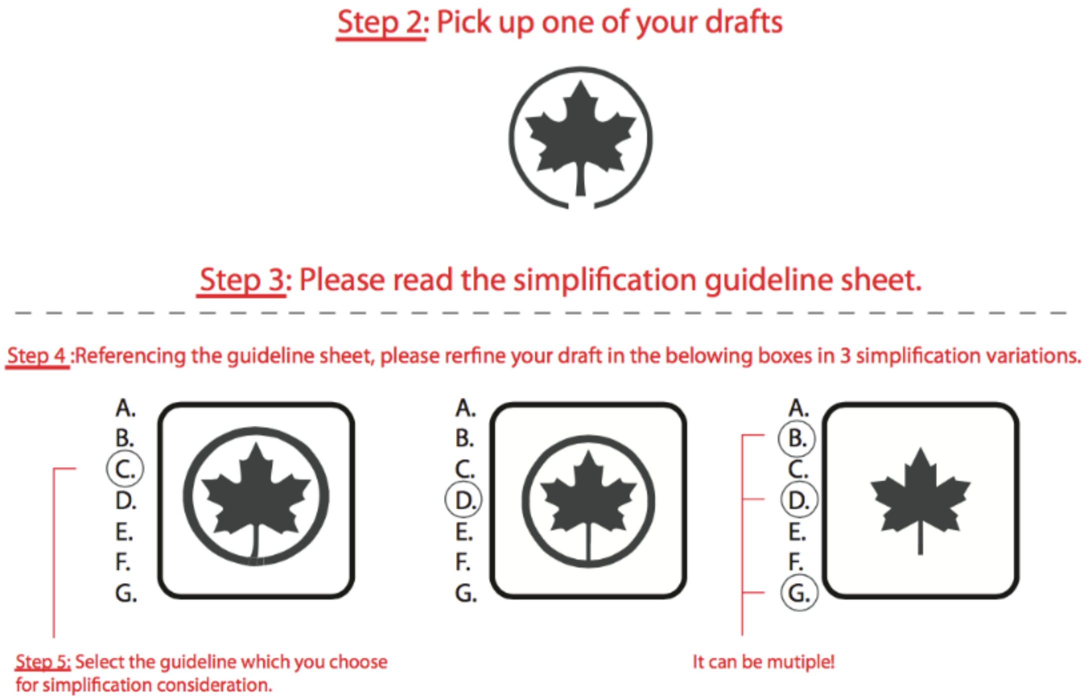


Figure 8.3: Explanation page 2.

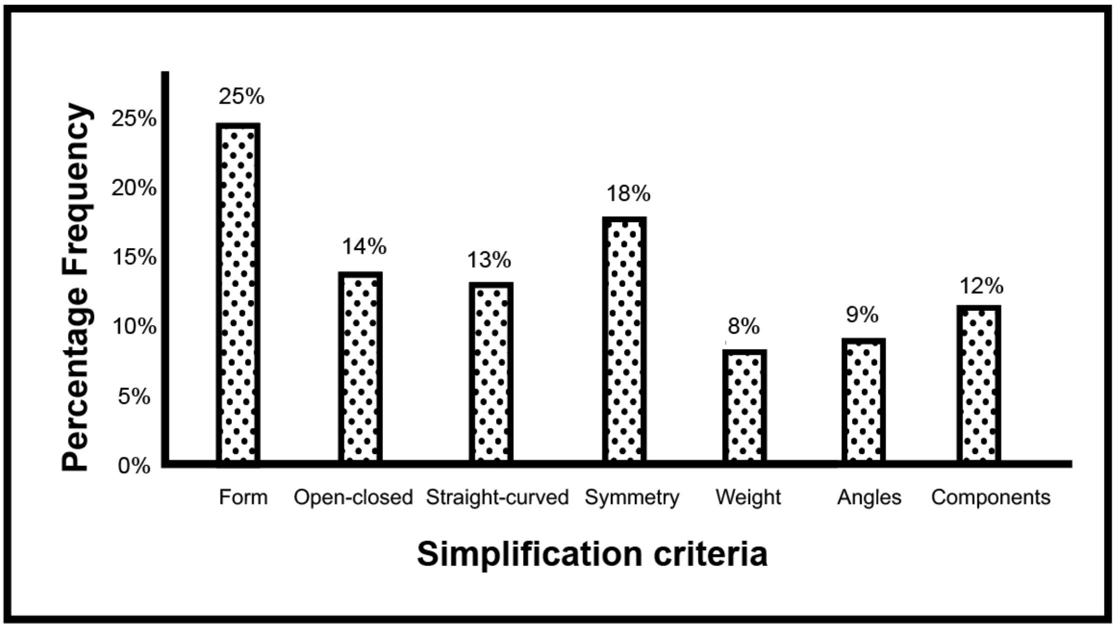
8.5 Statistical analysis

A total of 30 original logo drafts and 90 modified logo drafts were submitted on paper. To answer the research questions in this chapter: When designers use the simplicity guidelines, simplicity criteria have been used and how does it work? This experiment analysed the data in two parts: (1) the frequency of simplification criteria application; (2) the comparison between with and without simplification guidelines.

8.5.1 Frequency of simplification criteria application

A large number of modification syntheses were designed based on the guidelines instruction. The simplification criteria can be applied in multiple choice, 90 simplification variations designed by 10 designers in total. Among the total proportion of modified submissions, the percentage of each simplification criterion usage is shown in Table 8.1.

Table 8.1: The frequency of simplification criteria application.



While asked to modify their original logo drafts, designers could employ one or multiple simplification strategies. The result shows that form is the most common strategy when designers modified their drafts. A quarter of the 90 results were modified based on the form criterion. 14 per cent and 13 per cent of logo drafts were modified respectively based on open-closed and straight-curved criteria. Symmetry criterion was placed in second position of modification usage having a total of 18 per cent. However, weight and angles criteria had the least usage in the 90 results, with only 8 per cent and 9 per cent respectively. The modification method referenced by the components criterion had 12 per cent in all results.

This report could present the most common usage of simplified criteria; however, some possibilities may explain the result. Firstly, the reason for considering the use of criteria was not only based on the designer's personal preference but also on the level of ease or difficulty of use. In the form criterion application, adding a geometric shape outline to surround the original drafts is the easiest method, not requiring a huge redesign. Secondly, it is not surprising that the symmetry criterion was in second place. To the symmetry original drafts, the results commonly used the reflection method to make it as a pair. However, the criteria of open-closed, straight-curved and components were limited to strong associations with the original drafts design. For instance, if the original design was an object with a complete outline without a gap, the only way to improve it was to add an extra circle or other geometric shape. Straight original drafts also had to consider the original object sample. For example, if the sample was a circular object such as a cloud or ball, it might be difficult to apply this method. The component criterion could be a good method for deleting extra details, but it might take a longer time while modifying. The criteria of angles and weight were in last position in all comparisons. In the angles section, it was clearly used to smooth the complicated outline, but only depended on original drafts that were designed in that way. As the lowest application criterion, some difficulties of weight criteria use might be to swap the heavy background shape to a lighter line. It might be too vague and too much variation for designers to understand completely in a short time.

8.5.2 Comparison of simplification guidelines application

While performing these simplification tasks, which require modification of only a small number of results, there are a potentially larger number of strategies and possibilities which can be employed. Designers were asked to simplify their own drafts based on the guidelines instruction as mentioned above. According to the description, criteria can be combined for simplification; therefore, various types of synthesis are illustrated in this section. There is no maximum limitation of guideline criteria application; thus, some simplified results will present more than one category in this section. A total of 120 simplified results shown in this section with clear comparison of before and after guidelines use will be discussed. The following paragraphs are divided into seven sections by analysing seven simplification criteria – form, straight-curved, open-closed, symmetry, weight, angles and components. Each category of criteria usage is shown as follows in Figure 8.4 to Figure 8.10.

<u>A: Form (Regular form as outline)</u>

According to the guideline ‘please take regular shape as logo outline base’, adding an extra geometric shape to surround the original logo draft or transforming the logo drafts into circular, triangular and square shapes were common methods applied by participants. As shown in Figure 8.4, participants added circle, triangle and square shapes to surround their original logo drafts. Some of the original logo drafts already had a shape outline but were modified again with other possibilities. The total 30 results are shown in Figure 8.4.

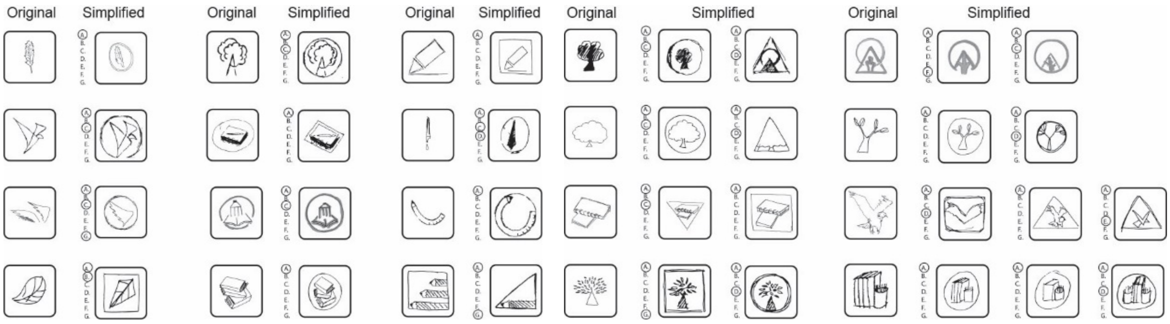


Figure 8.4: The transformation of the guideline used for form criterion.

B: Straight-Curved (Straight/Curved outline)

According to the task strategy 'please take either straight line only or curved line only in a logo', high percentages of participants chose to straighten the original logo drafts rather than curve them. Some of the original logo drafts were transformed into sharp and neat lines based on guideline suggestions. The majority of modifications in this criterion maintained the original appearance and transformed the curved part into horizontal, vertical, or angular lines. The results of straight-curved modification are shown in Figure 8.5.

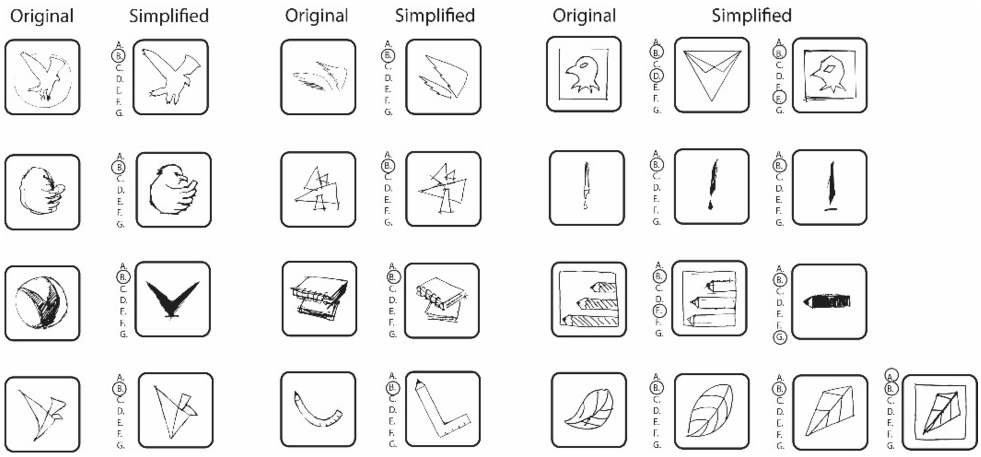


Figure 8.5: The transformation of the guideline used for straight-curved criterion.

C: Open-closed (Complete outline node/point)

In the open-closed guideline instruction which was described as 'please complete the broken gap outline', this method was required to make the outline of logo drafts smoother with a complete outline without a gap to increase concentration (Figure 8.6). However, most of the open-closed criterion results overlapped with the form criterion strategy. One of the possibilities is that adding an extra geometric shape is the easiest and fastest way to complete the original gap.

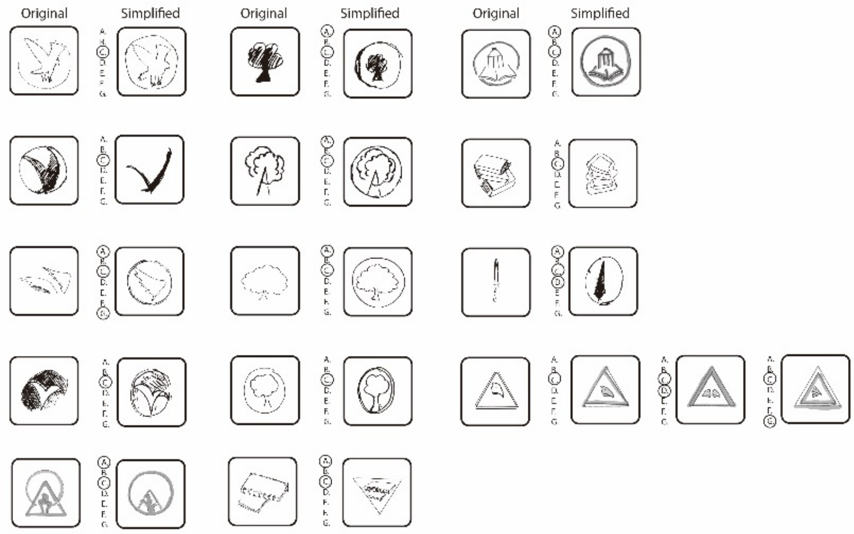


Figure 8.6: The transformation of the guideline used for open-closed criterion.

<u>D: Symmetry (Symmetrise)</u>

Based on the instruction 'please choose any types of symmetry for logo modification', the symmetry criterion took second place of usage compared to the others. There are various types of symmetry which can be described as translation, reflection and rotation, etc.; the most common type and easiest way to symmetrise shape is by reflection. According to the results, most of the simplified works tended to be a pair or mirror reflection. Figure 8.7 shows 22 modification results by symmetry criterion application.

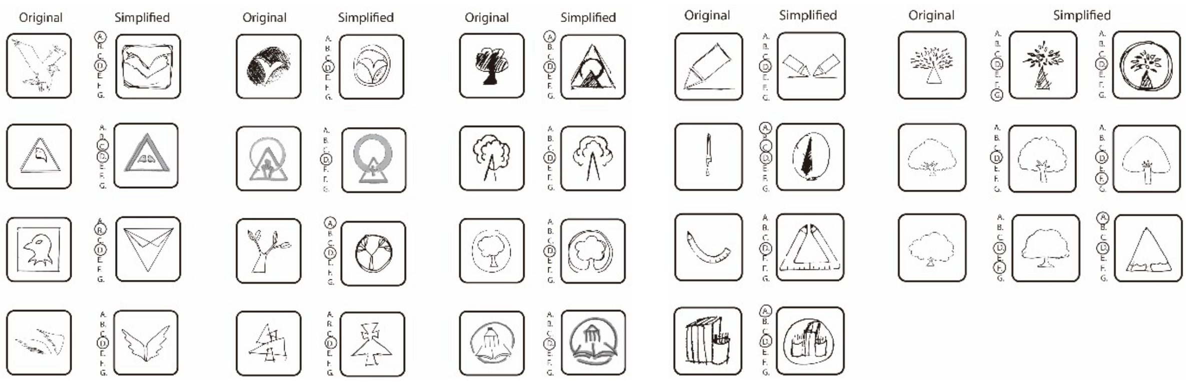


Figure 8.7: The transformation of the guideline used for symmetry criterion.

<u>E: Weight (Lighten the shape):</u>

The lowest percentage of simplification strategy is the criterion of weight. The instruction of weight is described as 'please use lighter/thinner line for logo modification'. Participants modified their original works by deleting extra details or reducing the proportion of the heavy filled background. The results are shown in Figure 8.8.

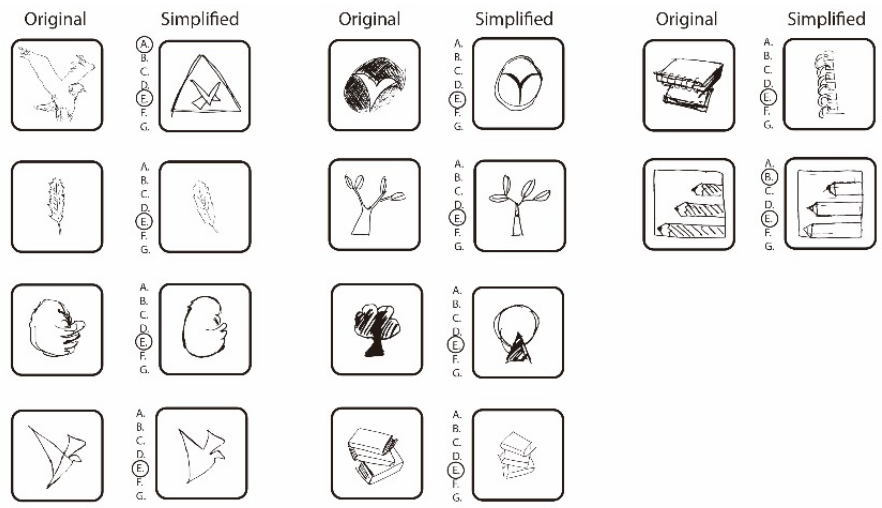


Figure 8.8: The transformation of the guideline used for weight criterion.

F: Angles (Delete extra angle/point)

In the angle task section, the instruction is 'please smooth and straighten the outline for deleting extra details'. Participants tended to smooth the outline angles and delete some extra details. The task in the tree sample section presents the clearest usage of this strategy. The results are shown in Figure 8.9.

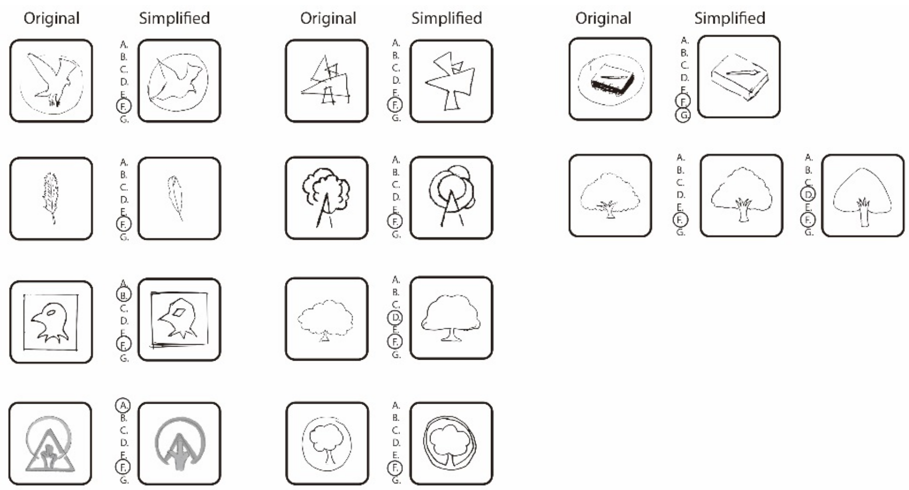


Figure 8.9: The transformation of the guideline used for angles criterion.

G: Components (Minimise the number of components)

In the components section, the request is as follows: 'please minimise the number of components for keeping key visual'. This strategy asked participants to delete some irrelevant or less important components from their original logo drafts. Participants minimised their own work into a more clear and narrow concept. The results are shown in Figure 8.10.

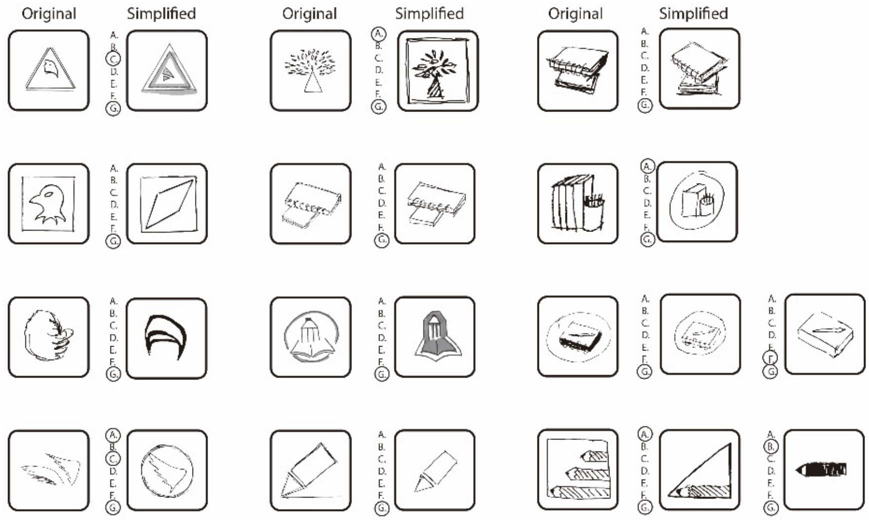


Figure 8.10: The transformation of the guideline used for components criterion.

8.6 The problems and limitations of this experiment

The data could illustrate the comparison between original and simplified graphics and the potential for combination. This experiment's result could indicate that, for a particular design task, the simplification guidelines can be seen as a useful method in the stage of logo development for designers. In general, this experiment reports the application of the guidelines with 90 various combinations of simplified results. The drawing method successfully examined the guidelines application for designers; furthermore, it showed a vivid synthesis of logo modification.

However, the limitation of this experiment includes the simplification guidelines summary, particularly the variation setting between each criterion which narrowed participants' modification results. One of the difficulties is that some of the simplification criteria are hard to modify with only one choice, for instance, the criterion form and criterion open-closed are mostly overlapping. Once participants had added an extra geometric shape surrounding their original drafts, this fitted in with the open-closed criterion request. It is hard to split the variation of each criterion completely. This experiment is also limited by the lack of information about the creative processes which occur during the design task, as it only compares the objective evaluation of guidelines application.

Chapter 9: Simplicity criteria and legibility improvement

9.1 Introduction

Wearable electronic products with small screens have become popular owing to their convenience in portability and working efficiency; however, their restricted display space leads to limited dimensions of display information. Icons and logos are adopted extensively on small screens, since they apply less display space than text; however, the legibility of icons and logos are degraded if they are too small on wearable smart devices. Hence, this experiment consider the use of simplification criteria – form, straight-curved, open-closed, symmetry, weight, angles and components, to improve the degraded legibility caused by the reduction in size of small icons and logos. This, the application of graphic legibility research on smart devices is still a growing area of study.

This experiment was run in order to test whether different levels of simplicity affect legibility. This chapter`s goal was to define the appropriate simplicity modification for legibility improvement in order that smart device users can receive the information immediately. An experiment was devised to gauge the level of simplicity which is in the safer legibility range, and which simplicity criteria are the most effective. For this, the experiment was separated into two sections. The first part of this experiment aims to find out the limitation of legibility according to image scores selected from Experiment 3 (in Chapter 6). This selection was based on several factors. Those images selected from Experiment 3 (Chapter 6) already had a specific score for each image which was calculated through the template statistic. Furthermore, from the total of 100 images placed in order from simple to complex, this experiment selected those images which were calculated as higher scores (scores over 50) to test legibility limitations. The second part of this experiment aims to compare the usability of the simplicity guidelines by applying it to designers' artworks which were selected from Experiment 4 (Chapter 7). The result in Experiment 4 explains the difference between before and after the simplification guidelines application; it will help to doubly confirm whether or not the guidelines improve legibility by evaluating accuracy and reaction time.

9.2 Research methodology review

The purpose of this experiment was to investigate the effects of small app icons on legibility. Legibility of shape has been of great interest in the information design area. Shape legibility is directly related to the ease with which visual systems can detect characters and is important in the use of smart devices. Various methods have been used to measure legibility; however, there is still a lack of academic research in the graphic and visual communication design area. Previous methods of measuring legibility have mainly used text-reading experiments, including (1) reducing contrast to establish threshold, and (2) increasing viewing distance to establish threshold and defocusing to establish threshold (Sheedy et al., , 2005). Although numerous text-reading experiments have taken accuracy and reaction time as their legibility research methods, the comparative effects of these various criteria upon the legibility of logos formed by shape combinations have not been studied. This information is needed to help guide designers of logo modification. The objective of this experiment is to utilise a threshold identification technique to identify the logo modification design and smart device display factors that most affect logo legibility.

Due to the lack of research methods for shape legibility analysis in the design area, therefore, this experiment took the previous font legibility experiment method as a reference. The many experiments on legibility that provided a valuable insight into speed of recognition of letter and words forms are useful for many practical applications, for instance printed texts and traffic signals (see, e.g. Akhmadeevaet al., 2012; Waard et al., 2005; Arditi and Cho, 2005). However, the legibility of image on small devices is a complex process that involves not just familiarity of the image, but rather the comprehension of image structure. Therefore, this experiment settled the task by asking participants to read the image at their normal speed, and then measured the results via both accuracy and reaction time.

Referencing previous legibility experiments, comparison was made using the rapid serial presentation method. The question of the influence of shapes on logo-reading speed in natural conditions can be applied by the same method and analysis. Therefore, this experiment chose to ask the subjects to indicate accurate samples with their ‘normal’ speed and measure the results. A similar approach was used by

Akhmadeeva et al., in 2012 who analysed serif and sans serif fonts by time counting and accuracy counting. Another legibility test addressed by Nedeljković, Puškarević, Banjanin and Pinćjer in 2013 was applied to examine letter recognition, visual word recognition and parallel letter recognition. It measured the response times for a given stimulus which was categorised by two different types of letter in order to prove which one was more legible. Using Rot and Kostic's (1987 cited in Nedeljković et al., , 2013, pp.22) study for example; they examined letters to define that straight lines and sharp corners are the most important factors of greater legibility. Accuracy and reaction time were suggested to define as an appropriate method to examine the legibility of an object.

According to previous studies which examined a similar research goal – the legibility of an object – this experiment will take logos as stimuli and test both accuracy and reaction time. This study was conducted in the quest to answer the basic questions: 1) Are there logos in both original and simplified modification from relatively consistently legible, i.e. more legible than the original; and 2) which simplicity criteria influence legibility? Referencing previous study research methods, this experiment examined and tested stimuli in a similar way – by accuracy and reaction time.

9.3 Objective and research questions

This experiment is to examine the impact of the simplicity principle on legibility improvement. Research questions are stated as follows:

(1) Which level of simplicity design has legibility limitations?

(2) Do simplicity criteria improve legibility in application?

9.4 Experimental design

9.4.1 Participants

Twenty students enrolled at the University of Leeds (6 males and 14 females) with an age range between 21 and 39 took part in the experiment. Each observer carried out the experiment twice and, therefore, the total number of observation results was forty.

9.4.2 Images

This experiment was designed in two parts – (1) legibility limitation and (2) legibility improvement. Images from Question 1 to Question 10 were selected and referenced by Experiment 3, the quantitative research. Images from Question 11 to Question 24 were selected and referenced by Experiment 4. The size of sample was stated as 0.6 centimetres which referenced the size of the Apple watch app display. The distance between observers and screen was 30 centimetres which referenced the distance when using a watch. The images were displayed on an 11-inch laptop. The participants operated the test samples on the screen with one hand, and the researcher recorded their reaction time.

Image conditions from Item 1 to Item 10 (Figure 9.1), those with higher scores which mean the logos with more complex elements, were selected from Experiment 3. In this task, the aim was to try and find the limitation boundary of legibility by a systematic calculation method.

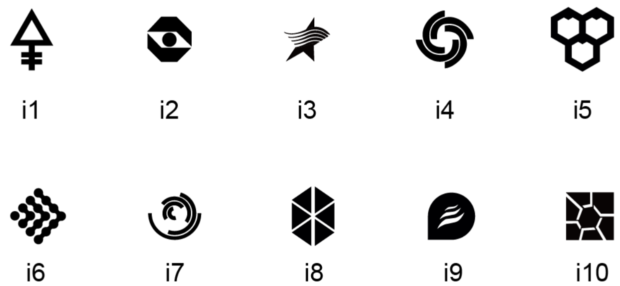
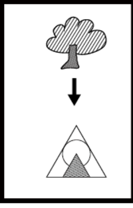
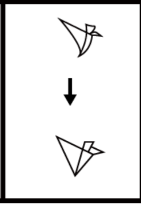
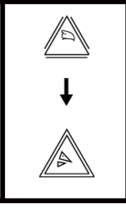
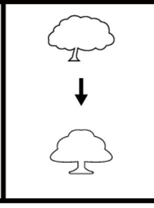
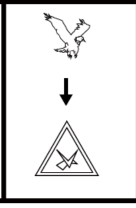
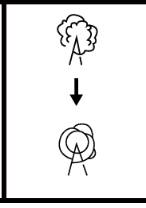
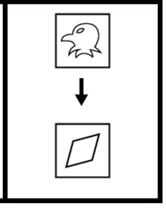


Figure 9.1: Images selected from Experiment 3 (Chapter 6).

Image conditions from Item 11 to Item 24 were compared before and after by applying the simplicity guidelines. In the second task, aimed at testing legibility improvement, images were selected from Experiment 4. In the previous experiment, the task was to ask design students to draw some drafts inspired from a real image – eagle, tree and stationery. At this stage, the design students simply drew their design work creatively without any limitations or criteria. Next, the design students could pick up any one of their drafts for a second step task – simplified draft with simplicity guidelines. Therefore, the logos were selected based on a total of seven criteria, which design students used for their logo simplification. As shown in Table 9.1, seven images were chosen for each simplification criteria. The upper seven images were those drafts drawn before applying the simplicity guidelines; the lower seven images were those images that were modified by the simplicity guidelines. Table 9.1 clearly explains the condition of image choice and the comparison between with and without the simplicity guidelines. Figure 9.2 shows the images selected from previous experiment.

Table 9.1: Images selected from Experiment 4 (Chapter 8).

Criteria	A : Form	B: Straight -curved	C: Open -closed	D: Symmetry	E: Weight	F: Angles	G: Components
Before guideline ↓ After guideline							

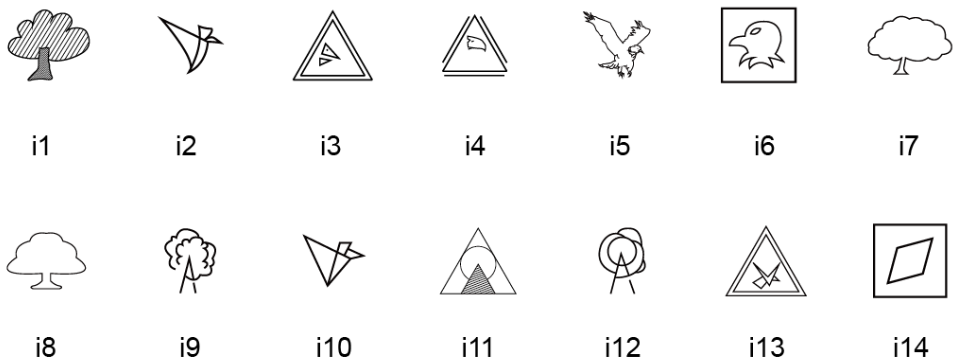


Figure 9.2: Images selected from Experiment 4 (Chapter 8).

9.4.3 Hypotheses

The hypotheses of the study are stated as follows:

H1: Simplicity criteria development has a positive impact on increasing image recognition accuracy.

H2: Simplicity criteria development has a positive impact on shortening image recognition reaction time.

9.4.4 Experiment procedure

A series of image identification tasks was conducted to evaluate legibility. In this experiment, participants were presented with a total of forty-eight sets of images by PowerPoint slide. Each set of slides contained three images; the centre image determined the reference sample; either the right or the left hand side of the sample was exactly the same as the centre sample and one was certainly dissimilar. The observers' task was simply to choose which one (right or left) was the same as the reference sample under time-recording conditions. Figure 9.3 shows an example of the images presented to the participants.

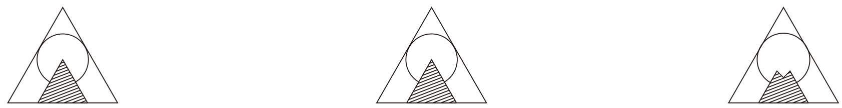


Figure 9.3: An example of experiment image presented.

Each participant was required to proceed with the following steps: (1) measure the distance between eyes and screen by 30 centimetres; (2) indicate whether the right or left image is the same as centre reference sample by simply answering 'right' or 'left'; (3) press the next page button once they finish each task. The experiment required 5 minutes to complete, per participant, per set.

9.5 Statistical analysis

The data was analysed in two parts: (1) Question 1 – Question 10 using accuracy and reaction time to determine the relationship between simplicity level and limitation of legibility; (2) Question 11 – Question 24 using accuracy and reaction time to determine the improvement of legibility by applying simplicity criteria. Furthermore, in the second part of this experiment, the analysis used two comparisons: a) comparison between before and after using the simplicity guidelines; b) comparison between the sample modification criteria. The following paragraphs are divided into two sections in order to answer the research question.

(1) Which level of simplicity design has legibility limitations?

According to the calculation results in Experiment 3, ten out of one hundred samples were selected to be stimuli in Experiment 5. This experiment selected those ten images which scored over fifty and the level between each image was scored five per one; for example, this experiment picked up one sample from five with a score between 51-55, other samples were selected from scores between 56-60, 61-65,66-70,71-75,76-80,81-85,86-90,91-95,96-100. In total, ten samples were selected for this experiment as seen in Table 9.2.

Table 9.2: Sample selected based on Experiment 3 scoring.

Score	55	60	65	70	75	77	82	90	91	98

The averages of accuracy and reaction time in Questions 1 to 10 are shown in Figure 9.4 and Figure 9.5. As seen in Figure 9.4, images in Q1, Q3, Q4 and Q7 had significant effects on accuracy within 40 results. Regarding Figure 9.5, the reaction times of Q1, Q3, Q4 and Q7 were significantly less for shorter exposure time with less than 3 seconds in general from an average of 40 results. In these two tables, Q6 and Q9 attained nearly 100% accuracy (98% and 90%) and took 2 seconds and 5 seconds reaction time respectively. On the other hand, accuracy in Q8, Q5 and Q10 (85%, 73% and 63%) was obviously decreasing and reaction times were increasing in the same way from 3 seconds, 6 seconds and 7 seconds respectively. However, a surprising result emerged in Q2, which had lower accuracy (43%) and a higher reaction time (9 seconds) in this experiment.

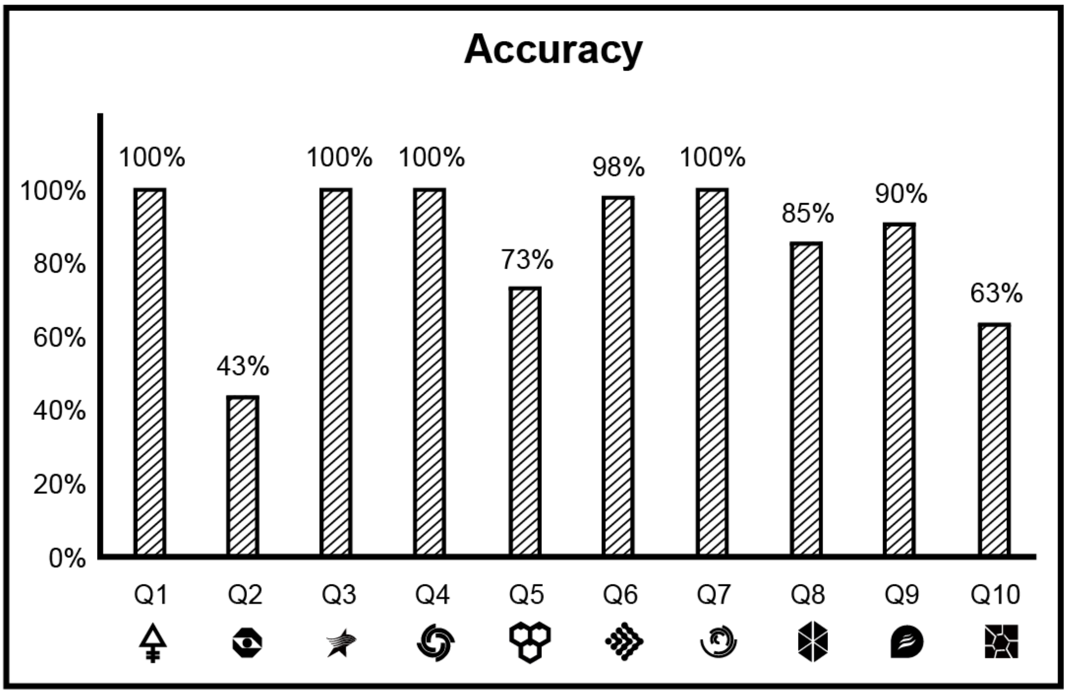


Figure 9.4: Accuracy of Q1 to Q10.

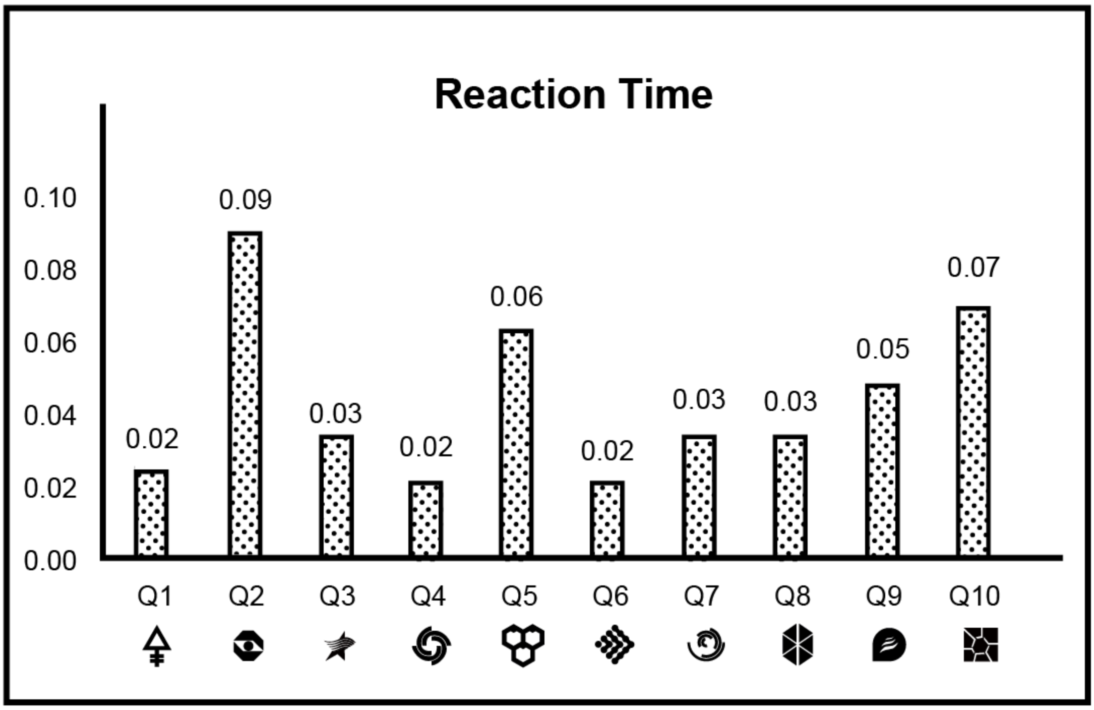


Figure 9.5: Reaction time of Q1 to Q10.

A series of correlations was carried out to assess whether there was any relationship between simplicity calculation score, accuracy and reaction time (Table 9.3). At the higher accuracy and shorter reaction time, images of Q4, Q1 and Q3 took exactly the same sequence when sorted by scores from simpler to complex calculation in Experiment 3. The image of Q4 was scored as 55 simplicity level which had the fullest accurate and shortest reaction time within 40 results. Both Q1 and Q3 also had significant ranking correspondence with Experiment 3 scoring. On the other hand, images of Q5 and Q10 which had been placed in 6th and 10th position were ranked 8th and 9th respectively in the accuracy and reaction time result. Overall, the correspondence between the former three results (Q4, Q1 and Q3) and latter two (Q6 and Q10) results had high agreement.

However, surprisingly, an unexpected result in Q2 showed dramatic disagreement between the calculation score, accuracy and reaction time, taking second place in the simplicity score but with lower accuracy and the longest reaction time. Some possible mistakes might be due to the scoring system and image reproduction. According to Experiment 3, the system has some limitations in criteria determination; on the other hand, the reproduction method for the Q2 image modified its inside detail – circle to polygon, rather than its outline shape. However, in the 0.6

centimetre size image, it is hard to recognise circle and polygon, especially those polygons with more sides.

Table 9.3: Comparison.

Q1-Q10 Ranking	Q4	Q2	Q1	Q3	Q6	Q7	Q5	Q9	Q8	Q10
Score	55	60	65	70	75	77	82	90	91	98
Q1-Q10 Ranking	Q4	Q7	Q1	Q3	Q6	Q9	Q8	Q5	Q10	Q2
Accuracy	100%	100%	100%	100%	98%	90%	85%	73%	63%	43%
Q1-Q10 Ranking	Q4	Q6	Q1	Q3	Q7	Q8	Q9	Q5	Q10	Q2
Reaction Time	0.02	0.02	0.02	0.03	0.03	0.03	0.05	0.06	0.07	0.09

Overall, the trend of legibility generally followed the trend of simplicity. Legibility of images decreases gradually from scores including and higher than 75. The result briefly tells us that if the image simplicity level is higher than 70, it might possibly lose its clarity. Furthermore, images scoring over 82 will increase the risk of users reading the image accurately. To answer the first research question: Which level of simplicity design has legibility limitation? The result shows that an image scoring higher than 75 is the starting point of losing clarity; images scoring higher than 82 will be at risk of being illegible. Both scores of 75 and 82 are the boundary of legibility limitation in the two steps of evaluation.

(2) Do simplicity criteria improve legibility in application?

As shown in Figure 9.6, the bar chart illustrates the accuracy of image legibility applied to those stimuli selected and digitalised from Experiment 4. The top three images which have highest accuracy were Q13, Q18 and Q24, and had a one hundred per cent accurate response from the participants' task. Q12, Q17, Q20 and Q21 also had over ninety per cent accuracy in the task results. A slight error occurred in the image legibility decision in Q11, Q19, Q22 and Q23 which had a range of between eighty to ninety per cent accuracy in this experiment. However, the results for accuracy dropped remarkably in Q14, Q15 and Q16 which only got 68%, 60% and 68% respectively.

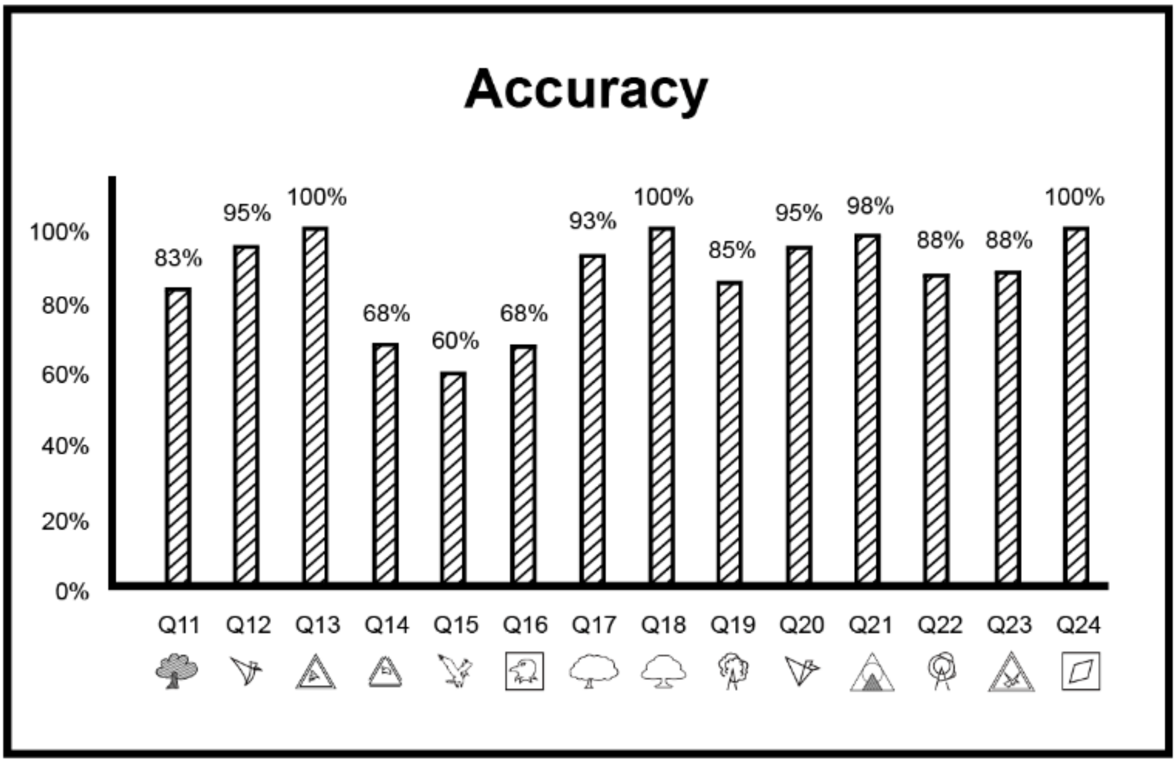


Figure 9.6: Accuracy of Q11 to Q24.

The bar chart shown in Figure 9.7 illustrates the length of reaction time of how participants recognise the image from similarity decision. With regard to the shortest reaction time results, which indicated those images which were easier or faster for participants to recognise the similarity of the reference sample and modified one, Q12, Q13, Q18, Q20, Q21 and Q24 took the shortest time with less than 3 seconds. The second longest class of reaction times were Q11, Q19, Q22 and Q23 which ranged between 5 to 6 seconds for making a decision. This result is interesting in that it shows that the class of 80% accuracy group (Q11, Q19, Q22 and Q23) is exactly the same as the class of 5/6 seconds reaction time group (Q11, Q19, Q22 and Q23). Moreover, Q14, Q15 and Q16 took the longest judging time in general, averaging around 7 to 8 seconds per task. These three tasks also achieved the lowest accuracy as shown in the accuracy bar chart. The result of this experiment shows a significant relationship between accuracy and reaction time. The result of these two tables has a high agreement of legibility.

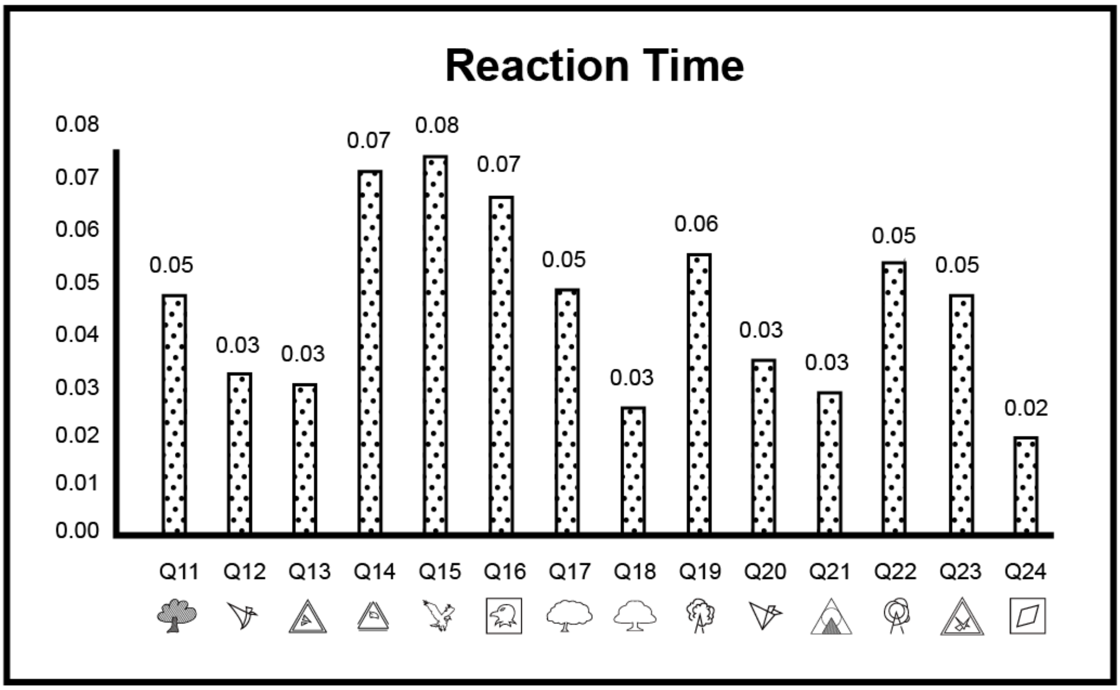


Figure 9.7: Reaction time of Q11 to Q24.

To answer the research question - Do simplicity criteria improve legibility in application? Statistical analysis is divided into two parts – a) comparison between before and after using the simplicity guidelines and b) comparison between sample modification criteria. The first part (a) is going to examine whether the simplicity guidelines are applicable or not by the growth of accuracy and the decline of reaction time. The second part (b) is going to analyse which simplicity criteria have the most significant impact. The following paragraphs are going to provide statistical analysis and explanation.

A) Comparison between before and after using the simplicity guidelines

Based on Experiment 4, the selection of stimuli for this experiment was according to designers' work before and after using the simplicity guidelines comparison. The definition of a useful and applicable guidelines in this experiment was reference legibility improvement by comparison of each pair. As seen from Figure 9.8, the variance in the speed of reaction increases significantly in a positive way. In Figure 9.8, the bar with line pattern shows the design works before using the simplicity guidelines; the bar with star pattern shows the effect after using the simplicity guidelines. The comparison of the simplicity application in pair Q11 and Q21 shows a 15% accuracy increase. Pair Q12 and Q20 maintained accuracy steadily.

Moreover, the result of pair Q14 and Q13 shows a strong impact of the simplicity guideline application with the accuracy increasing dramatically from 68% to 100%. The accuracy of pair Q17 and Q18 also improves slightly from 93% to 100%. Pair Q15 and Q23, pair Q19 and Q22 and pair Q16 and Q24 also have positive improvement with around 28%, 3% and 32% respectively.

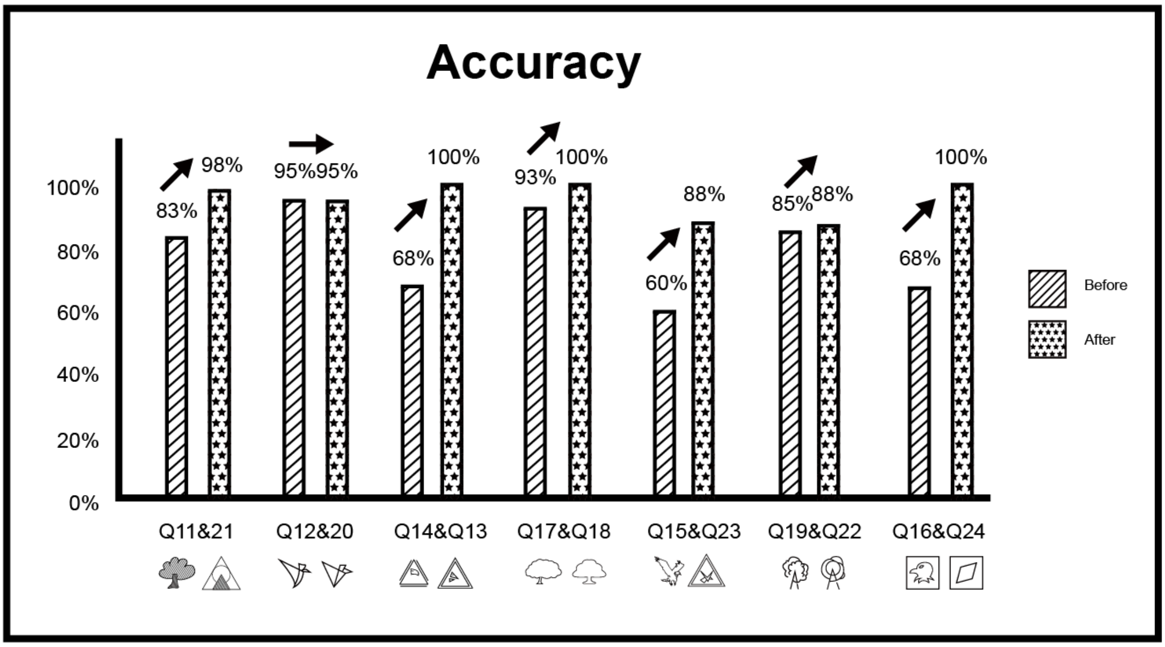


Figure 9.8: Accuracy comparison of Q11 to Q24.

On the other hand, the comparison of reaction time speed also decreased on each pair. In Figure 9.9 there is a 2 second reading speed increase in the first pair Q11 and Q21 from 5 seconds to 3 seconds. In the same table, the result of the second pair (Q12 and Q20) is maintained steadily as 3 seconds. The speed of reaction time dropped obviously in pair Q14 and Q13 from an average 7 seconds to 3 seconds. Pair Q17 and Q18 also decreased by 2 seconds in reaction time. Pair Q15 and Q23, pair Q19 and Q22 and pair Q16 and Q24 have clear improvement with a faster reaction time, which is 3, 1 and 5 seconds improvement respectively.

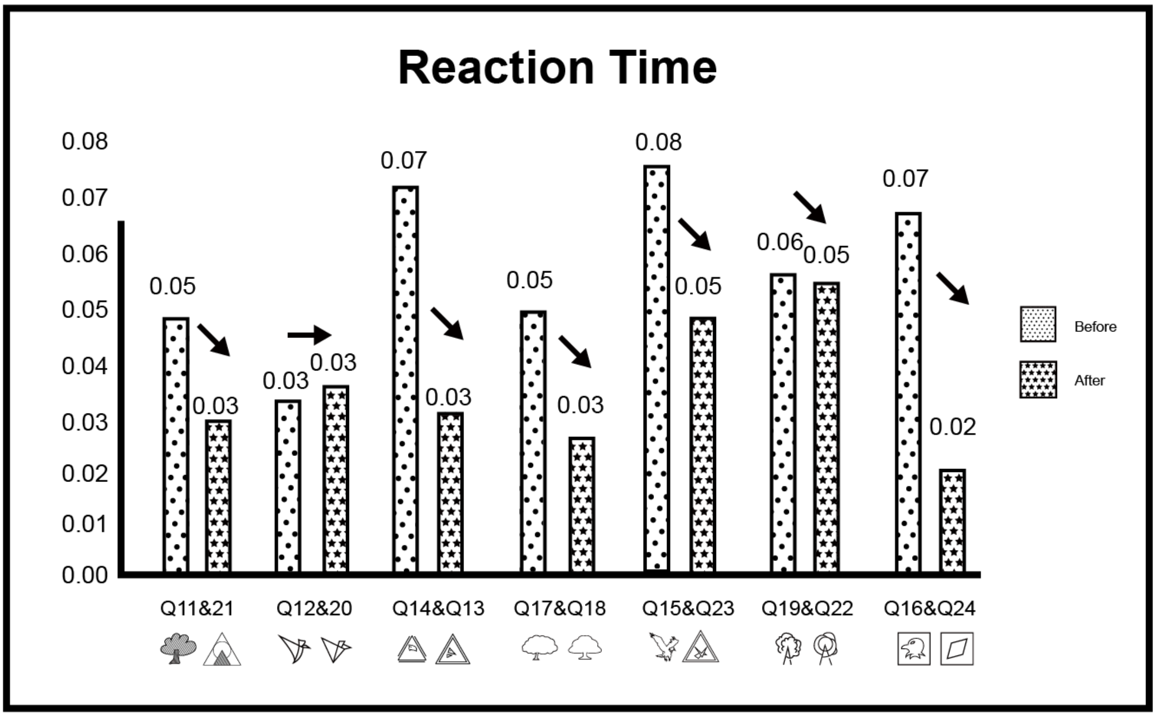


Figure 9.9: Reaction time comparison of Q11 to Q24.

The result of this experiment answers part of the second research question - Do simplicity criteria improve legibility in application? Through comparison between before and after using the simplicity guidelines, the results of accuracy and reaction time clearly show legibility improvement.

b) Comparison between sample modification criteria.

Comparing the highest legibility improvement from accuracy and reaction time charts, Table 9.4 and 9.5 illustrate this in detail. According to Experiment 4, these criteria were used for participant decision and selection. All images are referenced from Experiment 4 work and modification was categorised by participant selection. In the form factor section, participants drew an irregular tree as an initial draft without any principle or rule. Secondly, after viewing the provided simplicity guidelines, this design was modified into a triangle outline and consisted of all geometric shapes. This modification improves 15% accuracy and a 2 second reaction time decline. However, the straight-curved factor section seems to just have a slight improvement, maintaining both accuracy and reaction time result. This modification simply compares straightened and curved outlines. The open-closed factor section shows a remarkable improvement, obtaining 32% accuracy improvement and 4 second decline. The modification of open-closed was to erase the three triangle-sided corner, to make this shape with a fully closed or open outline condition. Another improvement in the symmetry factor added 7% accuracy with a 2 second decrease in reaction time. In symmetry modification, the designer didn't make a big change in outline shape. The outline of the tree is simply modified by reflection symmetry technique. Weight factor seems to involve some changes and the deletion of a lot of extra details. The improvement in the weight section is an increase of 28% accuracy and a 3 second decrease in reaction time. A slight improvement in the angle factor increases accuracy by 3% and a I second reaction time saving. This modification simply smooths and deletes the extra tree outline into a more geometric circular outline. A good impact in the component factor was an increase of 32% accuracy and 5 second reaction time reduction.

Table 9.4: Comparison of modification criteria by accuracy.

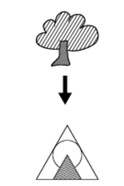
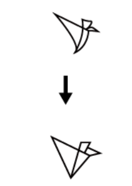
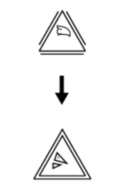
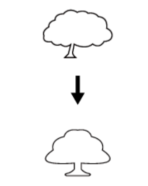
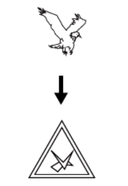
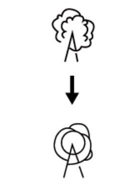
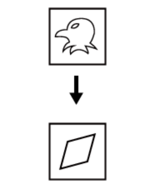
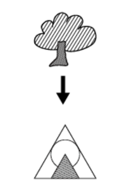
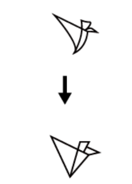
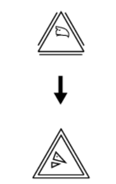
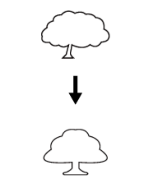
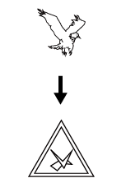
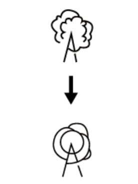
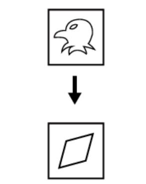
Criteria	A : Form	B: Straight -curved	C: Open -closed	D: Symmetry	E: Weight	F: Angles	G: Components
Before guideline ↓ After guideline							
Accuracy improvement	+15%	±0%	+32%	+7%	+28%	+3%	+32%

Table 9.5: Comparison of modification criteria by reaction time.

Criteria	A : Form	B: Straight -curved	C: Open -closed	D: Symmetry	E: Weight	F: Angles	G: Components
Before guideline ↓ After guideline							
Reaction time improvement	-2 sec	±0 sec	-4 sec	-2 sec	-3 sec	-1 sec	-5 secs

Furthermore, the following radar chart (Figure 9.10) shows the impact combination of both accuracy and reaction time. The dark grey colour represents criteria impact on accuracy; the light grey colour represents criteria impact on reaction time; the overlapping part is the high agreement part in both the accuracy and reaction time analysis.

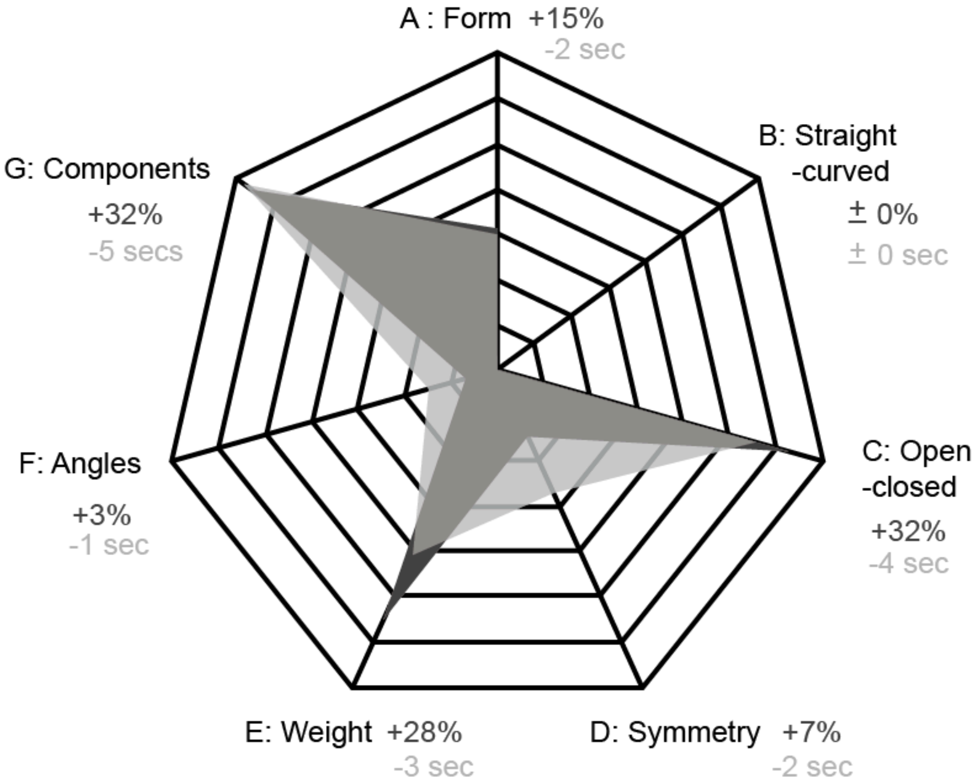


Figure 9.10: Radar chart of simplicity criteria impact.

In general, according to this chart, the impact of simplicity criteria can be briefly placed in sequence. First of all, open-closed and components criteria have a major impact on legibility improvement. Secondly, form and weight criteria also have a significant improvement on legibility but slightly less impact compared to open-closed and components. Thirdly, symmetry and angles criteria also have a positive impact on legibility improvement. However, the last criterion, straight-curved, didn't show a remarkable improvement. The difference when applying this criterion was negligible as it maintains the same level of legibility.

To conclude the second research question: Do simplicity criteria improve legibility in application, part (a) which compares before and after applying the simplicity guidelines answers the first question – Yes, simplicity criteria did improve legibility in application; part (b) gives further details of the criteria impact level in the following order - open-closed, components, weight, form, symmetry, angles and straight-curved.

In conclusion, this experiment provides a clear statistical and significant confirmation of both legibility limitation and simplicity guidelines application. The trend of legibility generally follows the trend of simplicity. The first result of this experiment shows that the legibility of images decreases gradually from a score of 75 and higher which means that if the image simplicity level is higher than 70, it might possibly lose its clarity; also, if the image has a score over 82, it will be difficult for users to read the image accurately. The second result of this experiment shows that the simplicity guidelines provided in the previous experiment has a positive impact in its application which can successfully improve legibility; in addition, it also shows that simplicity criteria are applicable and successful.

9.6 The problems and limitations of this experiment

This is the final experiment of this study. The results of this experiment explain and confirm both the research question and hypothesis clearly. The results prove that the simplicity guidelines has a positive impact on legibility improvement, confirmed by both accuracy and reaction time. However, this experiment still contained some problems and difficulties in its progress.

Firstly, samples from Experiment 3 had real limiting problems in both sample calculation and selection. As mentioned before, this study aims to provide a systematic calculation method for determining simplicity level; however, the calculation method has some minor problems such as manual or automatic calculation. There's a gap between human selection and computer selection which means that the results of scoring are still not yet perfect. It may be a good reference but is not one hundred per cent reliable.

Secondly, the samples from Experiment 4 are all designed and modified by participants. However, the first difficulty concerns the criteria they chose to modify their drafts as sometimes more than one criterion was included. Therefore, even though this experiment has briefly categorised the factors, some images consist of more than one criterion which could be an influence on the result.

Thirdly, another difficulty in this experiment is image reproduction. In order to test legibility, the task is to request participants to indicate which sample is similar to the reference sample. However, the variation will be another dissimilar sample that is modified for the test. As mentioned in 8.4.4, each task shows three images on one slide; two of them are exactly the same; however, the one dissimilar was modified with a variable rule. One of the reasons is that it is hard to adjust just one specific criterion in the image. In a general image, once a criterion has been adjusted, such as the outline smoothed, it can be categorised as angles and straight-curved adjustment. In this case, one of the variables which was hard to avoid was image reproduction.

Overall, there still exists some limitations in this experiment; the results of this study illustrate a fundamental simplicity principle for legibility improvement. It can be a reference in the application of the design of user interfaces and for logo designers to enhance legibility quality in smaller devices.

Chapter 10: Conclusion

10.1 Introduction

The aim of this study is to enhance the graphic legibility display on a small screen through graphic simplification. The study specifically focuses on logo and app icon modification. This issue is related to designers (subject), legibility (object), the tool (simplification) and the final outcome (logo/app icon modification). Thus, the literature review explores the area of (1) the design thinking process, (2) logo and app icon design trends, (3) graphic legibility evaluation methods, and (4) graphic simplification methods.

Summarising the four areas mentioned in the literature review, the simplification guidelines have been generated with seven criteria, (1) form, (2) open-closed, (3) straight-curved, (4) symmetry, (5) weight, (6) number/degree of angle, (7) number of components. To examine the idea of using these shape features to simplify a logo/app icon into a more legible form, five sets research questions are asked: (1) What is the definition of simplicity for each criterion? What would be an appropriate simplification method for a logo and how can its effectiveness be measured? (2) Does agreement of simplicity judgement exist? (3) Can the simplicity judgement be predictable via the results of research question 1 and research question 2? (4) Do the simplicity guidelines work properly? How do they work? (5) Which level of simplicity design has legibility limitations? Do simplicity criteria improve legibility in application?

To answer the research questions, Chapter 4 reviews the research methods for each question specifically. The study applies both quantitative and qualitative research to examining the objectives. The research questions stated above are answered in each chapter from Chapter 5 to Chapter 9. The results and answers to each question are discussed in the following sections.

<u>Research question 1: What is the definition of simplicity for each criterion? What would be an appropriate simplification method for a logo and how can its effectiveness be measured?</u>

The results of the experiment in Chapter 5 indicated that (1) form criterion- circle, triangle and rectangle are in the simplest order which give the possibility of simplicity judgement as also considering the number of angles from no angle (circle), three angles (triangle), four angles (square and diamond) and more than five angles (polygon, etc.) respectively; (2) Open-closed elements could be understood in two categories — over 180° and under 180° — the former tends to be defined as a simpler shape and the latter tends to be the least simple; (3) The result of straight-curved, symmetry, component and weight almost match the hypotheses, and the data shows a clearer statistic about the distance between each level. The most interesting finding is that the degree of angle results suggests that sharper angles tend to be seen as the least simple shape and the flat ones tend to be seen as simpler shapes. The template summarises the results of each level of the elements.

Research question 2: Does agreement of simplicity judgement exist?

Chapter 6 (Principle of simplicity judgement experiment) indicated the answer to be positive, and provided good evidence that the rules of simplicity are (1) regular form; (2) shapes with closed outlines; (3) shapes with pure straight and pure curved forms; (4) symmetrical shapes; (5) shapes with lighter superficial measurements; (6) angles in the shape over 180°; and (7) fewer components. These hypotheses are further examined in Chapter 6 (Simplicity criteria comparison) which deduces the influence of each criterion ratio as follows (Figure 10.1).

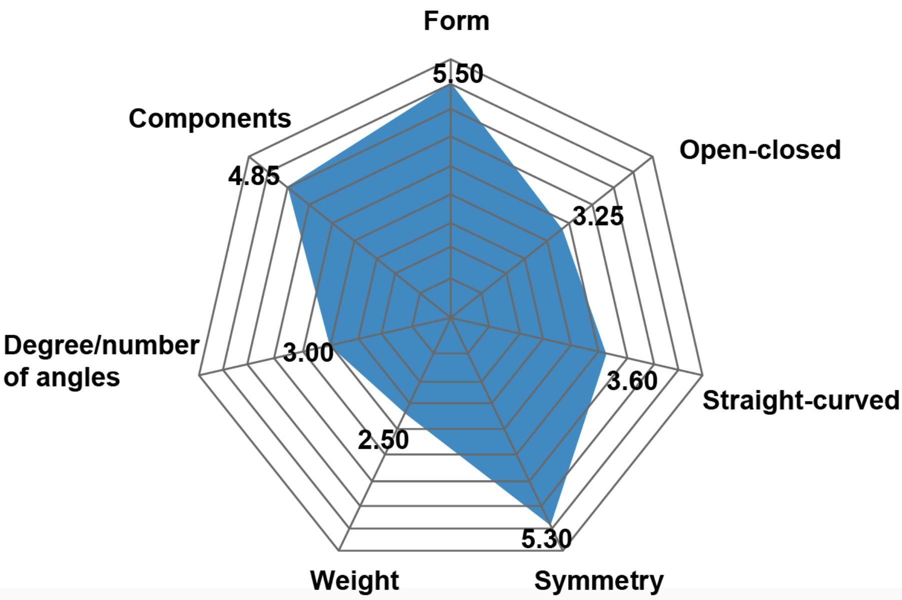


Figure 10.1: Impact of each criterion comparison.

Research question 3: Can simplicity judgement be predictable from the data collection results of Research question 1 and Research question 2?

The R- squared is the statistic of Chapter 7 and determines how well the hypothesis (Research question 1) fits the aim (Research question 2). As mentioned in Chapter 7, R-squared is a statistical measure of the closeness of the data (hypothesis) to the fitted regression line (aim) which is always represented between 0 (0%) and 1 (100%). In general, the higher the R-squared presents, the better the model (hypothesis) fits the aim. The regression model in this experiment presents 0.4239 of the variance. This number indicates that the agreement of simplicity hasn't been solved completely; however, it commonly reveals 0.3-0.5 R-squared value in the human behaviour prediction field. The result of this experiment still allows the possibility of partial prediction.

Research question 4: Do the simplicity guidelines work properly? How do they work?

This question was answered in Chapter 8; the result shows that form is the most common strategy when designers modified their drafts. A quarter of the 90 results were modified based on the form criterion. The symmetry criterion was placed in second position of modification usage. Moreover, open-closed and straight-curved took third and fourth place respectively. However, component, angles and weight criteria had the least usage. These results show the sequence of modification criteria, and also represent that the geometric form is the most adaptable criterion for simplifying graphics from a designer`s point of view. Following on from the results of these experiments, guidelines for simplification are generated and examined in Chapter 8 (Application of simplicity guidelines). Seven simplification design guidelines have been generated: (A) form: regular form as an outline (circular, triangular, rectangular, polygon etc.); (B) straight-curved: straight/curved outline; (C) open-closed: complete outline node/point; (D) symmetry: symmetrise; (E) weight: lighten the shape; (F) number/size of angles: delete extra angles/points; (G) components: minimise the number of components. 10 out of 90 design modification works were selected to examine the enhancement of legibility based on the simplification criteria that designers followed. The results of this experiment indicate that 'Weight' has the least impact on simplicity judgement; it also represents that the shape in either stroke or filled-in doesn't influence its simplicity significantly. Thus, in the conclusion of this experiment, this study suggests to exclude ‘Weight’ as a key criterion of simplicity guidelines.

<u>Research question 5: Which level of simplicity design has legibility limitations? Do simplicity criteria improve legibility in applications?</u>

Finally, this research question was addressed in Chapter 9. To examine the application of the simplification guidelines to graphic legibility enhancement, the results of the final experiment have to answer two questions in order to confirm the achievement of the aim: (a) Which level of simplicity design has legibility limitations? (b) Do the simplicity criteria improve legibility in application? Question (a) addresses the graphic legibility limitation in numbers, and Question (b) has a yes/no answer to confirm the enhancement of graphic legibility through the simplification guidelines.

For Question (a), the trend of legibility generally follows the trend of simplicity and shows that the legibility of images decreases gradually since the scores measure higher than 70; and if the score is over 82 it is difficult for users to read the image accurately. For Question (b), the results show that both reaction time and accuracy improve, which indicates that the application of the simplicity guidelines has a positive impact on legibility enhancement; thus, the answer to Question (b) is positive. In addition, the simplicity criteria impact level is in the following order - open-closed, components, weight, form, symmetry, angles and straight-curved.

10.2 Guideline practical summary

To sum up the conclusion from five research questions, this section extracts some initial drafts from previous chapters. The original hand-draw design works are illustrated in Chapter 8. The application of this study is the comparison of logo/app icon modification based on the simplification guidelines, on both circle and square canvas, as shown in Figure 10.2. The examples above are the designers’ original works which are simply inspired by the object image without restriction. The examples below are the logo/app icon modifications after the designers modified their original works with the simplification guidelines. Thus, it is an example of how the simplification guidelines work.

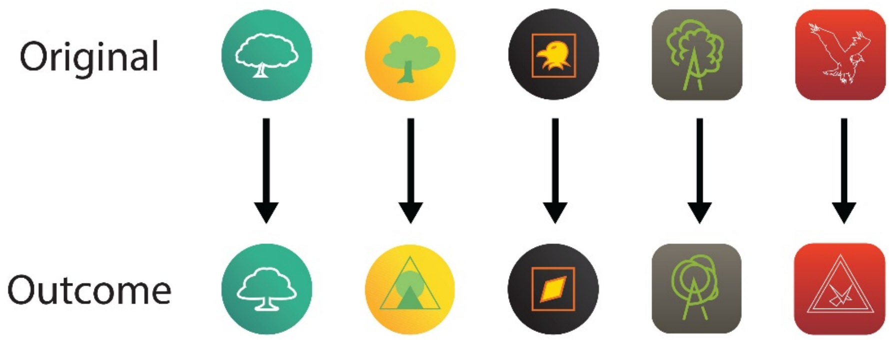


Figure 10.2: Example of logo/app icon modification.

Figure 10.2 shows one example of the modification edition presented in various sizes in Apple Watch. As shown in Figure 10.3, even though the app icon is presented in small sizes, the quality of legibility of this app icon is maintained at a specific level.

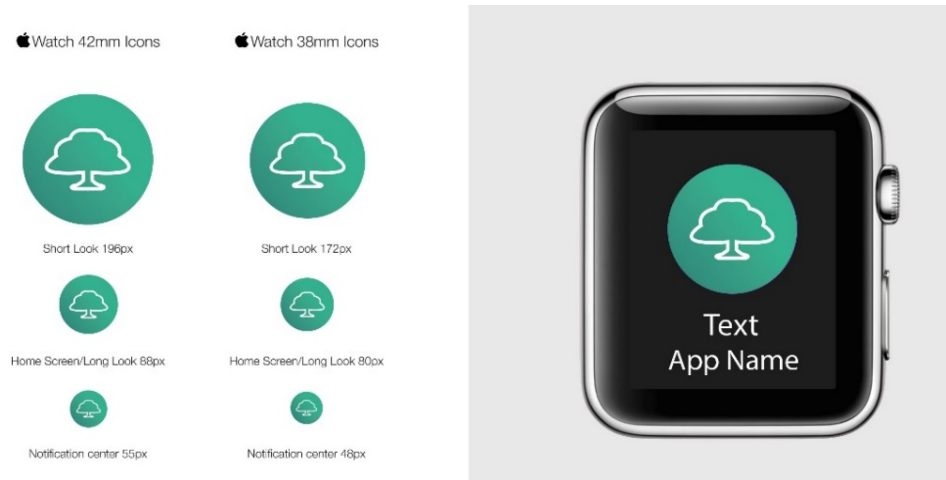


Figure 10.3: Example of showing in Apple Watch.

This study addresses the requirements of graphic legibility on a small screen and gives simplification guidelines to support designers in order to facilitate logo and app icon design. A simplification measurement template (Chapter 7) is useful to identify into which level of simplicity the logos and app icons are categorised. The simplification guidelines (Chapter 8) clearly provide the methods for designers' modification reference. The limitation of logo and app icon legibility determine scores between 70 and 80, according to the users' reaction time and accuracy (Chapter 9).

Overall, as stated in the introduction chapter (Chapter 1), this study aims to apply effective graphic simplification to logo/app icon modification in order to enhance graphic legibility on smart devices. Summarising all the knowledge from the four areas found in the literature review and five sets of experiments, simplicity definition, simplification criteria judgement, simplification criteria comparison, simplification guidelines application and legibility experiments, this study achieves the aim stated and answers the five research questions presented in Chapter 1. The findings of this study, (1) provide a more systematic method of measuring ‘simple’ in statistics; (2) give simplification guidelines for designers; (3) define the limitation of legible boundaries to avoid risk, and (4) fill the idea step gap in the current design thinking process. This study provides designers and app developers with a reliable method to develop logos and app icons with legible redesign reference.

10.3 Limitations of the research

This study has been carried out, and achieved its aim, with theoretical and practical experiments. However, there are some limitations of this study. In order to achieve the aim stated, the four research areas are included, and each of them has their own limitations. In addition, the five experiments run in this study show that there is still room to improve. This section is divided into three main aspects to discuss the limitations of the simplification judgement, the simplification calculation template and the application of the simplification guidelines.

First, in determining the characteristics of simple shapes, the term ‘simple’ is a very subjective word (Chapter 2, Chapter 5 and Chapter 6). Therefore, according to the R-squared result, the evaluation of a simple shape could include some grey areas. As mentioned in Chapter 7, one common problem in form matching is that some participants judge the shape in detail, others consider the outline of the shape, and some judge the sample in its totality. Thus, in summarising the judgements of subjective factors, the R-square value is commonly between 0.4 and 0.6. In this study, the result for simplicity judgement is 0.42, which is a quite standard result in human emotion prediction fields. However, there is still potential to obtain more accurate statistics.

Secondly, apart from the simplification judgement of humans, another limitation of the simplification calculation template is the difference between how humans understand an image and how a computer receives the information for the image.

This limitation of the experiment was shown in Chapter 8. Take one of the simplification criteria for example: the calculation of weight is the percentage of foreground pixels, which means that the two shapes in Figure 10.4 have exactly the same weight according to a computer calculation; however, humans tend to indicate that stripes are lighter than a solid rectangle. Therefore, the gap of the level of simplification calculation between human and computer has to be considered more fully in future experiments.

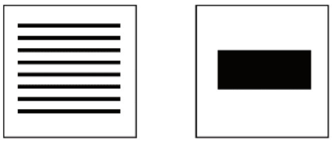


Figure 10.4: The computer detection of weight measurement.

Thirdly, using simplification guidelines leads to some difficulties, such as some criteria are hard to modify with only one choice, for instance the criteria form and open-closed are overlapping. Once designers add an extra geometric shape surrounding their original drafts, this fits the open-closed criterion request. It has the limitation of splitting the variation of each criterion completely. This experiment is also limited by the lack of information about the creative processes which occurs during the design task, as it only compares the objective evaluation of guidelines application. Flexibility and creativity are also key to design, and how to combine them with the tasks of simplification should be further considered.

10.4 Recommendations for future work

As stated, the core application of this study is to develop more legible logos and app icons for presenting on small devices. In reviewing this study, both theoretical and practical perspectives are discussed. The following are recommendations for future work and experiments.

From a theoretical perspective, the academic resources in the design area are still not as vivid as other fields, so the research methodology of running an experiment should be made more aware of the ‘subjective’ topic. The methodology used in this study provides quantitative and qualitative research methods for measuring graphic simplicity and legibility, however, future work which aims to continue similar projects should consider the potential variables more carefully.

From a practical perspective, the sample selection rules stated in Chapter 2, and applied in all experiments, do not include text or colours, but only focus on the outline in greyscale. Therefore, future study should take more variables into consideration. In addition, even though this projects focused on function examination, the design process should always be aware of uniqueness and preference. Therefore, future research could include the current user interface designer and app developer teams in a central role in the development procedure, which will be more complete work combining theoretical and practical perspectives on design research.

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Appendix:

Table 1a: The result of SL

SL	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	15	0	0	2	0	0	0	0	23	0
OPEN-CLOSED	0	8	0	0	0	7	13	1	11	0
STRAIGHT-CURVED	0	0	0	0	2	38	0	0	0	0
SYMMETRY	34	0	0	1	2	1	2	0	0	0
WEIGHT	0	0	0	38	0	2	0	0	0	0
DEGREE/NUMBER OF ANGLES	6	31	2	1	1	2	30	0	1	0
COMPONENTS	0	5	3	0	0	0	32	0	0	0

SL	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	7.92
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		6.06
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	1.66
WEIGHT				4.63		6.29			9.02		4.63
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	1.276
COMPONENTS		2.52	3.78			6.1	7.58			10	7.58
										Total	35.516

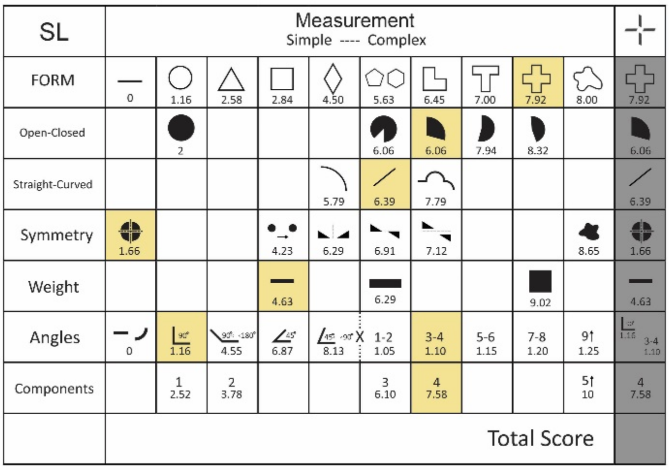


Table 1b: The result of SS.

SS	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	0	0	35	0	1	3	0	0	1
OPEN-CLOSED	0	29	0	0	0	6	3	1	1	0
STRAIGHT-CURVED	0	0	0	0	3	30	7	0	0	0
SYMMETRY	1	0	0	13	3	6	4	0	0	13
WEIGHT	0	0	0	1	0	10	0	0	29	0
DEGREE/NUMBER OF ANGLES	2	37	0	1	0	14	11	0	12	1
COMPONENTS	0	1	36	0	0	0	0	0	0	3

SS	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	2.84
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	4.23
WEIGHT				4.63		6.29			9.02		9.02
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	1.218
COMPONENTS		2.52	3.78			6.1	7.58			10	3.78
										Total	29.478

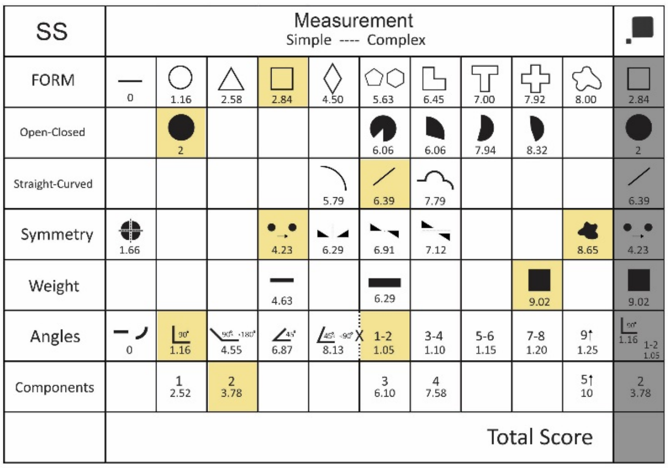


Table 1c: The result of SB.

SB	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	40	0	0	0	0	0	0	0	0
OPEN-CLOSED	0	37	0	0	0	1	2	0	0	0
STRAIGHT-CURVED	0	0	0	0	40	0	0	0	0	0
SYMMETRY	35	0	0	4	1	0	0	0	0	0
WEIGHT	0	0	0	4	0	36	0	0	0	0
DEGREE/NUMBER OF ANGLES	39	0	1	0	0	1	0	0	0	0
COMPONENTS	0	2	30	0	0	8	0	0	0	0

SB	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	1.16
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				5.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	1.66
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	0
COMPONENTS		2.52	3.78			6.1	7.58			10	3.78
										Total	20.68

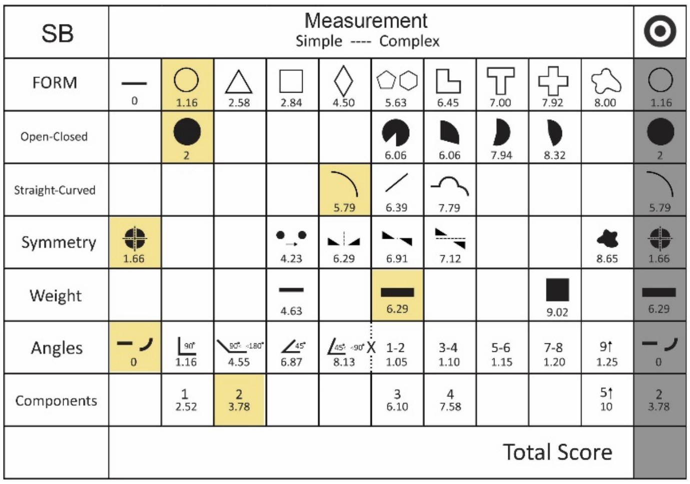


Table 1d: The result of SU.

SU	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	0	0	40	0	0	0	0	0	0
OPEN-CLOSED	0	30	0	0	0	6	2	2	0	0
STRAIGHT-CURVED	0	0	0	0	0	40	0	0	0	0
SYMMETRY	4	0	0	2	6	11	10	0	0	7
WEIGHT	0	0	0	12	0	28	0	0	0	0
DEGREE/NUMBER OF ANGLES	0	30	0	8	2	8	27	2	3	0
COMPONENTS	0	0	35	0	0	4	1	0	0	0

SU	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	2.84
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.91
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	1.276
COMPONENTS		2.52	3.78			6.1	7.58			10	3.78
										Total	29.486

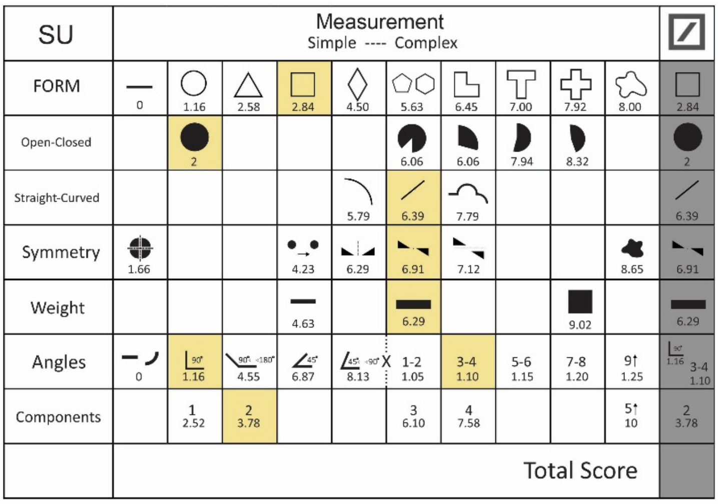


Table 1e: The result of SF.

SF	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	37	0	0	3	0	0	0	0	0
OPEN-CLOSED	0	34	0	0	0	5	0	1	0	0
STRAIGHT-CURVED	0	0	0	0	18	1	21	0	0	0
SYMMETRY	4	0	0	2	5	16	11	0	0	2
WEIGHT	0	0	0	1	0	29	0	0	10	0
DEGREE/NUMBER OF ANGLES	15	3	17	3	2	14	13	0	0	0
COMPONENTS	0	4	31	0	0	3	2	0	0	0

SF	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	1.16
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				7.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.91
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	4.7775
COMPONENTS		2.52	3.78			6.1	7.58			10	3.78
										Total	32.7075

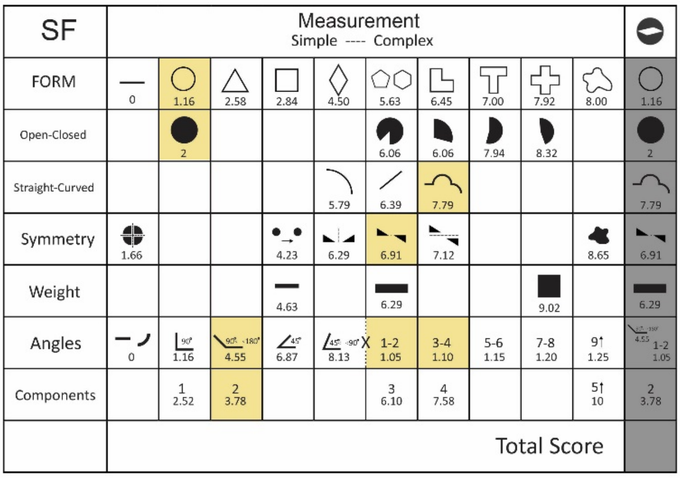


Table 1f: The result of SA.

SA	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	40	0	0	0	0	0	0	0	0
OPEN-CLOSED	0	38	0	0	0	0	2	0	0	0
STRAIGHT-CURVED	0	0	0	0	40	0	0	0	0	0
SYMMETRY	2	0	0	11	22	0	2	0	0	3
WEIGHT	0	0	0	4	0	34	0	0	2	0
DEGREE/NUMBER OF ANGLES	40	0	0	0	0	0	0	0	0	0
COMPONENTS	0	2	22	0	0	16	0	0	0	0

SA	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	1.16
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				5.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.29
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	0
COMPONENTS		2.52	3.78			6.1	7.58			10	3.78
										Total	25.31

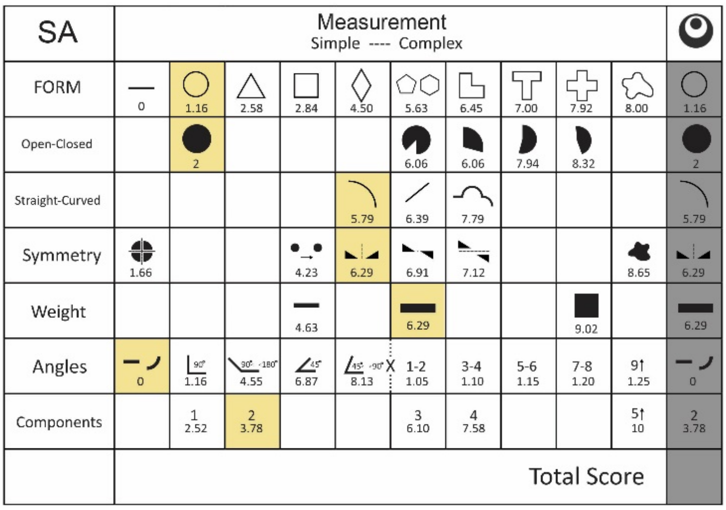


Table 1g: The result of SO.

SO	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	3	0	24	0	2	0	0	2	9
OPEN-CLOSED	0	24	0	0	0	7	6	2	1	0
STRAIGHT-CURVED	0	0	0	0	6	2	32	0	0	0
SYMMETRY	31	0	0	1	5	2	1	0	0	0
WEIGHT	0	0	0	6	0	32	0	0	2	0
DEGREE/NUMBER OF ANGLES	2	31	4	1	2	4	30	3	1	0
COMPONENTS	0	1	11	0	0	1	8	0	0	19

SO	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	2.84
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				7.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	1.66
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	1.276
COMPONENTS		2.52	3.78			6.1	7.58			10	10
										Total	31.856

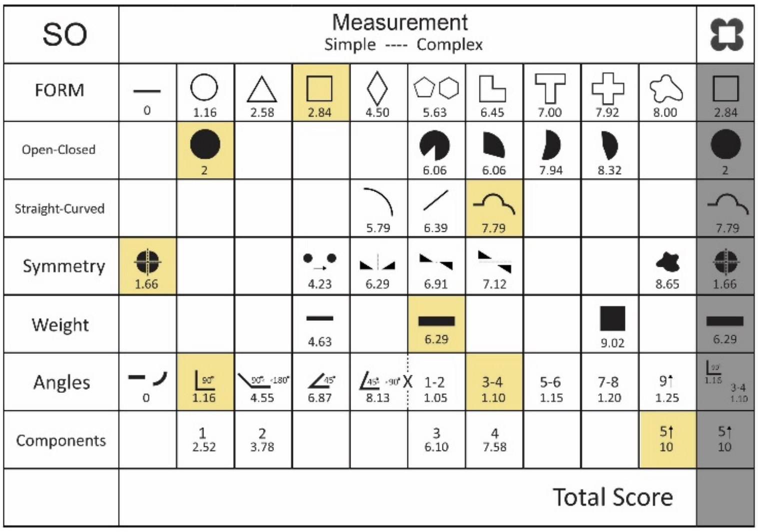


Table 1h: The result of SY.

SY	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	0	0	39	0	0	0	1	0	0
OPEN-CLOSED	0	32	0	0	0	4	3	1	0	0
STRAIGHT-CURVED	0	0	0	0	1	39	0	0	0	0
SYMMETRY	13	0	0	0	25	1	1	0	0	0
WEIGHT	0	0	0	0	0	26	0	0	14	0
DEGREE/NUMBER OF ANGLES	0	38	0	2	0	5	17	0	8	10
COMPONENTS	0	2	14	0	0	22	0	0	0	2

SY	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	2.84
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.29
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	1.276
COMPONENTS		2.52	3.78			6.1	7.58			10	6.1
										Total	31.186

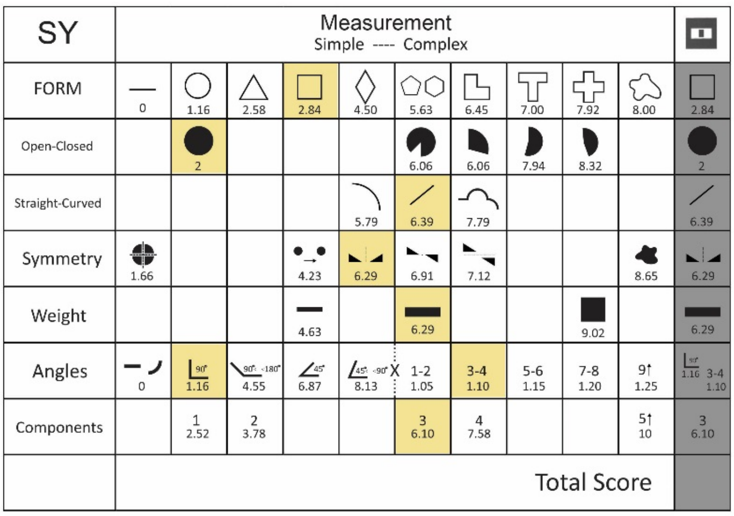


Table 1i: The result of SD.

SD	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	34	0	0	1	1	0	0	0	4
OPEN-CLOSED	0	32	0	0	0	6	1	1	0	0
STRAIGHT-CURVED	0	0	0	0	35	0	5	0	0	0
SYMMETRY	0	0	0	13	6	2	3	0	0	16
WEIGHT	0	0	0	3	0	23	0	0	14	0
DEGREE/NUMBER OF ANGLES	35	0	3	2	0	4	1	0	0	0
COMPONENTS	0	2	7	0	0	27	3	0	0	1

SD	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	1.16
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				5.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	8.65
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	0
COMPONENTS		2.52	3.78			6.1	7.58			10	6.1
										Total	29.99

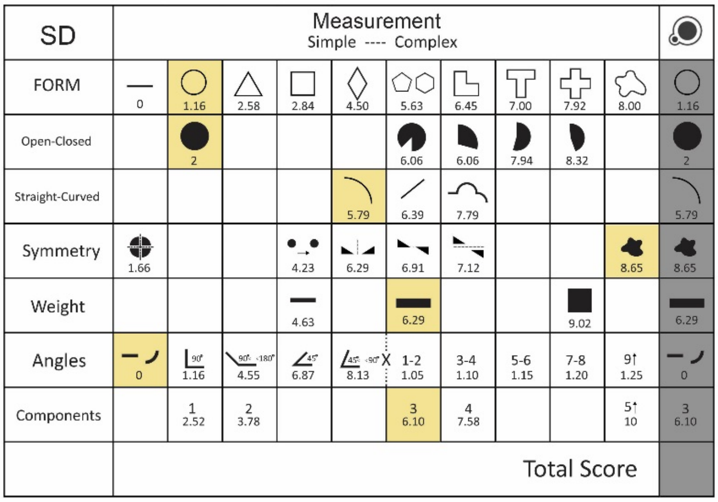


Table 1j: The result of SR.

SR	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	0	0	16	14	3	2	0	1	4
OPEN-CLOSED	0	4	0	0	0	10	8	12	6	0
STRAIGHT-CURVED	0	0	0	0	0	39	1	0	0	0
SYMMETRY	0	0	0	3	15	5	4	0	0	13
WEIGHT	0	0	0	6	0	33	0	0	1	0
DEGREE/NUMBER OF ANGLES	2	15	6	13	4	7	13	7	5	6
COMPONENTS	0	0	16	0	0	22	2	0	0	0

SR	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	2.84
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		7.94
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.29
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	1.276
COMPONENTS		2.52	3.78			6.1	7.58			10	6.1
										Total	37.126

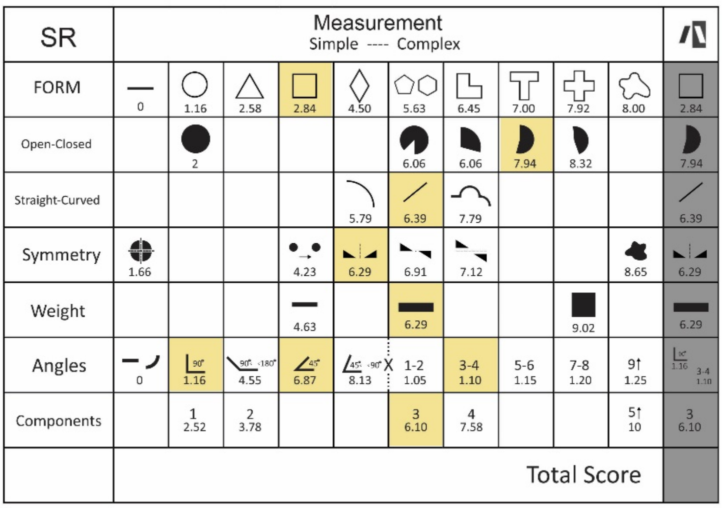


Table 1k: The result of SK.

SK	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	2	10	0	0	0	2	0	0	10	16
OPEN-CLOSED	0	6	0	0	0	18	8	3	5	0
STRAIGHT-CURVED	0	0	0	0	5	6	29	0	0	0
SYMMETRY	3	0	0	1	27	2	1	0	0	6
WEIGHT	0	0	0	5	0	34	0	0	1	0
DEGREE/NUMBER OF ANGLES	7	3	0	22	8	2	0	7	22	2
COMPONENTS	0	1	36	0	0	2	0	0	0	1

SK	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	8
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		6.06
STRAIGHT-CURVED					5.79	6.39	7.79				7.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.29
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	8.244
COMPONENTS		2.52	3.78			6.1	7.58			10	3.78
										Total	46.454

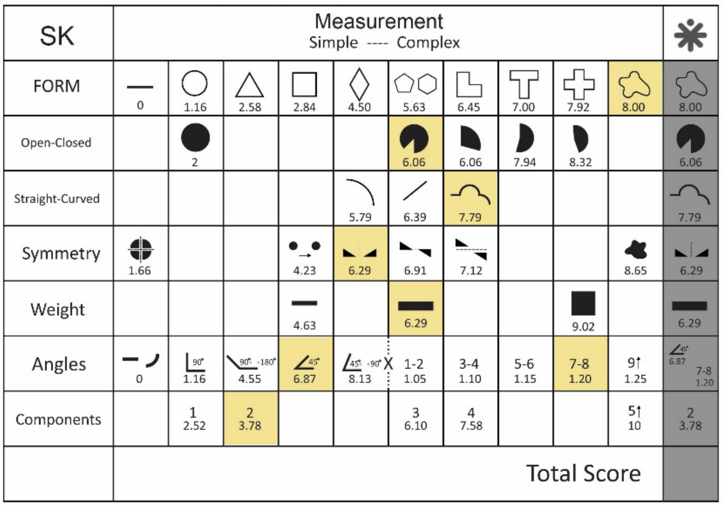


Table 1l: The result of SI.

SI	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	3	0	0	6	28	0	0	0	3
OPEN-CLOSED	0	19	0	0	0	16	4	1	0	0
STRAIGHT-CURVED	0	0	0	0	3	12	25	0	0	0
SYMMETRY	3	0	0	1	3	13	16	0	0	4
WEIGHT	0	0	0	2	0	28	0	0	10	0
DEGREE/NUMBER OF ANGLES	1	1	27	8	3	5	5	3	15	11
COMPONENTS	0	0	7	0	0	28	3	0	0	2

SI	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	5.63
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				7.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	7.12
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	5.46
COMPONENTS		2.52	3.78			6.1	7.58			10	6.1
										Total	40.39

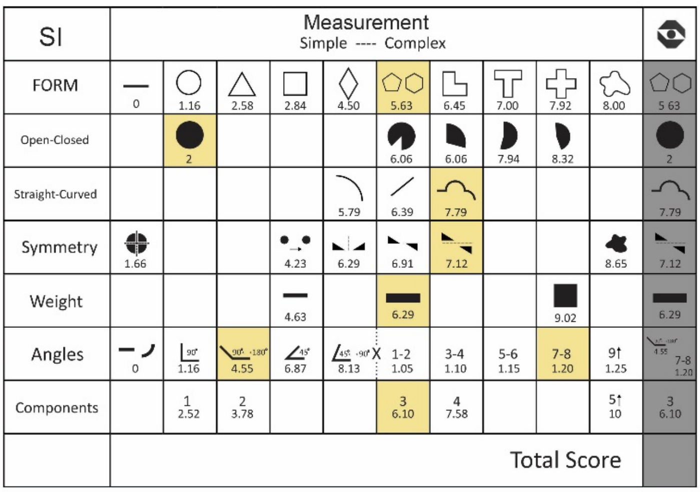


Table 1m: The result of SE.

SE	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	22	0	4	0	1	2	0	1	10
OPEN-CLOSED	0	6	0	0	0	14	9	9	2	0
STRAIGHT-CURVED	0	0	0	0	7	2	31	0	0	0
SYMMETRY	4	0	0	3	12	14	7	0	0	0
WEIGHT	0	0	0	0	0	29	0	0	11	0
DEGREE/NUMBER OF ANGLES	4	30	1	4	1	10	14	8	4	0
COMPONENTS	0	0	8	0	0	26	5	0	0	1

SE	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	1.16
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		6.06
STRAIGHT-CURVED					5.79	6.39	7.79				7.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.91
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	1.276
COMPONENTS		2.52	3.78			6.1	7.58			10	6.1
										Total	35.586

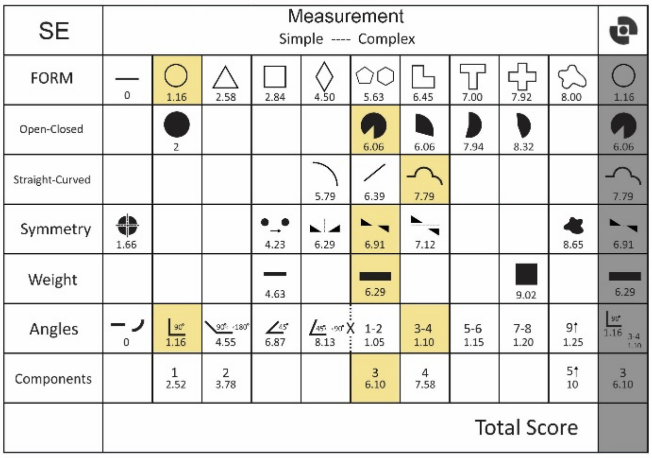


Table 1n: The result of SC.

SC	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	34	1	0	2	1	0	0	0	2
OPEN-CLOSED	0	2	0	0	0	21	8	6	3	0
STRAIGHT-CURVED	0	0	0	0	14	0	26	0	0	0
SYMMETRY	11	0	0	2	22	3	2	0	0	0
WEIGHT	0	0	0	2	0	37	0	0	1	0
DEGREE/NUMBER OF ANGLES	8	3	4	20	5	14	14	2	3	0
COMPONENTS	0	4	28	0	0	0	6	0	0	2

SC	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	1.16
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		6.06
STRAIGHT-CURVED					5.79	6.39	7.79				7.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.29
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	7.2135
COMPONENTS		2.52	3.78			6.1	7.58			10	3.78
										Total	38.5835

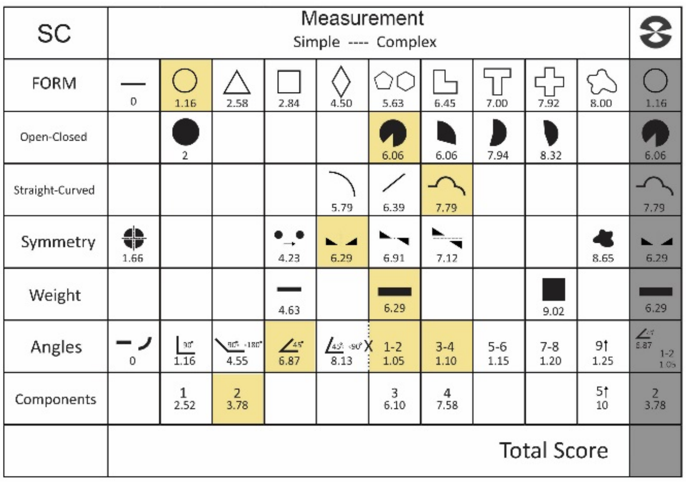


Table 1o: The result of SQ.

SQ	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	22	11	0	1	0	0	0	0	3	3
OPEN-CLOSED	0	12	0	0	0	10	9	2	7	0
STRAIGHT-CURVED	0	0	0	0	1	36	3	0	0	0
SYMMETRY	6	0	0	3	3	18	6	0	0	4
WEIGHT	0	0	0	39	0	1	0	0	0	0
DEGREE/NUMBER OF ANGLES	4	0	2	30	4	0	1	1	28	6
COMPONENTS	0	12	3	0	0	0	0	0	0	25

SQ	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	0
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.91
WEIGHT				4.63		6.29			9.02		4.63
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	8.244
COMPONENTS		2.52	3.78			6.1	7.58			10	10
										Total	38.174

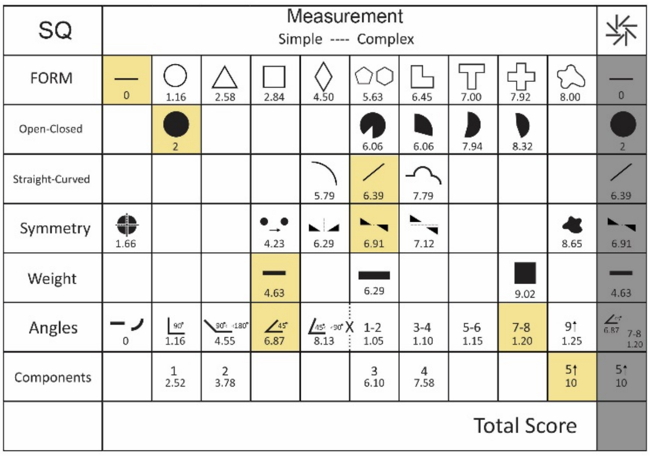


Table 1p: The result of SP.

SP	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	9	2	17	0	0	0	0	0	12
OPEN-CLOSED	0	7	0	0	0	16	5	4	8	0
STRAIGHT-CURVED	0	0	0	0	7	2	31	0	0	0
SYMMETRY	5	0	0	4	4	21	6	0	0	0
WEIGHT	0	0	0	3	0	31	0	0	6	0
DEGREE/NUMBER OF ANGLES	11	21	3	3	2	4	18	1	4	1
COMPONENTS	0	2	1	0	0	1	30	0	0	6

SP	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	2.84
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		6.06
STRAIGHT-CURVED					5.79	6.39	7.79				7.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.91
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	1.276
COMPONENTS		2.52	3.78			6.1	7.58			10	7.58
										Total	38.746

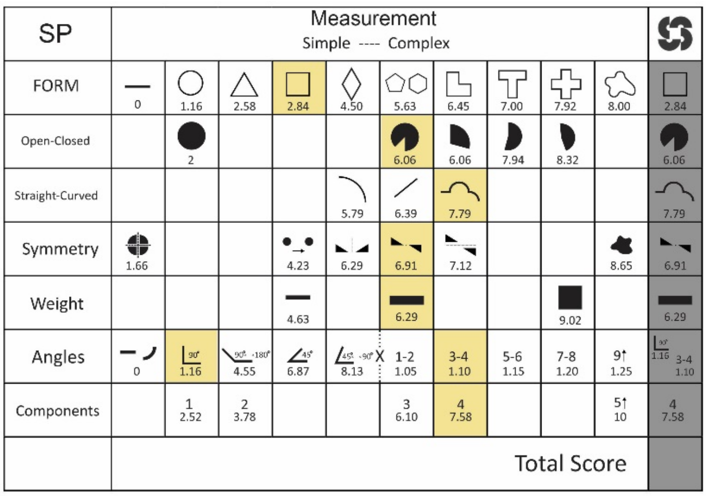


Table 1q: The result of SN.

SN	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	0	36	0	0	0	0	0	0	4
OPEN-CLOSED	0	3	0	0	0	28	5	1	3	0
STRAIGHT-CURVED	0	0	0	0	0	32	8	0	0	0
SYMMETRY	0	0	0	1	6	1	2	0	0	30
WEIGHT	0	0	0	1	0	13	0	0	26	0
DEGREE/NUMBER OF ANGLES	0	2	0	17	21	8	20	1	4	7
COMPONENTS	0	18	22	0	0	0	0	0	0	0

SN	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	2.58
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		6.06
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	8.65
WEIGHT				4.63		6.29			9.02		9.02
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	8.943
COMPONENTS		2.52	3.78			6.1	7.58			10	3.78
										Total	45.423

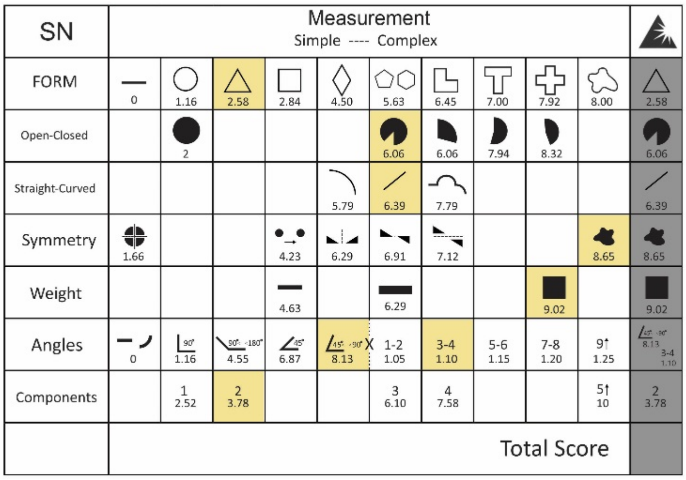


Table 1r: The result of SX.

SX	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	0	0	30	0	0	8	0	1	1
OPEN-CLOSED	0	30	0	0	0	3	6	1	0	0
STRAIGHT-CURVED	0	0	0	0	0	38	2	0	0	0
SYMMETRY	0	0	0	9	5	6	1	0	0	19
WEIGHT	0	0	0	12	0	26	0	0	2	0
DEGREE/NUMBER OF ANGLES	2	37	0	0	1	0	10	3	3	21
COMPONENTS	0	2	1	0	0	33	2	0	0	2

SX	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	2.84
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	8.65
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	1.45
COMPONENTS		2.52	3.78			6.1	7.58			10	6.1
										Total	33.72

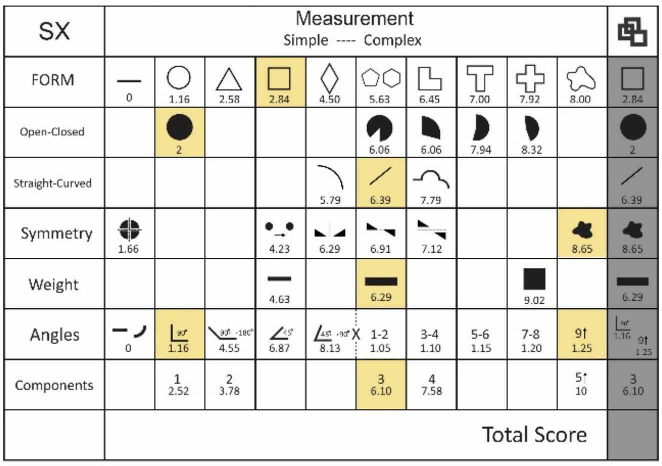


Table 1s: The result of SW.

SW	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	0	0	0	2	37	0	0	0	1
OPEN-CLOSED	0	15	0	0	0	18	5	0	2	0
STRAIGHT-CURVED	0	0	0	0	0	36	4	0	0	0
SYMMETRY	5	0	0	4	8	12	9	0	0	2
WEIGHT	0	0	0	5	0	34	0	0	1	0
DEGREE/NUMBER OF ANGLES	0	2	24	3	11	4	9	15	4	8
COMPONENTS	0	8	30	0	0	1	1	0	0	0

SW	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	5.63
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		6.06
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.91
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	5.2325
COMPONENTS		2.52	3.78			6.1	7.58			10	3.78
										Total	40.2925

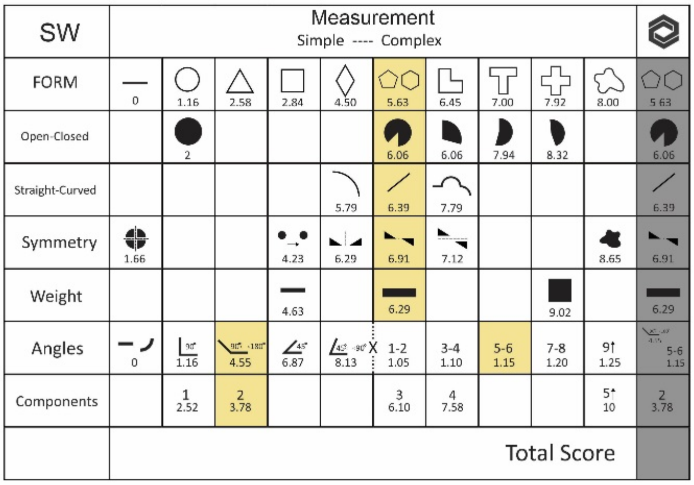


Table 1t: The result of SM.

SM	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	3	3	0	0	34	0	0	0	0
OPEN-CLOSED	0	17	0	0	0	19	2	1	1	0
STRAIGHT-CURVED	0	0	0	0	3	32	5	0	0	0
SYMMETRY	7	0	0	4	3	19	7	0	0	0
WEIGHT	0	0	0	1	0	30	0	0	9	0
DEGREE/NUMBER OF ANGLES	1	7	15	9	8	0	0	1	25	13
COMPONENTS	0	4	0	0	0	1	1	0	0	34

SM	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	5.63
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		6.06
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.91
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	5.46
COMPONENTS		2.52	3.78			6.1	7.58			10	10
										Total	46.74

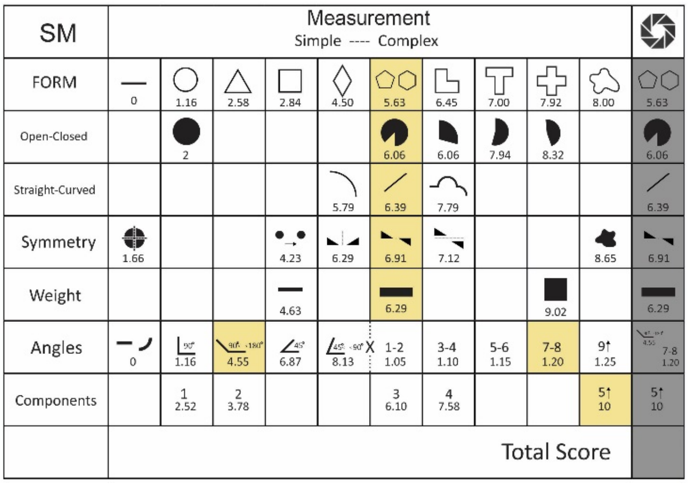


Table 1u: The result of ST.

ST	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	4	0	5	0	7	0	2	17	5
OPEN-CLOSED	0	19	0	0	0	8	4	7	2	0
STRAIGHT-CURVED	0	0	0	0	2	38	0	0	0	0
SYMMETRY	24	0	0	2	7	6	1	0	0	0
WEIGHT	0	0	0	22	0	18	0	0	0	0
DEGREE/NUMBER OF ANGLES	1	10	1	18	10	1	3	26	0	9
COMPONENTS	0	13	0	0	0	21	1	0	0	5

ST	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	7.92
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	1.66
WEIGHT				4.63		6.29			9.02		4.63
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	7.9005
COMPONENTS		2.52	3.78			6.1	7.58			10	6.1
										Total	36.6005

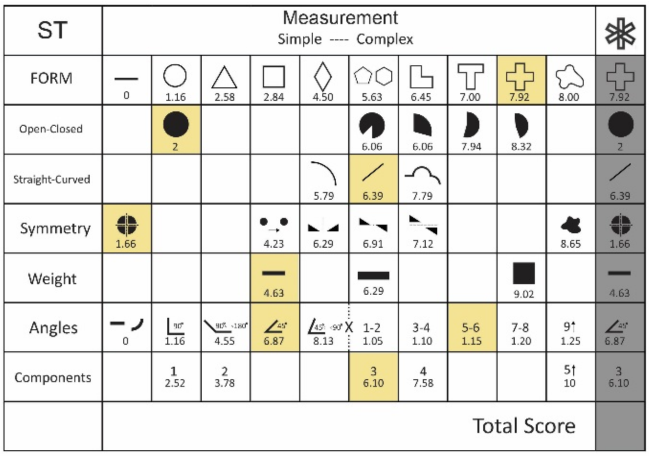


Table 1v: The result of SJ.

SJ	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	1	0	27	0	1	0	0	3	8
OPEN-CLOSED	0	34	0	0	0	2	4	0	0	0
STRAIGHT-CURVED	0	0	0	0	2	5	33	0	0	0
SYMMETRY	4	0	0	1	2	1	5	0	0	27
WEIGHT	0	0	0	14	0	21	0	0	5	0
DEGREE/NUMBER OF ANGLES	1	36	2	1	0	2	24	0	2	11
COMPONENTS	0	2	3	0	0	1	8	0	0	26

SJ	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	2.84
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				7.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	8.65
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	1.276
COMPONENTS		2.52	3.78			6.1	7.58			10	10
										Total	38.846

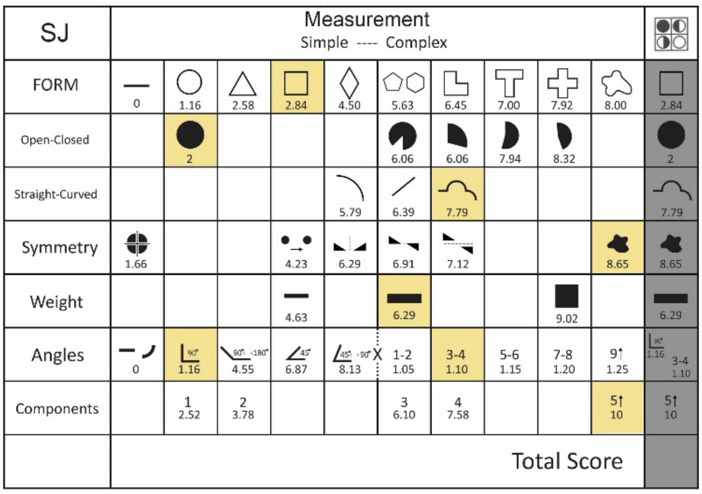


Table 1w: The result of SG.

SG	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	2	36	0	0	0	0	0	0	0	2
OPEN-CLOSED	0	14	0	0	0	17	3	4	2	0
STRAIGHT-CURVED	0	0	0	0	34	0	6	0	0	0
SYMMETRY	2	0	0	2	3	22	9	0	0	2
WEIGHT	0	0	0	10	0	30	0	0	0	0
DEGREE/NUMBER OF ANGLES	31	3	3	2	1	0	9	1	0	0
COMPONENTS	0	8	5	0	0	0	22	0	0	5

SG	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	1.16
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		6.06
STRAIGHT-CURVED					5.79	6.39	7.79				5.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	6.91
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	0
COMPONENTS		2.52	3.78			6.1	7.58			10	7.58
										Total	33.79

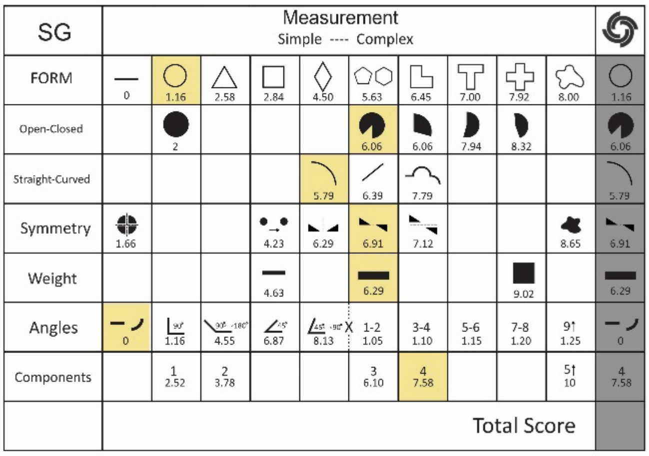


Table 1x: The result of SV.

SV	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	0	3	0	4	1	11	0	0	13	8
OPEN-CLOSED	0	17	0	0	0	10	5	5	3	0
STRAIGHT-CURVED	0	0	0	0	2	35	3	0	0	0
SYMMETRY	12	0	0	2	5	12	3	0	0	6
WEIGHT	0	0	0	13	0	27	0	0	0	0
DEGREE/NUMBER OF ANGLES	1	12	0	15	12	1	0	22	1	15
COMPONENTS	0	13	4	0	0	14	1	0	0	8

SV	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	7.92
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		2
STRAIGHT-CURVED					5.79	6.39	7.79				6.39
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	1.66
WEIGHT				4.63		6.29			9.02		6.29
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	7.9005
COMPONENTS		2.52	3.78			6.1	7.58			10	6.1
										Total	38.2605

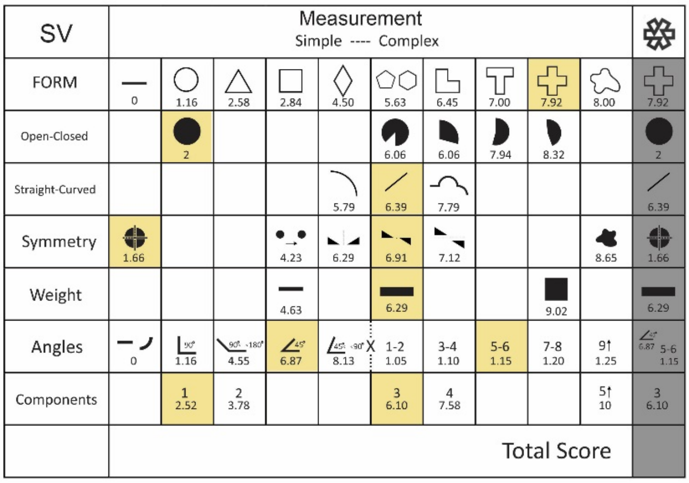
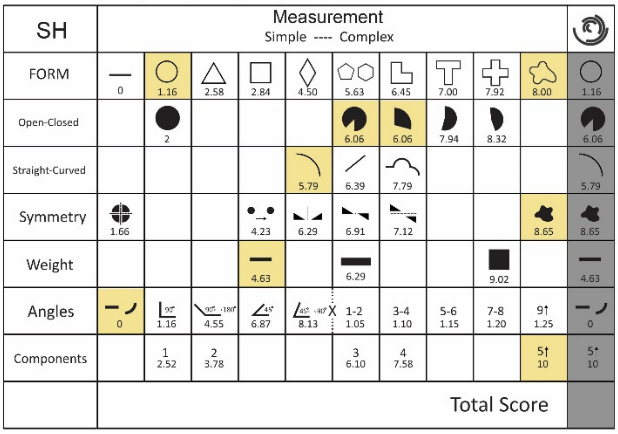


Table 1y: The result of SH.

SH	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10
FORM	2	20	0	0	0	0	0	0	0	18
OPEN-CLOSED	0	5	0	0	0	12	12	1	10	0
STRAIGHT-CURVED	0	0	0	0	30	0	10	0	0	0
SYMMETRY	0	0	0	3	0	6	3	0	0	28
WEIGHT	0	0	0	23	0	17	0	0	0	0
DEGREE/NUMBER OF ANGLES	35	0	2	3	0	0	0	3	1	1
COMPONENTS	0	9	1	0	0	1	0	0	0	29

SH	LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5	LEVEL6	LEVEL7	LEVEL8	LEVEL9	LEVEL10	SUM
FORM	0	1.16	2.58	2.84	4.5	5.63	6.45	7	7.92	8	1.16
OPEN-CLOSED		2				6.06	6.06	7.94	8.32		6.06
STRAIGHT-CURVED					5.79	6.39	7.79				5.79
SYMMETRY	1.66			4.23	6.29	6.91	7.12			8.65	8.65
WEIGHT				4.63		6.29			9.02		4.63
DEGREE/NUMBER OF ANGLES	0	1.16	4.55	6.87	8.13	1.05	1.1	1.15	1.2	1.25	0
COMPONENTS		2.52	3.78			6.1	7.58			10	10
										Total	36.29



Samples in Chapter 9 (legibility test)