CREATIVE MENTAL SYNTHESIS
IN DESIGNERS AND NON - DESIGNERS :
EXPERIMENTAL EXAMINATIONS

BY

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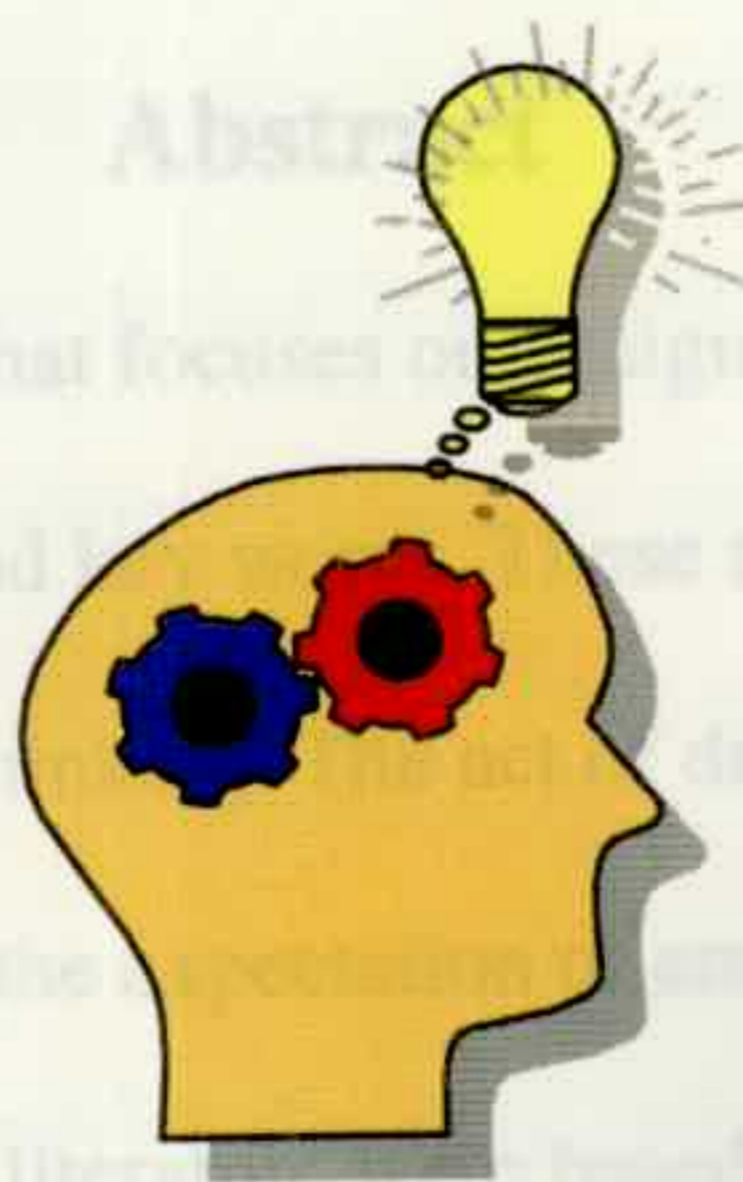
Creative Mental Synthesis in Designers and Non-designers: Experimental Examinations

by
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A Thesis Submitted to the Department of Architectural and Design Science,
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Abstract

A review of the design literature that focuses on design thinking reveals some common and consistent themes and key words. These are as follows: Creation-Synthesis-Manipulation-Visual Thinking. The act of drawing is also considered to aid the design thinking process, with the expectation of emergent ideas. A great deal of the views expressed in the design literature were based on introspection and anecdotal evidence, conversely this research examined design issues of creativity, mental synthesis, and drawing by conducting two experiments. These experiments used empirical methodologies, comparing and contrasting 3D designers, 2D designers, and Non-designers.

The first experiment investigated if designers were more creative than non-designers when given either 2D or 3D creative mental synthesis tasks. The results revealed they were. Additionally, with respect to 2D creative mental synthesis tasks, this first experiment examined issues of correspondence between a written description of a form and a drawn image of the form. With respect to 3D creative mental synthesis tasks, this first experiment also examined issues relating to the practicality of inventions. The results revealed design abilities may be in part tied to familiarity with sets of forms characteristic of the disciplines concerned.

The second experiment investigated the relationship of drawing and creative mental synthesis. Contrary to the widely held views expressed in the design literature, mentally resolving creative mental synthesis problems is more potent than generally given credit. Using the expert strategy of separating ideas from the embodiment of ideas substantially increases creative output for all subjects. Consequently, the results

revealed that how and when drawing is used in the design thinking process is very important. This has implications for design in that drawing and design representation appears to play a central role in the design thinking process.

Keywords. Mental synthesis, creativity, drawing, design, design representation, design-thinking research

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Contents

List of Tables & Figures

Chapter 1 Introduction

This research will build upon the body of knowledge relating to design thinking and the design thinking process. Central to the design process is an ability to mentally formulate a plan or solution to a design problem. Using an internal visual language that represents external forms, a designer manipulates these representations as a way of reasoning solutions to a design problem. These internal visual manipulations are thought to play a key role in design problem resolution.

It can be argued that design happens in the mind. In a range of design professions it is a generally accepted view that designers must be able to visualize their work in their minds. There are also indications that designers are able to manipulate mental images as a way of developing a design. In the creation of new forms and artefacts, designers visualize in the mind the design of the form/object and parts of the object. This seems to involve storing, retrieving, and manipulating a repertoire of mental images of shapes and forms in order to synthesise them thus creating a new form/object. Essentially this can be termed creative mental synthesis. However, while this has been a generally accepted view for sometime, it does not imply that it has been empirically validated. On the contrary, a great deal of the design literature discussing design thinking is based on introspection and anecdotal evidence. Consequently, there is a need to use a more systematic methodology in order to validate the views expressed in the design literature relating to creative mental synthesis. Muller (1989) suggested an educational need to investigate the capabilities of designers with respect to the mental manipulation of shapes in design.

In addition, the design literature reveals strongly held views that the act of drawing assists creative mental synthesis. That is to say, designers, using the act of drawing, can mentally manipulate imagined forms, and generate new creative forms based on these imagined forms. This should be explored using more empirical methods.

The reliance a designer places on the act or drawing was described by Schon & Wiggins (1992), who state the following:

> " A designer sees, moves and sees again. Working in some visual medium - drawing, in our examples - the designer sees what is 'there' in some representation of the site, draws in relation to it, and sees what has been drawn, thereby informing further designing." (Page 135)

The statement above suggests the designer not only generates an internal representation of what is visually presented, but via drawing responds to what is visually presented and is able to generate an external representation of what is seen. Designers place a heavy reliance on the visual language of drawing. It is important in that drawings are representations of the internal imagery that is generated.

Others believe that drawing, visual thinking, and visual reasoning play a major role in the design process. Tovey (1989) contends the following:

> " Seeing involves receiving visual information and interpreting it according to certain codes, conventions and stereotypes. Imagining is an internalized vision of seeing, using similar codes and conventions. Drawing is an externalized equivalent of imagining and seeing. The three activities work together complementing each other and encouraging purposeful and productive visual thinking." (Page 25)
> " Drawings and 3D models are languages for handling design ideas. The actual process of creating design ideas goes on in the mind, and the drawings and 3D models are attempts to reproduce the designer's mental images." (Page 25)

A similar view is held by Muller (1989) when he states the following:

" The design phase of the product development process can be considered the stage in which verbal starting points are transformed into an initial physical representation. This tentative definition of solutions requires visio-spacial thinking expressed in images resulting both from and in representations of a two-and three-dimensional nature. Sketches, drawings and models are indispensable elements in this stage, though as a design-technical means the emphasis is on their effective use in order to generate and develop solutions. A certain ability for the rendering of three-dimensional representation must therefore be seen as an indispensable skill for a designer." (Page 14)

This visual type of communication seems to play a pivotal role in the working life of designers for use in two-dimensional and three-dimensional representations of their thoughts. The drawings are a means of communication with themselves [designers] and others while developing a design. The design literature suggests ideas flow from observing drawings.

Design research relating to visual thinking and creative mental synthesis has relied on anecdotal evidence. Since by definition cognitive processes are central to design thinking, the area of cognitive psychology should be reviewed with the aim of adapting and adopting the research findings and the more rigorous research methods used.

Over the past thirty years, extensive research in the area of perceptual psychology that addresses mental manipulation, visual thinking, and creative mental synthesis has been conducted. In a sense it has been travelling parallel to design research, in that some research in these fields address some of the issues in design thinking. Developing a detailed understanding of creative mental synthesis will serve to support design education, and therefore the improvement of design practice. Cognitive processes are central to the process and practice of design. Consequently, it is important that some of these cognitive processes be identified and understood.

In order to explore the role of drawing in design and how effectively drawing might support creative mental synthesis, a systematic approach needs to be applied in lieu of the anecdotal evidence provided in the design literature, which is generally based on the personal experiences of designers.

Equipped with an empirical method [adopted from the area of cognitive psychology] for understanding a designer's creative mental synthesis abilities and strategies, assistance can be rendered to individuals to maximise their potential as a designer. Consequently, this study can contribute significantly to education, in that the methodology developed may be useful as a tool that would assist in moving novice designers [students] towards becoming experts.

1.1 Scope of research

This study will draw upon and review relevant literature from a number of sources around the world which relate to design thinking and the design thinking process.

When conducting experiments the subjects used will be drawn from various universities and design schools from around Australia.

While it is understood that some very complex design problems can be considered in long-term design projects, this study will focus on short-term creative mental synthesis activities and problems. Further, a core purpose of this study was to locate and adopt/adapt appropriate empirical research methodologies from beyond the design literature, which did not require protocol analysis [Specifically this study used

creative mental synthesis methodologies], and place them in a focused design context. Consequently, Two basic types of design type problems [creative mentals synthesis problems] will be used [2D problems and 3D problems].

1.2 Method

In order to systematically investigate the creative mental synthesis abilities of designers and non-designers, an initial experiment is proposed. The basic research strategy is to combine the experimental research methods in cognitive psychology [specifically the methods of Finke & Slayton (1988) and Finke (1990)] using a mix of subjects from different backgrounds [Industrial design - Visual Communications - Law]. A study using all three types of subjects would allow a comparison between and among designers who are practiced in two-dimensional work, designers who are practiced in three-dimensional work, and non-designers. In addition to the using three types of subjects, the study included two different types of problems (2D &3D), as there are two-dimensional designers and three-dimensional designers. However, in adapting the methods of Finke & Slayton (1988) and Finke (1990) some aspects of the methods needed modification.

In order to systematically investigate the relationship between drawing and creative mental synthesis a second experiment was proposed, again using designers and non-designers. In their work Anderson & Helstrup (1993) found virtually no difference in the number of creative figures when subjects were allowed to use drawing to aid in creative mental synthesis tasks and when they were to use mental imagery alone. This is contrary to strongly held views found within the design literature. This would suggest that drawing does not aid in solving creative mental synthesis problems.

However, they [Anderson & Helstrup (1993)] did not investigate the nature of the

drawing strategies used by the subjects. Therefore the basic research strategy in the

second experiment will be to combine the experimental research methods in cognitive

psychology [specifically the methods of Finke & Slayton (1988), Finke (1990) &

Anderson & Helstrup (1993)] using a mix of subjects from different backgrounds

[Industrial design - Visual Communications - Law] and drawing strategies. The main

difference will be the explicit directions of how and when drawing is used to aid in

creative mental synthesis tasks. In order to investigate different drawing strategies and

creative mental synthesis, various drawing instructions will be developed in order to

control how and when the drawing activity occurs.

If some of the subjects were practiced, by virtue of their university training, and some

were not trained and therefore less practiced in using drawing to aid in creative mental

synthesis, differences should be expected in creative mental synthesis abilities and

drawing strategies between the different groups of subjects.

1.3 Objectives of the Research

The purpose of this study is to research, develop, and use a systematic and empirical

approach while investigating core issues in the design thinking process. This study

will focus on the core issues of creative mental synthesis and drawing. By adopting

and adapting accepted research methodologies from specific areas within cognitive

psychology this thesis will demonstrate the importance of using these methods in

order to move design-thinking research forward beyond introspection and anecdotal

evidence.

The objective measures used will reveal findings, relating to themes commonly found in the design literature concerned with design thinking. In doing so this thesis will extend the debate regarding core issues in design thinking in a rigorous way, thereby adding to the body of knowledge on the subject of design thinking. This thesis will suggest future areas of research and possible experiments that may overcome limitations that may arise.

1.4 Thesis Outline

Chapter two presents and discusses the literature that offers a relevant background and framework to this study. In order to progress this research it was necessary review the relevant literature in both design thinking and cognitive psychology. While chapter two is divided into six sections or parts, the review focused on these two main bodies of literature.

Chapter three describes and details the design of the first experiment. The first experiment was based on empirical methodologies found within specific areas of cognitive psychology. The experimental design was adapted and modified from the original study in order to suit this study.

Chapter four presents the results of the first experiment. In reviewing the results, issues with respect judging the responses generated by the subjects were identified. As a consequence the responses needed to be rejudged by a new set of judges, with new judging criteria and new judging instructions. The results based on the new judgements are also presented.

Chapter five discusses the results of the post-trial questionnaires issued to the subjects in the first experiment. The questions related to the thinking techniques the subjects thought they used when resolving the creative mental synthesis problems.

Chapter six describes and discusses the rejudging of experiment one using new sets of judges. An analysis of correlation between the judgements of these new judges and the results of the earlier judgments is presented. The purpose of this was to investigate the reliability of consensual agreement techniques. In general there was correlation in judgments.

Chapter seven discusses and details the design of the second experiment. The second experiment was also based on empirical methodologies found within specific areas of cognitive psychology. The experimental design was adapted and modified from the original studies in order to suit this study. This second experiment investigated issues that focused on the relationship between drawing strategies and creative mental synthesis.

Chapter eight presents the results of the second experiment in the form of frequency tables. Issues relating to rules of classification and the layout of the spreadsheet are also discussed.

Chapter nine discusses the results of the post-trial questionnaires issued to the subjects in the second experiment. The questions related to the thinking techniques the subjects thought they used when resolving the creative mental synthesis problems.

Chapter ten, in general terms, discusses the findings, implications, and limitations of this study. In addition, chapter ten discusses possible future studies and presents some concluding remarks relating to this study.

Chapter 2 Literature Review

2.1 Introduction

The purpose of the literature review is to draw upon a wide range of literature from apparently diverse subject areas, thereby establishing the background context for the research to be presented. Synthesising the common elements of that literature serves to lay a foundation for the research to be reported.

In reviewing the design literature it is clear there is virtually no work, which integrates and empirically investigates issues of *creativity, mental imagery, mental synthesis, and drawing*, with respect to creating new designs. These central themes in the design literature, generally exist either alone, as separate issues, or as a combination of two themes (i.e. Creativity & Drawing), depending on the context of the research. Consequently, the search for relevant literature had to be widened.

Several diverse domains of research contain relevant studies. However, the primary literature is the design research pertaining to the design thinking process. This is particularly true of the design studies with their focus on visual thinking. Since a major part of the visual thinking process in design is drawing, it is seen as a relevant issue and included in this literature survey.

Since topics such as visual thinking and design thinking suggest some underlying internal mental process, the cognitive psychology literature was considered as a potential source of information relevant to this research.

These fields of research have a bearing on this research, as the intent is to develop a clearer understanding of the visual thinking processes utilised by designers and non-designers. This in turn will aid in advancing the design activity in general, (and design education specifically). Understanding the visual thinking abilities and strategies utilised by designers and non-designers as they create objects remains a key area in need of research.

While the central interest of this research was creative mental synthesis, the following serves to highlight how several supporting themes, found within the subsequent literature review, are related. To begin with, design is believed by many to be a creative and synthetic activity. This activity generally involves mentally combining shapes to **create new shapes**, which often are not predictable or predetermined. In order to aid in this process of mentally synthesising shapes, it is thought that visual/mental **imagery** abilities combined with **drawing** are necessary in the development or discovery of shapes in designs. Designers provide only anecdotal evidence of this, based on experience. This holds true for designers who work with predominantly two-dimensional shapes [graphic designers, cartoon animators, artist/painters] and designers who work with three-dimensional shapes [industrial designers, architects, engineers, interior designers]. Mental imagery and mental synthesis abilities as well as drawing abilities that support the creation of new shapes, are seen as central in the design thinking process. However, these abilities to designers have not been explored and researched empirically using systematic methodologies.

2.2 Design

2.2.1 Creative Mental Synthesis & Design (anecdotal evidence)

A term borrowed from research in cognitive psychology [see Thompson & Klatzky (1975; 1978)] **mental synthesis** is described as imagining the assembly of a final object or system from component parts. This requires visual/mental imagery abilities or visual imagination. In creating a design solution it is believed that designers use mental synthesis in the design thinking process. Writing about design thinking, Lawson (1980) states:

> *Design involves a highly organised **mental process** capable of **manipulating** many kinds of information, **blending** them all into a coherent set of ideas and finally generating some realisation of those ideas.* [my emphasis not Lawson]. (Page 6)

While the realisation of the design ideas generally results in a tangible artefact, throughout his text he refers to design not in terms of product, but **process**. This belief in a creative, mental, manipulative, synthesising process is consistently found in the design literature. While these are shared views within much of the design literature, they are essentially anecdotal in nature. That is to say they are largely based on designers thinking about, and speculating on, their personal experiences. In addition, the authors generally present these views through case studies, reasoned argument, or the more systematic protocol studies.

For example, in taking a systems approach to their work on the conceptual foundations of design problem solving, Smith & Browne (1993) while applying design theory to systems and management science, develop the argument that design research is concerned with human creations or "artefacts." These artefacts are

obtained by a person exploring "alternatives". These are seen as being precursors to solutions; they are **mentally envisaged possibilities** that problem solvers identify and evaluate. Further they suggest that a designer forms a mental representation ("mental picture ") of aspects of reality in the course of developing and producing the real artefact. This iterative process of exploring alternatives by utilising a **mental synthesis-creation cycle** was described by Hertz (1992), while seeking to develop a coherent description of the design process. Earlier, Lawson (1980), suggested that the mental synthesis process is central in design thinking, and that the output of the design process is generally two-dimensional drawings. However, the designed artefact could be either **two-dimensional or three-dimensional.**

In her work discussing design intelligence, Cross (1986) had shown that the peculiar ways in which designers think is fused in a visual thinking process. She argued that the use of the nonverbal codes or languages (e.g. drawings or three dimensional models), acquired by practice and used by designers, should be recognised as a separate and distinctive type of intelligence in its own right.

Consistently throughout his work presenting case studies of design concerning design thinking, Tovey (1984); (1986); & (1989) indicates this visual thinking process is widely used by designers and plays a major role in the whole design process. Visual thinking forms a part of the creative process of generating new ideas, which leads to the generation of the embodiment of those ideas. He contends that in order to specify and generate a physical form (the embodiment of ideas), an internal visual thinking/spatial transformation process is a necessity. Further he suggests some problems are impossible to solve without visual thinking abilities. He contends that

during the mental activity of thinking our brains manipulate and combine various pieces of information, which have generally been gained through the use of senses (sight sound touch etc...). Hence, he delineates the activity of *visual thinking*, as thinking which uses visual information. He further explains, visual imagination is *creative thinking*, which uses visual information to form new mental images, essentially imagining in the literal and precise sense.

This suggests the same creative mental synthesis theoretical construct that Lawson (1980) uses. Echoing this view is Muller (1989), in his discussion of the design discipline and the significance of visuo-spatial thinking which posited the notion that the design phase in a product development process requires visuo-spatial thinking resulting in two-dimensional or three-dimensional representations. In writing about visual design thinking in architecture, Goldschmidt (1991); (1994) sees visual thinking as central to all designers in many diverse fields from the arts to engineering. Her focus was on the production of ideas, and the visual reasoning driving the ideas, which bring about the creation of a tangible form.

As a way of promoting the notion of visual design thinking, Goldschmidt (1994) presented a case study of an architecture student working on a kindergarten building. The student started with a blank piece of paper. Then they began by writing their signature. This was done several times. The student then noticed an interesting interplay between two curved lines and interpreted them as a possible form the building could take. The next step was to explore these possible forms in conjunction with the L shaped sloping site, followed by the development of the structure of the building, and the stairs etc... Next the student began to develop the three dimensional

aspects of the building and entered a modelling phase. This case served to illustrate the relationship between the figural and conceptual (in cognitive psychology terms analogue and propositional) nature of the design process. The student's internal cognitive process moving the design forward to completion was heavily reliant on a visual means of communication. However, it was not the drawing that most interested Goldschmidt, but the visual thinking process that took place. The drawings were milestones on the mental journey the student took to solve the design problem. It was the internal visual representations and manipulations that ultimately generated the design solution. These internal representations developed into a three-dimensional model. The three-dimensional form of the building did not exist before the student generated it internally. This suggests a visual reasoning ability and some type of strategy to combine forms to make **new** forms. This ability to mentally combine forms to make new forms is by definition mental synthesis. Sometimes the resulting and unexpected new forms created are considered to be creative by others who review/observe them. Therefore, this process can be defined as **creative mental synthesis**.

When exploring the literature other than that of architecture or design generally, visual thinking is deemed to be important in other fields. In writing about teaching visualisation skills to planning students, Cunningham (1995) laments the lack of confidence some planning students have in their abilities to " *visualise*". He sees this thinking skill as one of the core activities in design. He accepts that in and of itself it does not constitute design. On the basis of studio work with planning students, he contends that design is the ability to *create* tangible worlds in the imagination (synthesise/construct worlds mentally) and *realise* them in practice (construct in the

real world). In the field of engineering Ferguson (1993) argues throughout his work

that visual thought is an intrinsic and inseparable part of engineering, despite the fact

it seems to hold a low academic status.

There are common reoccurring terms/themes throughout the literature. These are

presented in Table 1 below. Reading across the rows in the table are terms/themes

attributed to an author. At the bottom of each column is a term, which best describes

the common themes from the authors listed. Whether the authors are writing about

problems with planning students, the thought processes of architects, the thought

processes of industrial designers, or the thought processes of engineers, the common

threads that run through all of their work are as follows: **Synthesis–Creation–**

Manipulation–Visual thinking.

	Synthesis ⬇	Create ⬇	Manipulate ⬇	Visual Thinking ⬇
Lawson (1980)	Blending	Generating	Manipulating	Mental Image
Smith & Browne (1993)	Producing	Construction	Transformations	Visual Representations
Hertz (1992)	Synthesis	Creation	Registration	Mental Picture
Tovey (1989)	Combine	Creative	Juxtapose	Visual Thinking
Goldschmidt (1994)	Synthesis	Creation	Transformation	Visual Thinking
Cunningham (1995)	Synthetic Thinking	Creating	Arranging	Visualisation
Ferguson (1993)	Combinations	Creativity	Arranging	Visual Thinking
	Synthesis	**Create**	**Manipulate**	**Visual Thinking**

TABLE 1: COMMON THEMES

The collective view is that a core ability to **imagine** the **assembly** of a final part (two dimensional or three dimensional) from component parts is important in design thinking. Hence, creating new forms and using mental synthesis abilities (which includes visual thinking) are important in design. However, these views are only supported by anecdotal evidence, which is evidence based on the experience of individual designers or the authors themselves.

2.2.2 Design Thinking and Design Representations

The task of design educators is to help a novice designer (student) become an expert designer (professional). Mathias (1993) found that there were marked differences in the problem solving strategies employed by novice and expert designers. One of these was in the way drawings are used while solving design problems. In his protocol study Mathias found:

* Novice designers tend to use conceptual solution drawings. They focus on holistic solutions early in their work. Conversely, experts tend to use drawing as an aid in **analysis** and the development of first **ideas**. In later stages of the design process experts use drawing and modelling for synthesis.

* Expert designers tend to use sophisticated drawing and modelling techniques. Novice designers use unsophisticated techniques.

Research by Kimbell et al. (1991) concerning secondary education students [novice designers] supports the view that as soon as we begin to perceive the outline of a task, pictures or images of solutions begin to appear in our minds. Kimbell et al. (1991) graphically depict the design thinking /design representation process throughout their work as reflected in Figure 1 below. At first these images or ideas are not well

defined and need to undergo considerable development. Then as thinking moves toward a solution, innumerable possible routes and ideas are investigated in moving toward an optimal solution. They refer to this determined change as **modelling**.
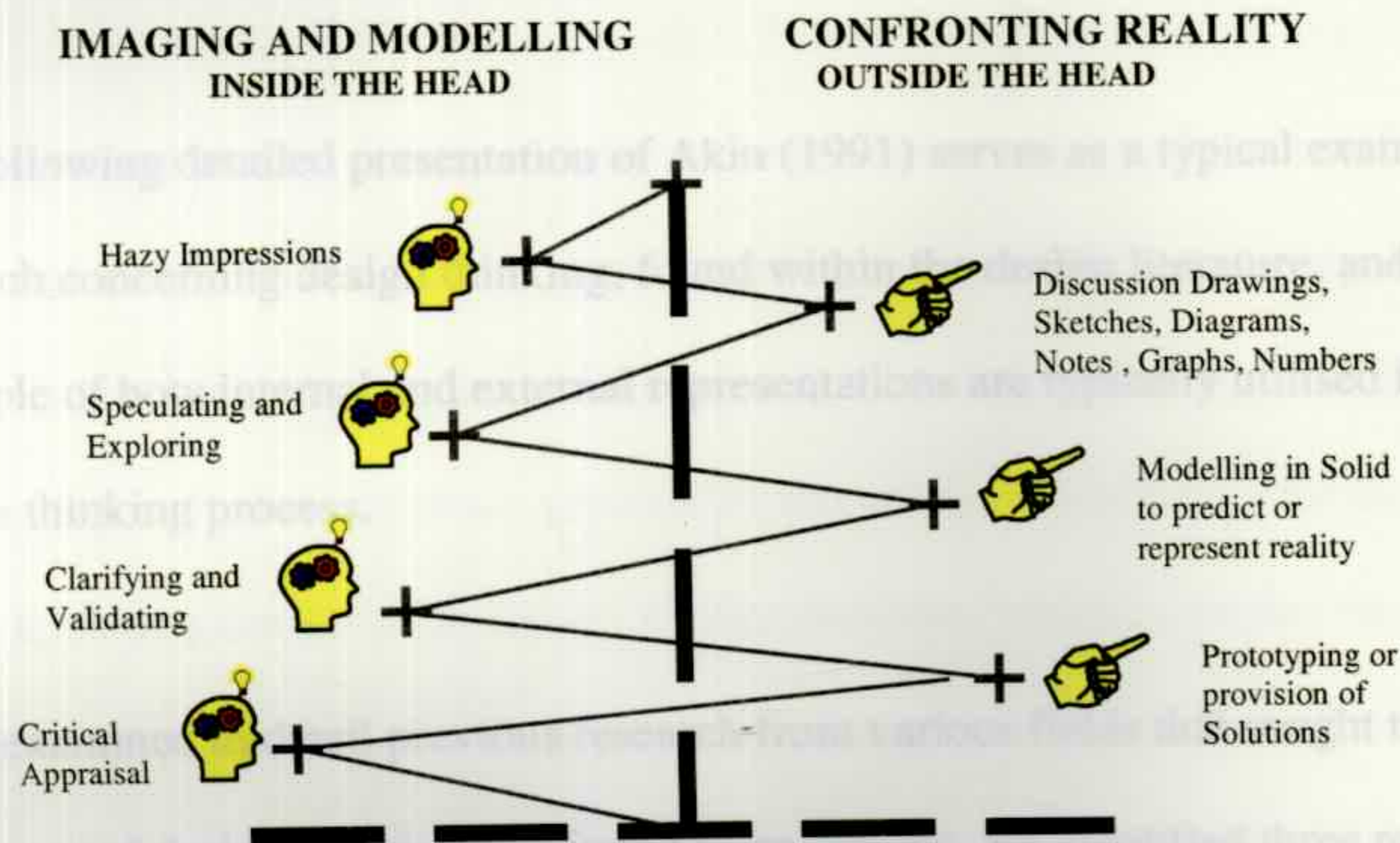
FIGURE 1: INTERACTION BETWEEN MIND AND HAND (KIMBELL ET AL., 1991)

They believe the design process to be a conscious capacity that can be based on both thought and practical activity. They support the notion that this interaction of ideas in the mind with their expression in the concrete world is a common feature of the design thinking process.

Thus far, the literature review has provided a variety of authors who incrementally add to our understanding of the **design thinking / design representation** body of knowledge. However, at this juncture a detailed theoretical framework is necessary for three reasons, 1. To provide an overarching context, 2. Suggest a way forward for more rigorous examinations of design thinking research other than anecdotal evidence 3. Reinforce our understanding of the design thinking/design representations relationship. To that end, Akin (1991) has attempted to develop a detailed theoretical framework for the design thinking process that appears to parallel the work of

Kimbell et al. (1991). His detailed research, based on an analysis of the design process, also demonstrates the notion of progressing a design by moving between internal and external representations.

The following detailed presentation of Akin (1991) serves as a typical example of research concerning design thinking, found within the design literature, and as an example of how internal and external representations are typically utilised in the design thinking process.

Akin examined in detail previous research from various fields that sought to address the issues of design thinking and found them lacking. He identified three reasons for this:

1. There was a lack of clarity in the research.

2. There was a lack of shared tools, methods and theories.

3. There seemed no common purpose between the studies.

He further argues that previous studies which lay claim to a theoretical foundation for design thinking are either derived from outside the area of design thinking, or the theories are so specific they cover only a very narrow aspect of design thinking. Akin contends that a strong theoretical framework should be developed. These were the motivating factors that led him to develop a theoretical framework for design thinking. The parameters he set for the theoretical framework were as follows:

1.) That it be explicitly based on design phenomena and involve the manipulation of design information by a designer during a design related task including some of the basic subtasks of design.

2.) That it is operational, representing all aspects of information manipulation found under design thinking and allows for formal

descriptions of the phenomena including computation, algorithms or formal proofs.

3.) That it is extendable to all important aspects of design including generation, evaluation, and selection of designs, formulation of design problems, and so on.(Akin 1991)

To understand clearly Akin's work let us review some of his definitions of key phrases at this point. He defines *design thinking* as the totality of the cognitive activities that occur during design. His view is that *design reasoning* is distinguished from intuition by the conscious, predictable use of rules of inference for the purposes of manipulating design information. *Design intuition*, which is another facet of design thinking, implies manipulations-of a subconscious kind, where the rules of manipulation are not explicit. As design thinking is a comprehensive concept and intuition is in the realm of the subconscious, Akin makes it clear he is concerned with design reasoning.

As a way of exploring design reasoning in order to develop a design thinking theoretical framework, he conducted a protocol experiment. Four senior designers in architecture were given what Akin calls reasoning tasks. The tasks consisted of sets of architectural drawings of modest size buildings that contained nine errors. Three of the nine errors were errors of commission (modified bracing, structural beams, or insulation errors), there were errors of omission (eg. missing elements of the building) and there were operational errors (eg. doors or windows inappropriately placed with regard to clearances and which could not operate). The subjects had to identify the errors in the drawings. While the subjects were doing this they were to "think aloud" to reveal their mental process. In addition the subjects could make sketches and mark the sets of drawings they were given. To further capture the subjects' reasoning

process they were videotaped for later analysis. The dialogue of the subjects was transcribed as a list of statements, with each statement constituting a single idea.

Analysis of the transcribed statements revealed two major groupings into which the statements could be categorised. The first category is the mental process of evaluating old designs (unaltered drawings and designs). The next category is the mental process of generating new designs (changed drawings and designs). It was noted that in either the **generative** or **evaluative** sections of the transcripts, each statement contributed to the generation of new information based on previous statements. The subjects built sequences of inferences, constructing ultimately a reasoned explanation of a solution to the problem.

Further analysis of the transcripts indicated what Akin called different domains of reasoning. He isolated three such domains, the *objective domain*, the *representation domain*, and the *construction domain*. The objective domain is taken to mean that knowledge which is brought into the reasoning process. That is, knowledge that consists of principles of the objective world. What Akin called the representation domain deals with representations brought into the reasoning process such as drawings, words and gestures used to describe concepts of the designs to themselves and others. It was found that once the problem was identified and understood, the subjects' domain of reference shifted. Having an understanding of the problem, gained from evaluating old designs, the subjects began utilising inferences in the construction process. Representations made the pertinent properties of the objective world become clear. In addition special knowledge of physical principles was brought out utilising representations to explain the objective world. Once a problem

was identified the subject's domain of reference shifted to what is considered a

construction domain. That is, where the designer is manipulating surrogate lines on

paper, and words, to understand the manipulation of real objects. This process is

represented diagrammatically in Figure 2 below, where the representational domain

has a pivotal role in connecting the operations of the other two domains.
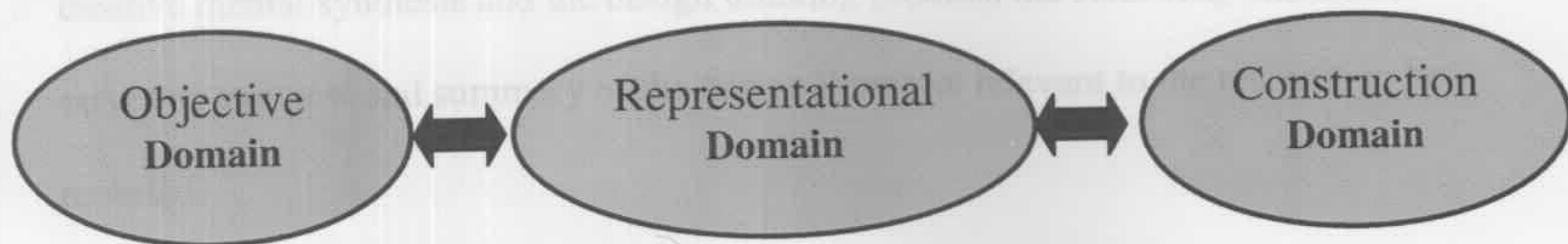
FIGURE 2: DOMAINS [AKIN 1991]

Once a possible solution was constructed attention shifted to the objective domain,

where utilising the representation domain subjects mentally manipulated the newly

generated information or geometry for verification of the solution. These mental

manipulations of the representations seem to play a pivotal role in the design

reasoning process, as Akin found that the subjects used the representation domain as a

way to express the objective domain and the construction domain. Akin concluded

from his protocol study that a designer mentally manipulates surrogate forms as a way

of exploring a design.

While Akin used expert designers in his research, he assumed that experts bring with

them expert knowledge which allows them to solve the problems stressing the

objective domain. This may not be the case with respect to either the expert or the

novice designer. The possibility exists that it is not the knowledge but the

manipulation of representations that plays a central role. If, as he suggested, it is the

representational domain that is central to the design process, then it is important that

these capabilities of the designer be explored. Research with a focus on the

representational aspects of *visual thinking/visual reasoning* abilities needs to be

conducted using empirical methods.

2.2.3 Creative Mental Synthesis & Drawing (summary)

With a view towards contextualising the general role drawing is thought to play in

creative mental synthesis and the design thinking process, the following discussion

serves as a review and summary of the design literature relevant to the research to be

reported.

On a number of occasions, the discussion above revealed the design literature

suggests mental synthesis (which includes visual thinking) is important in the design

thinking process. In addition to that view, the design literature also consistently offers

the view that the act of drawing forms a necessary part of the design thinking process.

The general consensus is that there exists a need for a symbiotic relationship between

the internal mental synthesis process and the external act of drawing to develop a

design or synthesised object. The argument is that in the act of drawing, **discoveries**

can emerge from the drawings and the drawings can both describe and depict the

mental imagery of the designer. This would suggest that it is difficult for creative

synthesis to occur and develop in the mind without the external act of drawing, owing

to the apparently heavy reliance on the discoveries expected from the drawings

[emergence]. The design literature consistently supports the idea of creativity

occurring through discovery by drawing. However, this view is largely supported by

anecdotal evidence and is generally based on personal experience.

A typical example of the ideas posited by Akin (1991) and Kimbell et al. (1991) can be found in Goldschmidt (1994), who, as mentioned earlier, explored the visual reasoning process of an architecture student working on a kindergarten building. Her work pointed to the ability of a designer to use two-dimensional representations as a starting point, then internally generate images, inspect these images, maintain the images, manipulate the images, then add new images to generate a new solution.

A good deal of design literature is similar to Goldschmidt (1994). The similarity rests in the view that designers tend to focus on visual communication in exploring design solutions. Laseau (1980) describes quick drawing techniques, such as graphic thinking, which aids communication between the mind and the hand. Mckim (1980) also supports this view by saying " *Visual thinking employs three kinds of visual imagery: the kind we see, the kind we imagine, the kind we draw*".

In his work on drawing and cognition, while discussing the pragmatics of everyday graphic production, Van Sommers (1984) alluded to the notion of a graphic language when he had shown the proximity of what he called 'private drawing' to mental imagery. He had developed a diagram, illustrated in Figure 3 below, which depicts two types of communication [A] verbal and [B] pictorial. He suggests these types of communication move [across the diagram] through various phases, which are *public presentation, private presentation and personal thoughts*. The diagram also suggests that thought can be both pictorial and verbal in nature.

Pointing out that while many graphic acts are social, such as drawing a map on a scrap piece of paper to direct someone who is lost, Van Sommers (1984) contends a

substantial number of drawings or diagrams are not produced for an audience [general public viewing] either at the time of execution, or for other purposes later. They appear to be used as private drawings for organising thoughts (e.g. a man planning to line a ceiling in a basement room uses sketching to investigate how best to cut up a standard sheet of plywood to maximise its use). In a sense these sketches can be equated to someone talking to him or herself.

LANGUAGE			**THOUGHT**
(A)	PRIVATE SPEECH	THINKING IN WORDS	
PUBLIC SPEECH dialogue etc…	Soliloquy, talking to oneself	internal conversation	
PUBLIC WRITING letters, etc…			
GRAPHICS			
(B)	(C)	IMAGERY	
PUBLIC DRAWING	PRIVATE DRAWINGS Recreational Cognitive Expressive		
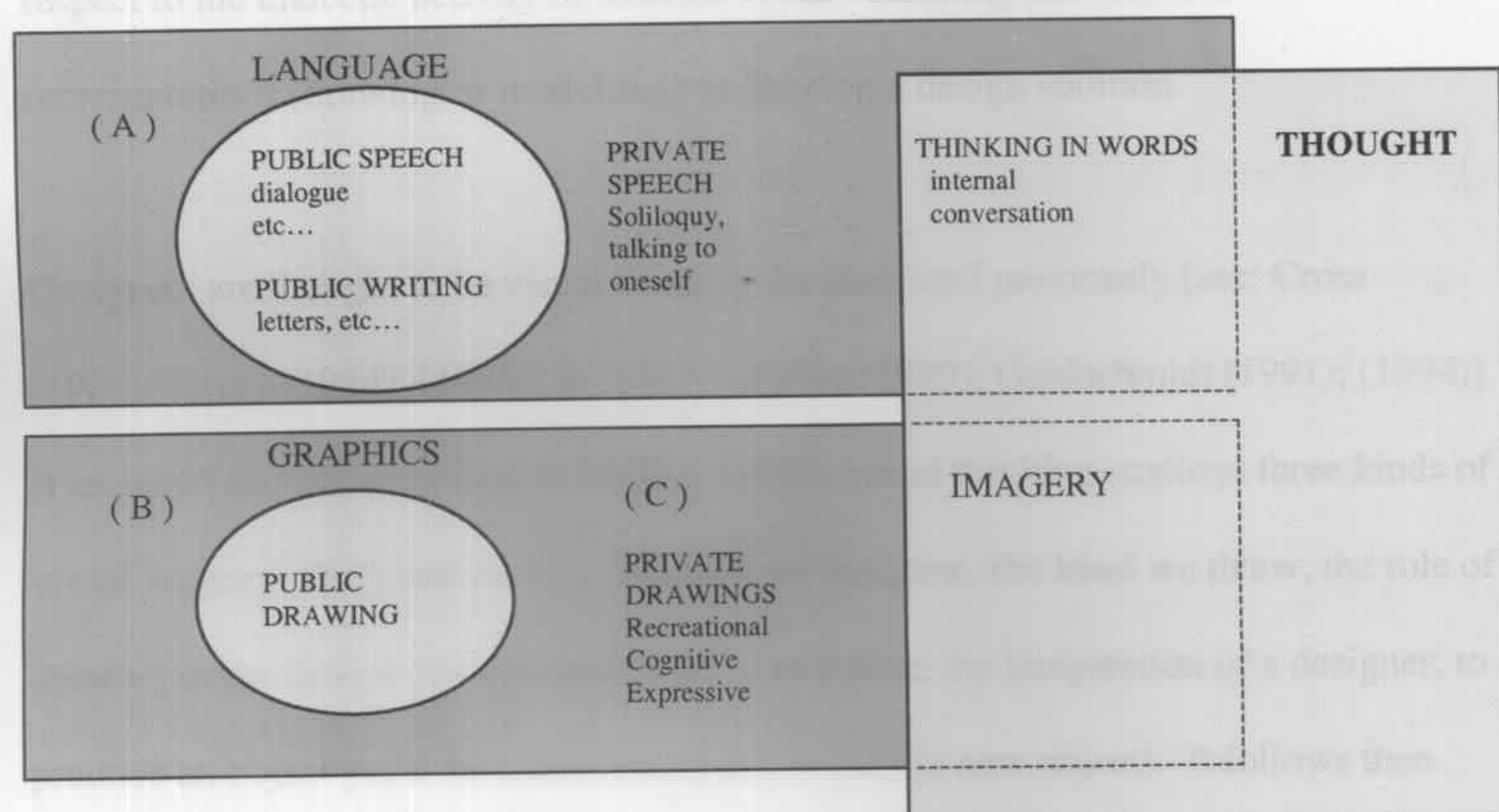
FIGURE 3: DRAWING LANGUAGE & THOUGHT [VAN SOMMERS 1984]

While Van Sommers (1984) explored drawing issues from a general perspective, this symbiotic relationship between drawing and visual thinking with a design perspective, was studied by Herbert (1988) when he investigated the exploratory nature of study drawings as a method of communicating design ideas privately to the designer, and publicly to others. This notion is also put forward by Tovey (1989), when he says " *Drawing is an externalised equivalent of imagining and seeing"*. This is further supported by Muller (1989) who saw the ability to render three-dimensional representations an indispensable skill.

The theme of using drawing to explore design solutions is reinforced by Cross (1991)

when he says: " *Designers explore problem-and-solution, using 'languages' of*

drawing and modelling." Schon & Wiggins (1992) presented the notion that

designers use drawing as a way of communicating with themselves and others to

further their design ideas. The design literature that holds this view is quite extensive.

It is also consistent with the views of Akin (1991) and Kimbell et al. (1991) with

respect to the dialectic activity of internal visual reasoning and external

representations (drawing or modelling) to develop a design solution.

Designers are thought to be visual thinkers, as discussed previously [see: Cross

(1986); Tovey (1984); (1986); & (1989); Muller (1989); Goldschmidt (1991); (1994)].

If as stated earlier, according to McKim (1980) visual thinking employs three kinds of

visual imagery: **the kind we see, the kind we imagine, the kind we draw**, the role of

drawing in the design process should act to stimulate the imagination of a designer, to

produce an object yet to be transformed into reality [a new object]. It follows then

that a personal visual communication relationship between the thoughts of the

designer and the drawings does exist.

Writing about design thinking, the conjecture of Lawson (1980) was that the use of

drawings by a designer was twofold: 1.) Drawings played an integral part in forming

both the end product of a design, and were part of the process of design 2.) Drawing

acted as a kind of additional memory to freeze and store spatial ideas for manipulation

and evaluation.

Later, Schon & Wiggins (1992) held the view that the activity of drawing was an aid to the designer in that it allows the representation of what is "seen" by the designer, to be "moved" and transformed and re-evaluated, thus progressing the design. Consistent with this evolutionary view of design and drawing is that of Nagakura (1990), who believes that the final form of a design does not spring, *sui generis*, nor is a drawing merely its visualisation. He contends the act of drawing helps a designer in that a design can only develop through the interaction of a designer and such a vehicle.

The reliance on drawings used by designers is important from the point of view that it is a representation of internal imagery that is generated. Others believe that drawing, visual thinking, and visual reasoning play a major role in the design process. Tovey (1989) clearly supports McKim (1980) with the view that the act of **seeing** is the interpretation of conventions and stereotypes according to certain codes received as visual information, and using these codes/conventions as an internalised version of seeing forms the act of **imagining**, with the externalised version of both these acts being the act of **drawing**. All three of these acts are seen as working together, complementing each other and encouraging powerful and productive visual thinking. Further, the languages of drawing and three-dimensional modelling are viewed as attempts to reproduce the designer's mental images, and the actual process of creating design ideas goes on inside the designer's mind.

Further illustrating the need for drawing, Muller (1989) conjectured that verbal starting points are transformed into physical representations via sketches and drawings, forming an indispensable part of the design phase of the product

development process, and therefore, a certain ability to render three-dimensional

representations is an indispensable skill of a designer.

The design literature consistently points to a personal visual communication

relationship between the thoughts of the designer and the drawings. Returning to

research by Kimbell et al. (1991), and their diagram (Figure 1) which presents the

view that as soon as we begin to perceive the outline of a task, pictures or images of

solutions begin to appear in our minds. At first these images or ideas are not well

defined and need to undergo considerable development. Then as thinking moves

toward a solution, innumerable possible routes and ideas are investigated in moving

toward an optimal solution. They argue this interaction of ideas in the mind with their

expression in the concrete world is a common feature of the design thinking process.

However, more systematic studies concerning the notion of the mental manipulation

of surrogate designs while using the act of drawing or modelling in the exploration of

a design solution are far from common.

In their very detailed, thorough, and cogent discussion of drawings and the design

process, Purcell & Gero (1998) tease out a number of themes consistent not only in

the design literature but literature further a field. Via reasoned argument, they were

able to demonstrate links between protocol studies found in the design literature with

more empirical studies conducted in the area of cognitive psychology. They argued

that while there is substantial anecdotal evidence in the design literature which related

to the use of drawing as a creative tool in the design process (mostly through

emergent features found in the drawings or as a memory aid), by adopting and

adapting the more empirical methods found in cognitive psychology, the pace of our

understanding with respect to drawing and the design process could be hastened.

Lawson (1980) directed our attention towards cognitive psychology when he said:

> *Of all the questions we can ask about design, the matter of what goes on inside the designer's head is by far the most difficult and yet the most interesting and vital. This leads inevitably into the realm of cognitive psychology, the study of problem solving and creativity, in short thought it (Pg. 94).*

However, it was Purcell & Gero (1998) who detailed a number of possible research directions, by utilising key theoretical issues found in the cognitive psychology literature, with a view to placing them in the context of design. These include, but are not limited to, the relationship between: creative mental synthesis and drawing; creative mental synthesis and expertise; expertise and drawing; working memory and drawing; enacted imagery and drawing. They argue that empirical data is needed particularly between design disciplines. This would hold true, as there are different types and styles of drawing between and among disciplines such as architecture (tending to be both viewer centred, and object centred) interior design (predominantly viewer centred) industrial design (predominantly object centred), and graphic design (predominantly working in two dimensions). Additionally, they raise the question of when and under what conditions (stages in the design process) drawing is more potent between the different disciplines.

2.2.4 Kinds of Drawing [how & when]

While the preceding section, intended as a summary, discussed the role drawing is thought to play in the design thinking process in general, it did not, however, detail issues relating to the *kinds of drawings used by designers*, nor *how and when drawing*

best serves the design thinking process. Therefore, the following discussion will

review the design literature relevant to these issues.

Kimbel et al. (1991) saw drawing as playing a central role in the design process.

However, their work suggests the use of sketches and diagrams occurs at the

beginning of the design process as opposed to being utilised for the embodiment of

those ideas (represented as prototypes towards the end of the design process). This

would suggest that abstract ideas (abstract drawings) are at one end of the spectrum

and concrete forms (realistic drawings and prototypes which embody them) are at the

other end. Reflected in Figure 4 below, McKim (1980) also differentiates between

conceptual externalisations (abstract drawings) that represent abstract ideas, from

representations that represent real forms (realistic drawings and prototypes).

Abstraction

ABSTRACT
GRAPHIC

charts
graphs
diagrams
schematics

CONCRETE
GRAPHIC

orthographic projection
isometric/oblique projection
perspective projection
rough 3D mock-ups
appearance or working models

Reality
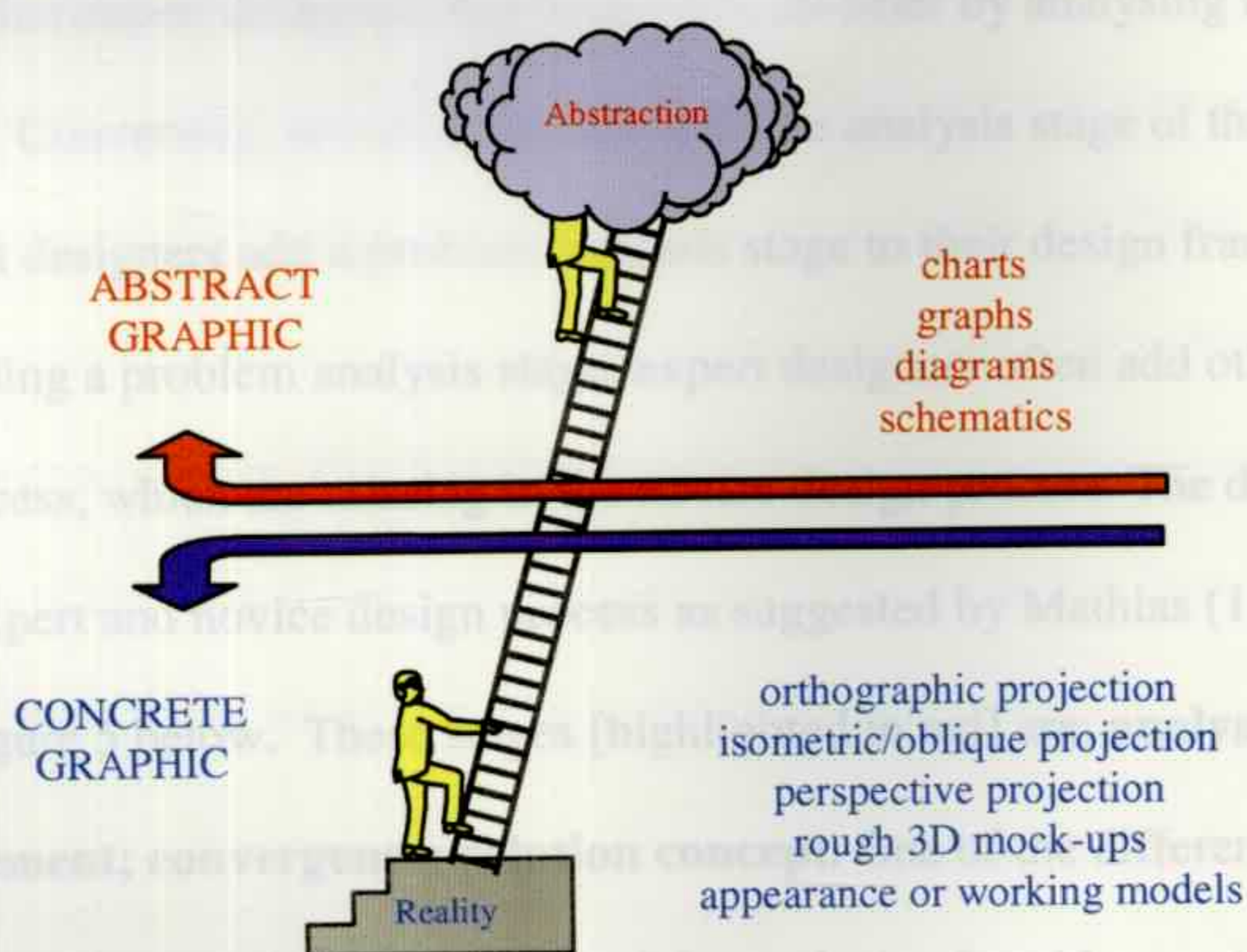
FIGURE 4: ABSTRACT & CONCRETE GRAPHICS [MCKIM 1980]

This dichotomy appears to suggest that if concrete graphic languages are used to

represent abstract ideas they may not be an effective aid, may perhaps even interfere

in the design process. It may be possible that using drawings to focus on the

embodiment of an idea too early in the design process may impede the flow of ideas at an abstract level.

As noted earlier, in his research studying the problem solving strategies of expert and novice designers, Mathias (1993) found that there were marked differences in the problem solving strategies employed by novice and expert designers. One of these was in the way drawings are used while solving design problems. In his protocol study Mathias found:

* Novice designers tend to focus on **holistic solutions early** in their work. Conversely, experts tend to use drawing as an aid in development of **first ideas**. In **later stages** of the design process experts use **drawing for synthesis.**

This suggests that expert designers step back form the brief by analysing it, and may even rewrite it. Conversely, novice designers omit the analysis stage of the design process. Expert designers add a problem analysis stage to their design framework. In addition to adding a problem analysis stage, expert designers often add other stages in the design process, which are missing in the novice design process. The differences between the expert and novice design process as suggested by Mathias (1993) are reflected in Figure 5 below. These stages [highlighted in red] are: **analysis of problem statement; convergence; solution concept.** One of the differences suggested by Mathias (1993) the omission of the analysis of problem statement, tends to lend support to the views found in Kimbell et al. (1991) where it is suggested that it is common for pupils (novice designers) to believe they have a complete solution in their minds from the start.
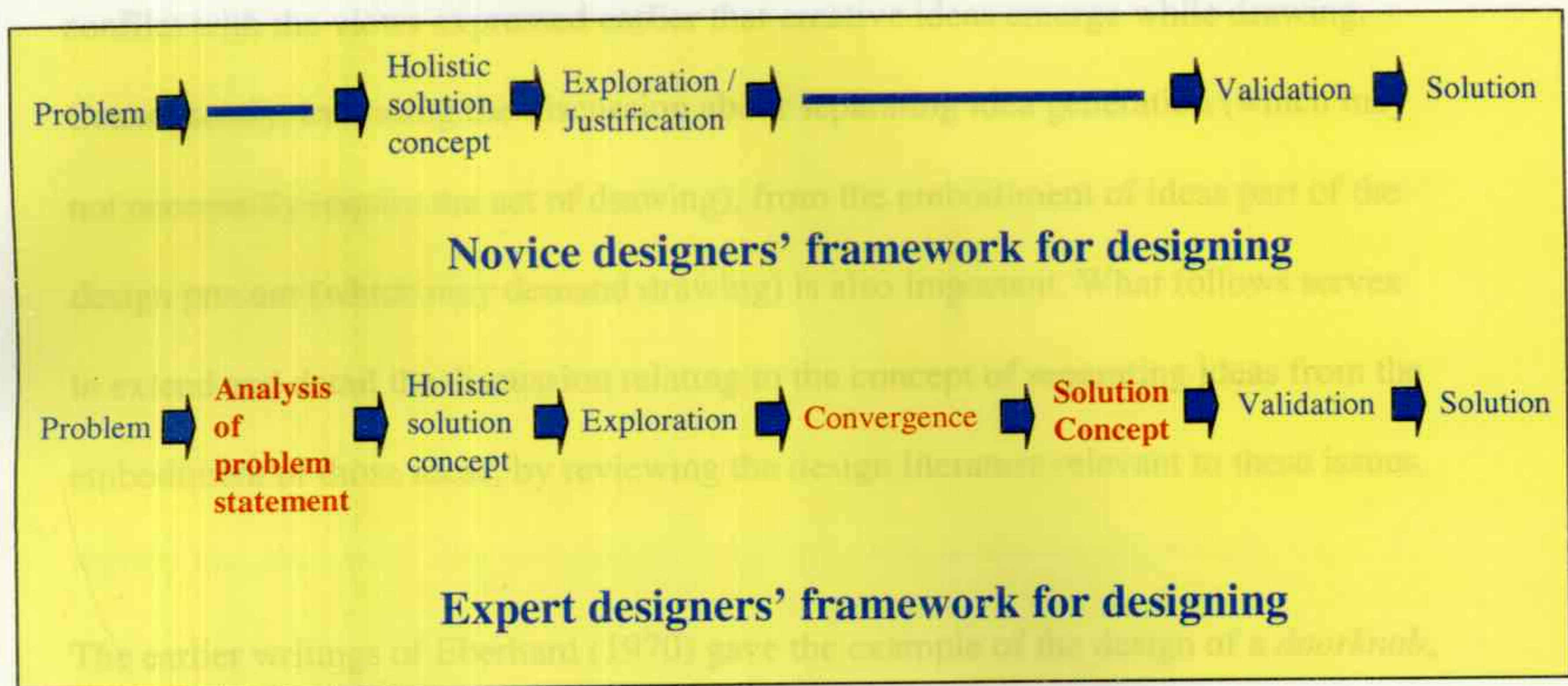
FIGURE 5: DESIGNERS' FRAMEWORK EXPERT/NOVICE [MATHIAS 1993]

The findings of Mathias (1993) concerning the dichotomy between idea creation (at the beginning of the design process) and modelling for synthesis (the embodiment of ideas later in the design process) are consistent with the views of McKim (1980), in that abstract drawing (drawings for ideas) rests at one end of the design process and drawing for reality (embodiment) at the other. It is conceivable that detail drawing or even the act of drawing may not play a large or even necessary role in the initial stages of the design process. This has clear implications for creative mental synthesis in that if the act of drawing is important, as suggested by the design literature, it is equally important to know when and how to use drawing.

2.2.5 Ideas, Embodiments of Ideas & Drawing

The preceding discussion, relating to the design processes used by expert and novice designers, revealed that how and when drawing is used in the design thinking process, and therefore in creative mental synthesis, is important. The premise was that drawing very early in the design process might not be as effective as first thought. This is in

conflict with the views expressed earlier that creative ideas emerge while drawing. Consequently, extending the discussion about separating idea generation (which may not necessarily require the act of drawing), from the embodiment of ideas part of the design process (which may demand drawing) is also important. What follows serves to extend and detail the discussion relating to the concept of separating ideas from the embodiment of those ideas, by reviewing the design literature relevant to these issues.

The earlier writings of Eberhard (1970) gave the example of the design of a *doorknob*, demonstrating that in the design process it is possible to develop a variety of different concepts or ideas (to be divergent/expansive) or to refine one idea in detail, exploring issues relating to that one idea (to be regressive/convergent). It should be pointed out that [as illustrated and highlighted in red text in Figure 5 above] an expert designer tends to reserve the stage of convergence until much later in the design process, in contrast to the novice designer. In his *doorknob* example, Eberhard (1970) argued that expanding the problem allowed the designer to step back from the brief [consistent with Mathias (1993)] and search for alternate possibilities or other ideas. This allows for an increased solution search space. If the designer questioned having a doorknob in the first place this could lead to all sorts of solutions. However, in the regressive mode the designer could not design the doorknob because he wanted to further study the shape of the hand before he could give the doorknob a form or shape (embodiment focused).

Considering the work of Mathias (1993) in the context of the doorknob of Eberhard (1970), if a novice were given the task of designing a doorknob they would tend to embody the doorknob early in the design process. As the novice designers tend to

focus on holistic solutions early in their work, they could synthesise the shapes of a cone and a sphere or a cylinder and a rectangular arm, thus trying to embody the solution early in the design process thereby limiting the search space for ideas. This is illustrated in Figure 6 below, revealing that the focus is clearly on the embodiment of the doorknob. In addition they would use drawing early in the design process to support their holistic embodiments. This is not to say the novice is not being creative, merely that the search space begins to be limited early in the design process.
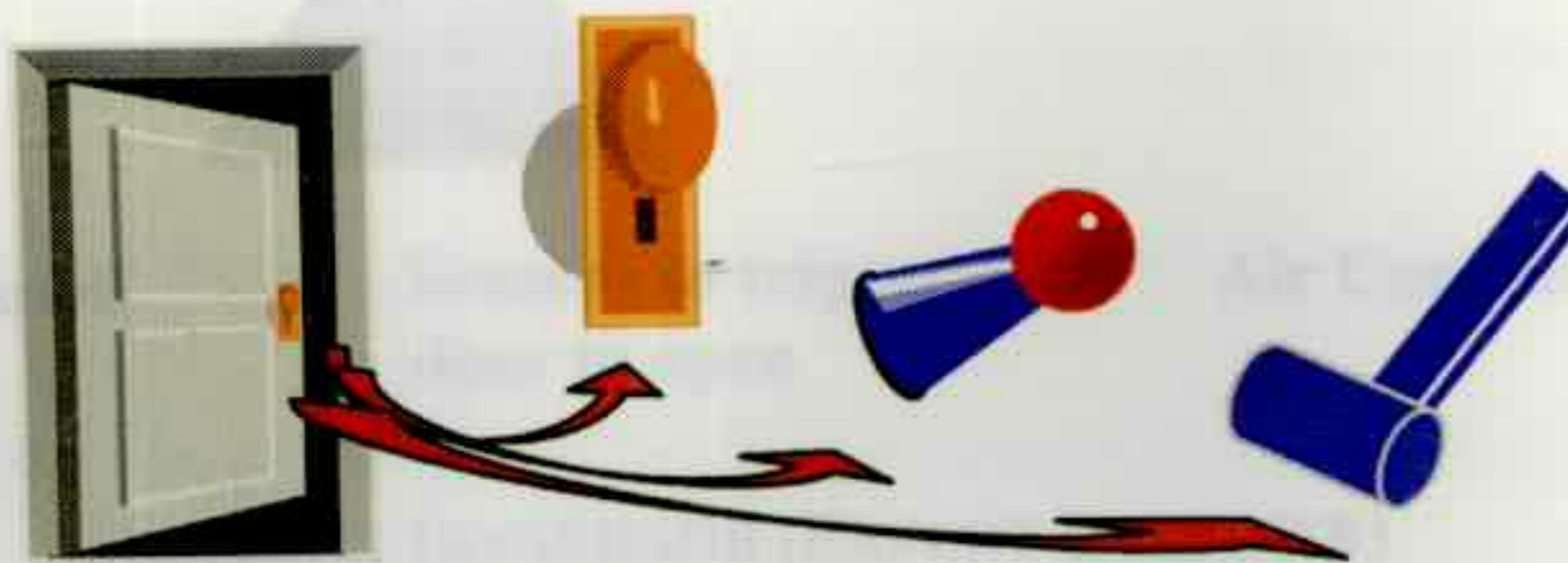
FIGURE 6: DOORKNOB (NOVICE DESIGNER)

Conversely, expert designers would approach the doorknob problem differently, stepping back from the brief, perhaps even rewriting it. They could focus on ideas/concepts rather than embodiment at this stage. They may step back and consider that the problem is really not about a doorknob, but it is about entry into a room. Perhaps a doorknob is not needed. Perhaps a sensor [i.e. a pressure plate or a light beam] could trigger the door to open. Perhaps a door would not be needed at all if a jet of cold air was continually blowing down to separate one temperature-controlled environment from another (i.e. separating a cold indoors from the hot outdoors). These ideas are graphically represented in Figure 7 below to suggest the focus is on concept variety. Clearly, the embodiment of the air curtain is very different to the embodiment of the sensor solution, which in turn is very different from the embodiment of a doorknob. Using the strategy of stepping back from the problem the

expert is able to open up the search space for solutions in contrast to the very narrow embodiment focused strategy of the novice. Therefore, the separation of ideas from the embodiment of ideas in the early stages of the design process (typical of experts) should yield more creative ideas.

Doorknob   **Sensors to trigger**   **Air Curtain**
                      door to open
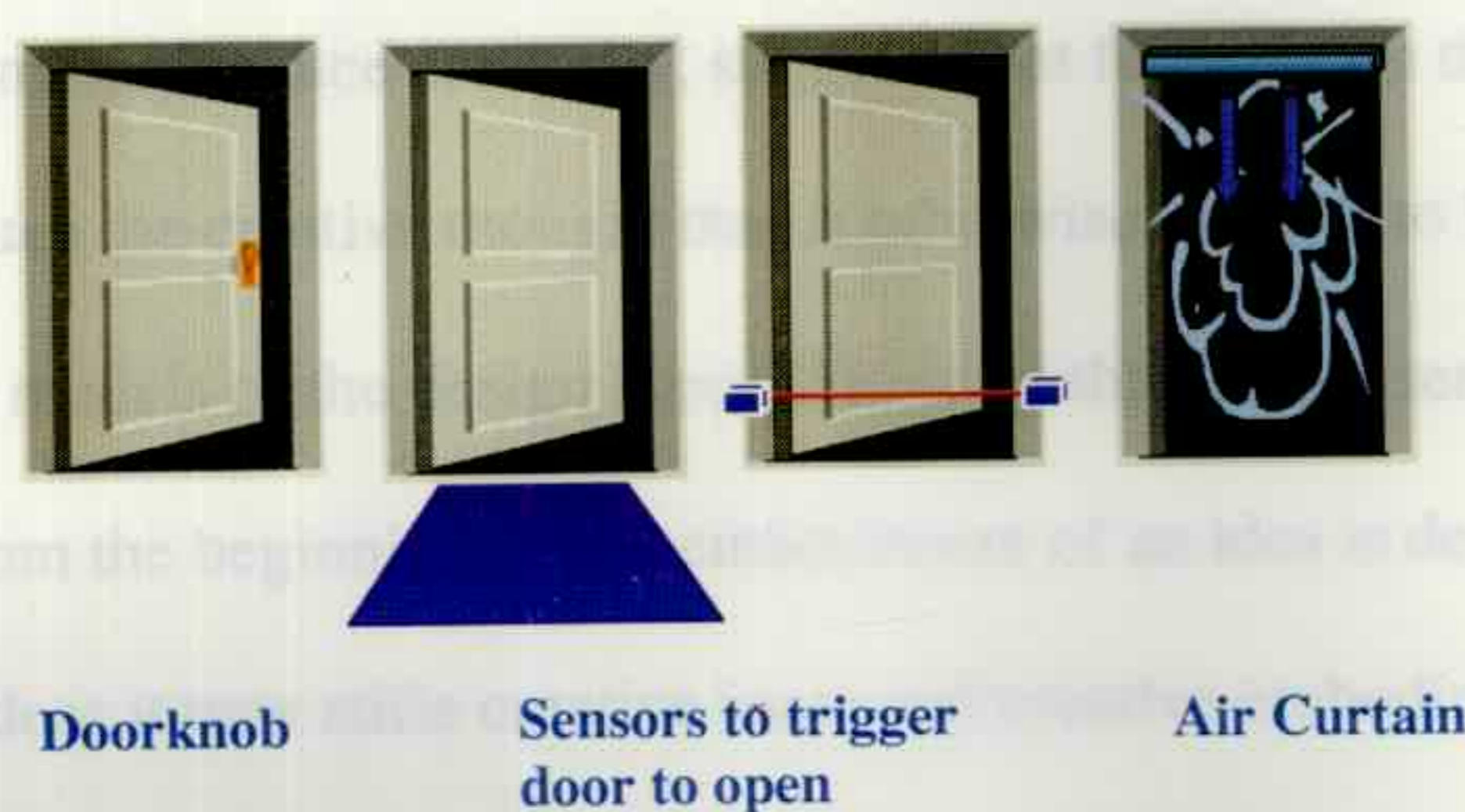
FIGURE 7: DOORKNOB (EXPERT DESIGNER)

Then perhaps it would be better to use drawing for synthesis/analysis in the embodiment stages of design, saving drawing for later in the design process, consistent with experts. This is not to say that drawing is not important, merely that perhaps when and how to use drawing is important.

In sharp contrast, the design literature consistently supports the view drawing is a creative tool, because ideas emerge from the drawings of a designer during the act of drawing. The story goes that Leonardo da Vinci suggested studying stains or spots on a wall, allowing the mind to aimlessly wander to discover ideas which may emerge from the patterns. Drawing is thought to induce this type of emergence or discovery of design ideas [See Goldschmidt (1994)]. Trial and error, and the 'luck of the draw' may not be very productive. While emergence of ideas from the patterns (discovery of ideas from drawings) may occur, it may not be as effective as relying solely on

creative mental imagery to develop ideas. In fact, thinking about the detailed embodiment of ideas may interfere with generating ideas.

Mathias (1993) says, *"The detailed structure embodied in a complex problem may reduce creative thought..." (p. 273)*. This notion that a detailed structure within a complex problem may reduce creativity, suggests that focusing on the details of a design may reduce the creative thought that is otherwise brought to bear on the problem. Many models of the design process suggest that a wide search space should be generated from the beginning. If the embodiment of an idea is developed early in the search for ideas it may stifle creative ideas and creative embodiments of those ideas. Perhaps this is why expert designers add convergence and solution concepts at the end of their design process and not at the beginning.

The clear differences in the design thinking process between expert and novice designers, along with the suggestion that how and when drawing is used is important, has implications for this study. Controlling how and when drawing is used to aid in resolving creative mental synthesis problems needs be explored. In order to explore the role of drawing in design and how effectively drawing might support creative mental synthesis, a systematic and empirical approach as suggested by Purcell & Gero (1998), needs to be applied in lieu of the anecdotal evidence provided in the design literature, which is generally based on the personal experiences of designers. This study intends to investigate this conflict identified in the design literature, by identifying and utilising an appropriate empirical approach.

2.2.5 Synthesis and Analysis

The preceding discussion identified a conflict within the design literature relating to the views expressed earlier that creative ideas emerge while drawing. However, while not mentioned in the preceding discussion, the design literature discussed earlier revealed drawing is also used by designers as an aid to memory. Although the design literature discusses these issues relating to emergence of ideas while drawing and using drawing as a memory aid, the discussions remain largely anecdotal in nature. However, some research was identified which explored emergence and sketching in a more systematic and empirical way. The following discussion serves to extend and detail the discussion relating to issues of drawing and emergence, by reviewing this relevant design literature.

As a way of investigating creative discovery and the role of sketching, Verstijnen (1997) conducted a series of experiments which utilised research methods found in the area of cognitive psychology. Her experiments were based on the seminal research of Finke & Slayton (1988), Finke (1990), and Anderson & Helstrup (1993). As in the groundbreaking empirical studies of Verstijnen, which have a direct bearing on design thinking research, this study will also draw heavily upon the work of Finke & Slayton (1988), Finke (1990), and Anderson & Helstrup (1993) in subsequent discussions. She conducted six experiments using undergraduate psychology students and industrial design engineering students in order to investigate issues relating to **emergent figures, creative discovery** and **drawing**. In her first three experiments, she investigated the relationship between **emergent figures** [explicit and implicit figures] and **drawing/sketching**.

In a series of trials the subjects were presented wire frame drawings, which had figures embedded in a larger figure. Some subjects were instructed to use drawing and sketching to resolve the problem of finding embedded figures in the original figure, other subjects were to resolve the embedding problem mentally. These tasks were considered to be analysis tasks.

In her second set of experiments she investigated creative mental synthesis tasks and modelled her experiments on the research of Finke & Slayton (1988) & Finke (1990). The work of Finke & Slayton (1988) & Finke (1990) will be detailed in subsequent sections. However, essentially, Verstijnen's subjects were to generate creative shapes when given a triplet of basic shapes (i.e. cube – sphere – cone). This was considered to be a figural combination task. As with the first set of experiments, some subjects were instructed to use drawing and sketching to resolve the synthesis problems, other subjects were to resolve the synthesis problems mentally.

In her research Verstijnen (1997) says creativity is made up of analysis and synthesis. She identifies restructuring shapes as analysis and figural combination as synthesis. In her creative process model with respect to the role of sketching, she advocates that the use of sketching for analysis (emergence of ideas or forms from existing ones) plays a significant role, whereas the role of sketching is not as necessary in the original synthesis of the forms. With respect to the synthesis process, the intended structure of the components remains intact, while the components are being joined into a more global whole. This suggests that an original and holistic concept is borne in mind while the synthesis is proceeding. With respect to the analysis process, the whole and its constituent parts are restructured. As a result new unanticipated forms may appear

and old ones may disappear (emergent forms develop), or constituents may undergo a transformation (a cube is transformed into a rectangular box).

Verstijnen (1997) concluded that contrary to the anecdotal evidence, memory restrictions are not the motivating factor for sketching as an aid in creative mental synthesis tasks. She found that the motivating factor is the expected *emergence* or *discovery* of novel shapes and forms. This restructuring and reinterpretation of shapes is thought to be difficult in imagery alone. Therefore, an aid is needed to develop ideas. This aid is the use of drawing for discovery.

In her more recent work, which was derived from her Doctoral thesis, she further reinforces this view. Verstijnen (1998a) states the following:

> *"Based on the combined results of both series of experiments, it can be concluded that mental images are not inspectable in the same ways as pictures. The inability to perform restructuring in mental imagery constitutes a major factor in sketching. [Page 532]"*

Again, Verstijnen (1998b) reinforces the above when she states the following:

> *"...the with-sketch condition received much lower creativity ratings if they applied few restructural features but their ratings increased faster when more resturctural features were applied. [Page 190]"*

Restructuring according to Verstijnen related to the changes of the basic forms given to the subjects [i.e. the size or scale of the given form such as a cone, sphere, or cube is altered by the subject]. Verstijnen discussed restructuring in terms of initial development of the ideas via drawing. In a sense this may be considered to be somewhat limiting in that reinterpretation of the final design was not investigated, only restructuring of the initial base forms were investigated.

In contrast, the possibility exists that ideas come first, prior to synthesis, and therefore before analysis. Verstijnen (1997) does not address this issue; her work seems to be based on **discovery** in drawing for creativity and not a reliance on the initial ideas followed by an embodiment of those ideas. The analysis is reinterpretation of the synthesised ideas. Reinterpreting drawings may be considered part of a discovery process in the design thinking process. However, this is more or less a trial and error process, which may not allow for a large number of creative ideas to be generated.

Her argument is that sketching for synthesis may not matter, sketching for restructuring or reinterpreting may matter. Given her work investigating creative mental synthesis, the strategy of drawing to reinterpret ideas should yield a very high number of creative forms, while drawing to aid in synthesis would be expected to yield a lower number of forms deemed creative.

While Verstijnen (1997) used designers and non-designers in her series of experiments, she did not *directly* compare and contrast designers and non-designers in her creative mental synthesis experiments with respect to either creativity or practicality. Notwithstanding Verstijnen (1997), **directly** comparing and contrasting designers and non-designers with respect to creative mental synthesis and drawing has not been tested empirically. Therefore, this study will do so.

2.3 Pursuit of an Appropriate Empirical Methodology

2.3.1 Introduction

The review of the design literature has revealed the following:

- **Visual thinking abilities are important in creative mental synthesis**
- **Mental synthesis is important in the act of designing new objects/artefacts**
- **Mentally manipulating visual imagery is important in creative mental synthesis**
- **Drawing is an important act to support creative mental synthesis in designing new objects/artefacts**

The review also revealed that these views are based largely on anecdotal evidence and personal experience. If the views reflected in the design literature regarding the importance of creative mental synthesis are to be investigated and substantiated, a systematic, empirical approach must be applied to investigate the presumed significance of creative mental synthesis in the act of designing. The design literature offers little in the way of an empirical methodology that would assist in such an investigation.

In addition, it was revealed that the role of visual imagery in design appears to be consistently used both internally (via mental imagery) and externally (via drawings) in the design thinking process. Externalised visual representations (drawings) must have a strong link to internalised visual representations (mental imagery) because each seems to inform the other, according to the design literature. However, in order for one to inform the other, the dominant role must rest with mental imagery, as the mind drives the hands to draw just as the mind interprets what the eyes see. With the exception of Verstijnen (1997), the design literature does not empirically investigate creative mental synthesis or the role of drawing in creative mental synthesis. However, as was mentioned earlier, Lawson (1980) pointed the way, with Purcell & Gero (1998) cogently arguing for the use of cognitive psychology methods to be applied in a design context.

In the pursuit of an appropriate methodology there are a number of areas in cognitive psychology that appear to be relevant to issues identified in the design literature. Each of these is associated with well-established methodologies. There were three very specific areas that were identified as being most relevant to this study. They were the following:

> **Mental rotation experimental methodologies**
> **Visual synthesis / mental synthesis experimental methodologies**
> **Creative mental synthesis experimental methodologies**

In subsequent sections these areas of cognitive psychology and their associated methodologies will be reviewed and assessed as possible ways of empirically examining these design issues.

2.3.2 Mental Rotation Experimental Methodologies

Initial investigations of the literature in cognitive psychology that appeared to relate to issues within design, centred on what are termed mental rotation experiments. When reviewing this literature themes emerged which were common to the design literature. The first obvious parallel to the design literature related to the importance of visual thinking (mentally processing visual information). This processing of visual information suggests the notion that internal **visual imagery** is some internal analogue of external artefacts, and these internal analogue shapes are **mentally manipulated** (mentally rotated). Over the past thirty years extensive research done in this area of perceptual psychology investigated the issue of these internal analogues [mental images]. It was hoped that a review of this literature would reveal an empirical research methodology appropriate enough to investigate the issues found within the design literature.

Historically, visual thinking research [mental imagery research] began as an experiment that explored mental manipulation. This mental manipulation research began as a recognition test; with recognition involving a comparison/selection task using predefined, predetermined, forms. The basic intent of the mental manipulation research was to investigate if the imagined spatial transformation process was essentially **pictorial** in nature or **verbal** in nature. The basic argument concerning these two opposing views, as illustrated below in Figure 8, revolved around the question, do we think using pictures or do we think using words? The design literature appears to clearly support the pictorial view, suggesting designers are visual thinkers.
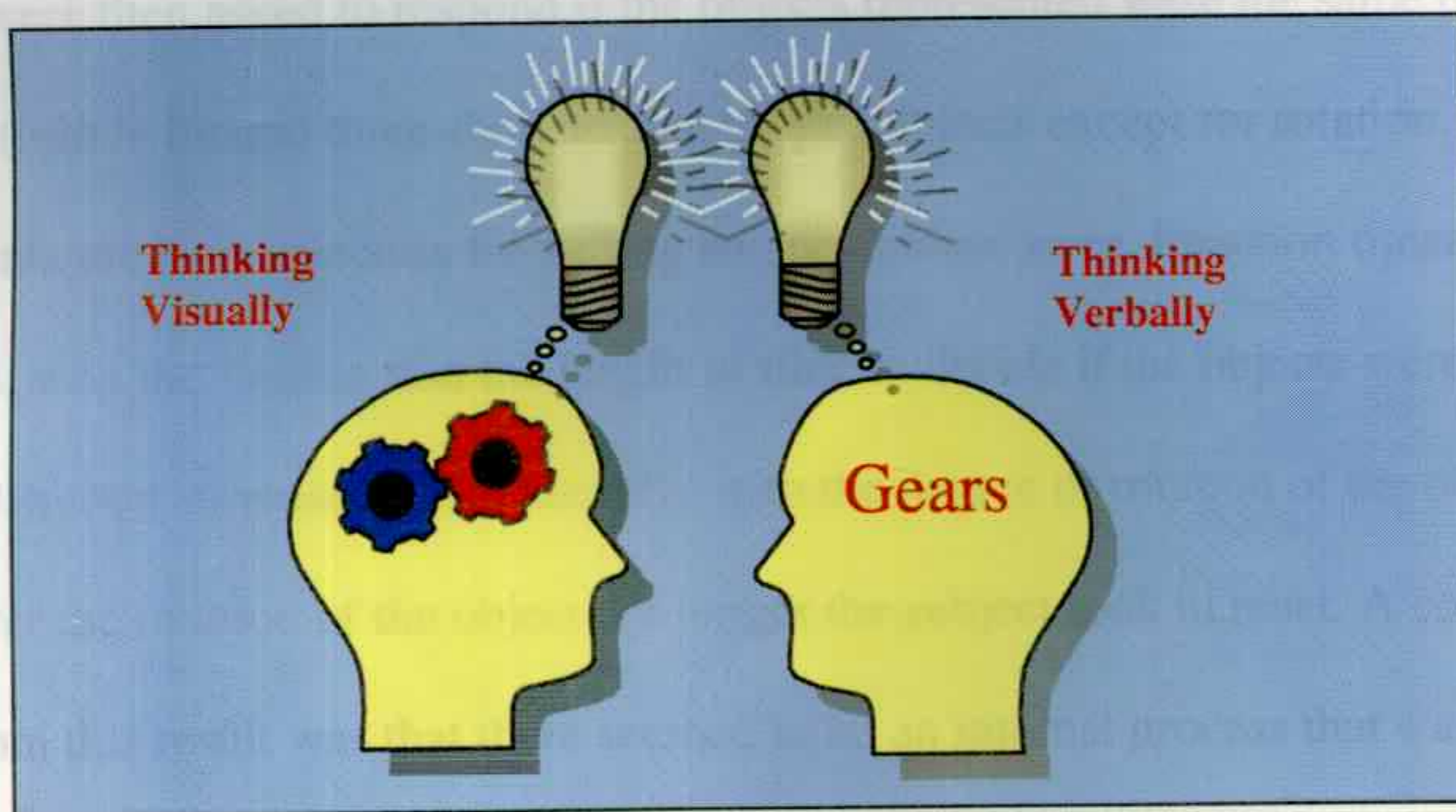
FIGURE 8: VISUAL/VERBAL THINKING
DO WE THINK USING PICTURES OR DO WE THINK USING WORDS?

As a way of investigating whether our thoughts were essentially pictorial or verbal in nature, a mental manipulation experiment was proposed in 1968. In the experiments of Shepard & Metzler (1971), each subject was presented with a series of trials consisting of two perspective line drawings of a three dimensional object in space. Illustrated in Figure 9 below, are paired examples [A, B, & C], typical of the line drawings presented to the subjects.
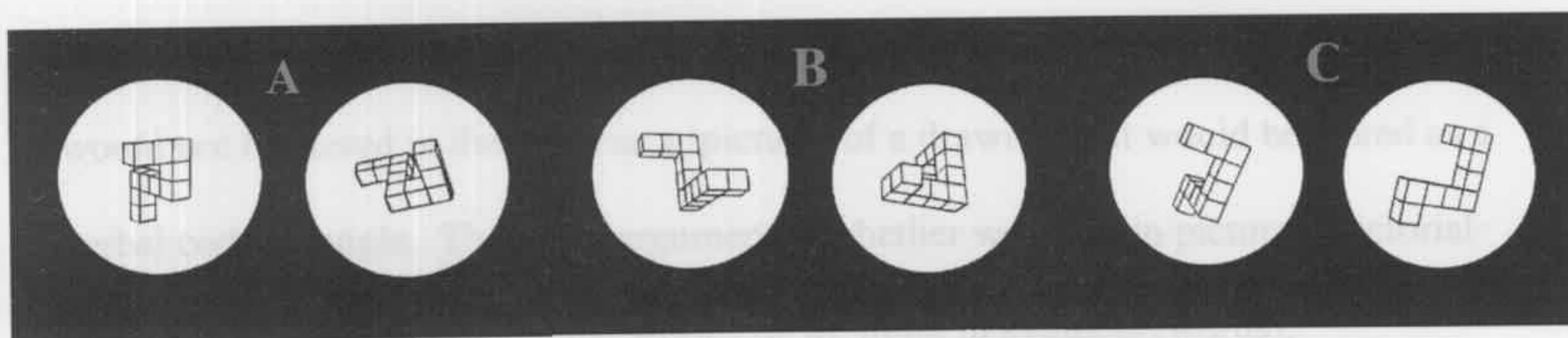
FIGURE 9: MENTAL ROTATION OF SHAPES [SHEPARD & METZLER 1971]

Each object consisted of ten cubic blocks attached face-to-face to form a connected string of cubes with three right-angled bends and two free ends. The objects were constructed so that each was asymmetrical and each was distinct from any of the other objects. Pairs of drawings, some of which contained mirror image constructions and having different rotations, were presented to the subjects one set at a time. The subjects were then asked to respond if the objects represented were the same or different (mirror image) three-dimensional shaped objects except for rotation. They were to indicate their selection by pulling an appropriate lever. Reaction times were measured, with the finding that the length of time to decide if the objects were the same or different increased proportionally with the degree of rotation of the object. The greater the rotation of the object the longer the subject took to react. A conclusion drawn from this result was that there seemed to be an internal process that was an analogue of an external physical rotation. On the basis of the reaction times when large differences in orientation were involved, it was argued the participants mentally rotated one object through a series of intermediate orientations to verify congruence of the two objects. Therefore, it was further argued that thought was essentially pictorial in nature.

The opposite view is generally described in the mental rotation research as being verbal in nature. That is, the visual stimulus is not maintained but converted to a heavily coded language. For example a person could be presented with a pictorial

representation of a line drawing of a " three sided equilateral polygon ", but this would not be stored in the brain as a 'picture' of a drawing, but would be stored as a verbal code–triangle. The basic argument is whether we think in pictures (pictorial representations–analogues of the world) or we think in symbols (words).

In order to investigate this further, Pylyshyn (1979) proposed that a subject be presented with a series of stimulus probes that consisted of two basic types (triangle and quadrilateral) with a range of embedded subfigures (illustrated in Figure 10 below).
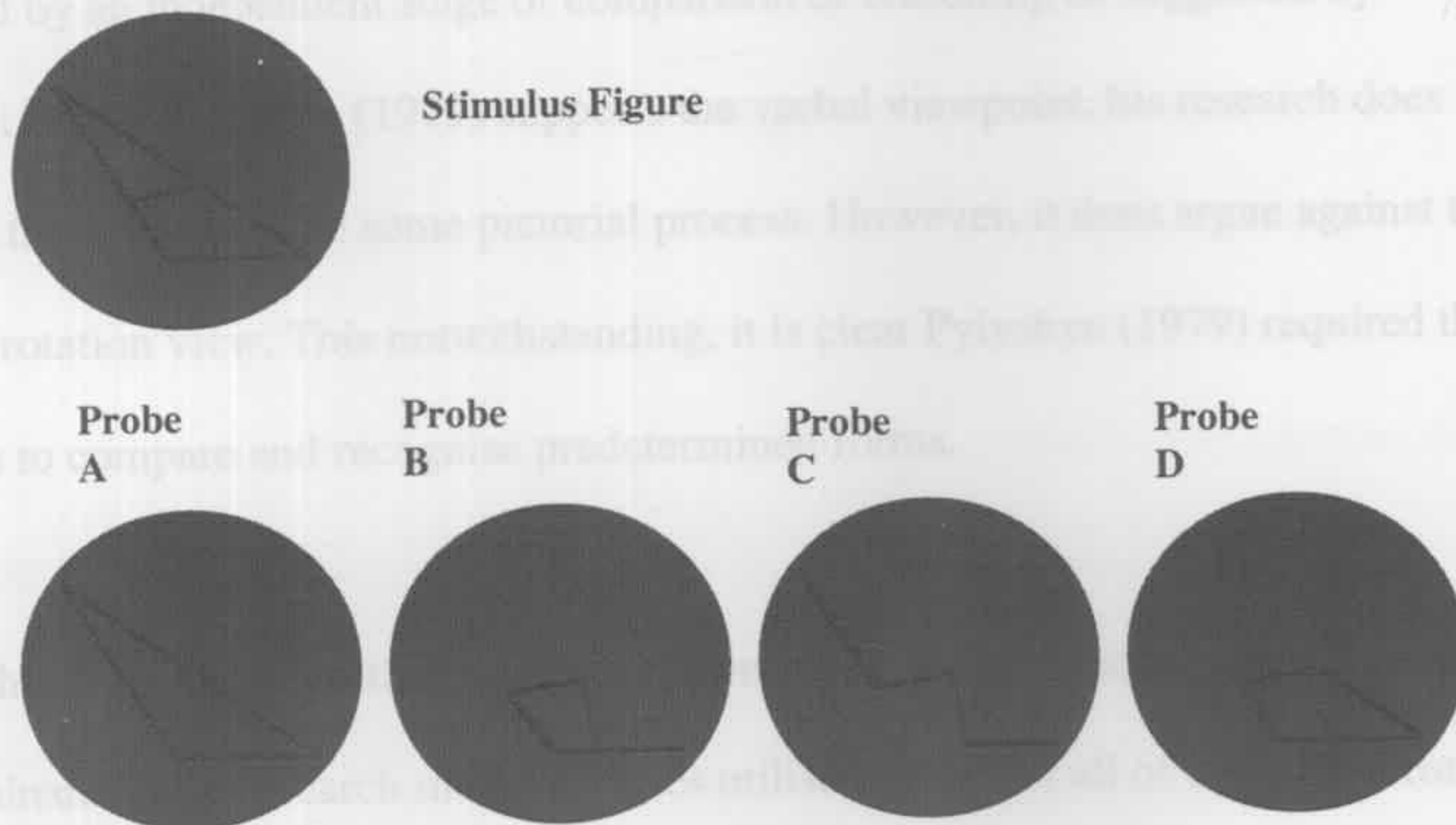
FIGURE 10: EMBEDDED FIGURES [PYLYSHYN 1979]

Each of the probes includes the baseline of the original figure in order to provide an orientation reference. Each of the original figures was used as well as the mirror images of the forms. In addition, each of the eight reference stimulus figures was paired with four "true" subfigure probes and four "false" mirror image probes. Subjects were instructed to mentally rotate the reference figure appearing on the left until it matched the orienting baseline of the probe figure on the right and then to indicate whether the probe figure was a true subfigure of the resulting superimposed image.

There were two main findings from this experiment: (1) The rate of rotation varied with attributes of the figure being rotated, and (2) For three out of the four reference figures, the apparent rate depended on the particular subfigure used as a probe and increased with increasing practice.

Based on these experiments it was argued that there is strong evidence that the process is not one in which a stage of holistic analogue rotation of the image is followed by an independent stage of comparison or reasoning as suggested by Shepard. While Pylyshyn (1979) supports the verbal viewpoint, his research does not exclude that there may be some pictorial process. However, it does argue against the holistic rotation view. This notwithstanding, it is clear Pylyshyn (1979) required the subjects to compare and recognise predetermined forms.

While this debate in cognitive psychology continues, their methods remain the same. Predominantly, the research methodologies utilised in almost all of the mental rotation studies relied on comparison/recognition tasks of predetermined forms, and consequently while they involved mental manipulation of images of physical forms, they did not involve the synthesis of forms by the perceiver. As revealed in the design literature a central motivation in many areas of design is to **create or generate new objects**. In addition, a review of the design literature revealed that the process of designing new objects involves the **synthesis of forms to create new forms**. The subjects in the mental rotation experiments did not create a new object, nor did they synthesise forms. Therefore, the mental rotation methodologies were determined to be inappropriate for this study.

2.3.2 Pictorial / Verbal (designer/non-designer)

While the mental rotation research and its attendant methodologies were not well suited to this study, the debate relating to the question, do we think in pictures or do we think in words, directly relates to the research to be reported, in that there may be different types of thinkers, those who think in pictures, and those who think in words.

The design literature appears to clearly support the pictorial view, suggesting designers are visual thinkers. This notwithstanding, it is not difficult to find a profession, such as lawyers, who could be categorised as predominantly verbal thinkers. Thus, a case could be made that those who are practiced at thinking pictorially (e.g. designers) would perform 'better' at pictorial type problems, in contrast to those who think in words (e.g. lawyers). The research to be reported makes these comparisons.

2.3.3 Visual synthesis / Mental synthesis Experimental Methods

The mental manipulation literature [for example see Shepard & Metzler (1971); Cooper & Shepard (1978); Pylyshyn (1979); Yuille & Stieger (1982)], does not offer an appropriate methodology for this study, because in general the subjects were not required to develop or synthesise shapes that resulted in a new object, key issues which relate to design. However, further investigations of the literature in cognitive psychology, which appeared to relate to issues within design, centred on what are termed visual synthesis or mental synthesis experiments.

An example typical of this research is the work of Klatzky & Thompson (1975) who

investigated integration or synthesis of whole stimuli. They presented subjects with

fragments of facial forms within oval frames (an oval represented the outline of a

head), as a first stimulus. This is illustrated under the heading 'First Stimulus' in

Figure 13 below. Subsequently, the subjects were to mentally integrate or synthesise

the fragmented forms. Then they were presented with a second stimulus (an oval

frame–a face with complete features). This is illustrated under the heading 'Second

Stimulus' in Figure 11 below. They were asked if the second stimulus (the face)

contained the features they saw in the first stimulus.
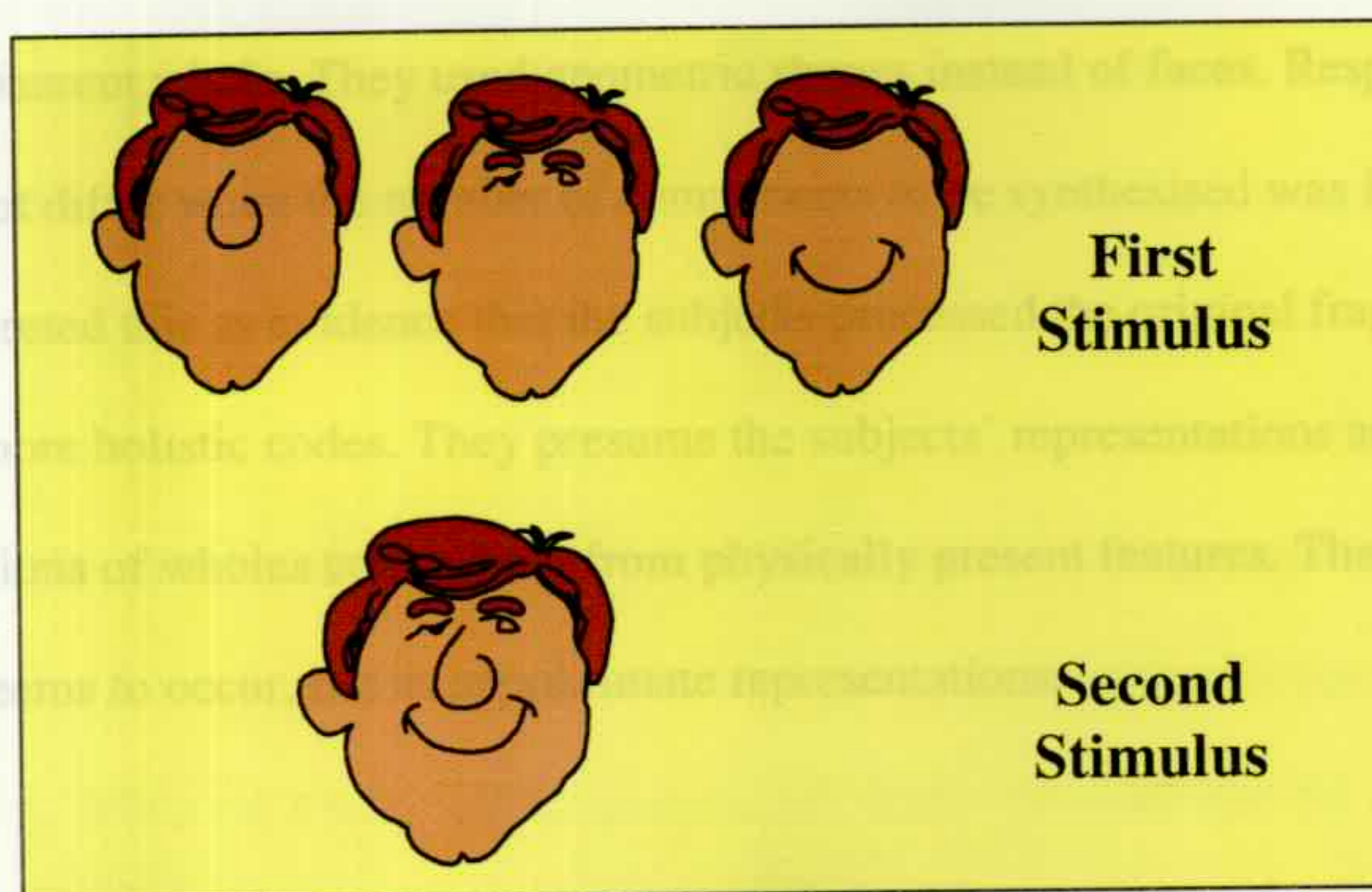
FIGURE 11: MENTAL SYNTHESIS OF FACIAL FEATURES [KLATZKY & THOMPSON 1975]

They measured the response times, arguing that if the subjects were accurate and

quick it indicated the occurrence of mental synthesis. That is to say, if the subjects

could **mentally construct a composite image** of the face (mental synthesis) and

subsequently **recognise** the face, it would indicate mental synthesis had occurred.

They found no support for the belief that subjects integrate fragmented stimuli into

wholes. The subsequent investigations of Thompson & Klatzky (1978) continued their

earlier work with respect to visual synthesis—integration of fragments into forms. Contrary to their earlier findings they were able to make a case for the occurrence of mental synthesis.

In order to overcome the problem found in their earlier work with respect to the fragmented parts being considered as having as good an identity as the whole figure presented later [e.g. a face fragment (i.e. a nose or eye) has as good of an identity as a face], Thompson & Klatzky (1978) used other types of fragmented parts and whole figures. They contended that synthesis would be more demonstrable if the components to be synthesised had little identity of their own but when synthesised formed a coherent whole. They used geometric shapes instead of faces. Response times did not differ when the number of components to be synthesised was increased. They interpreted this as evidence that the subjects processed the original fragmented stimuli in more holistic codes. They presume the subjects' representations are approximations of wholes constructed from physically present features. That is to say synthesis seems to occur, but as approximate representations.

The findings of Klatzky & Thompson (1975) and Thompson & Klatzky (1978) were less than satisfactory in terms of this study and its relation to design. Consequently a more detailed investigation of the literature in cognitive psychology which concerns itself with issues relating to synthesis, was necessary. A more detailed investigation revealed research, which had a loose connection to issues relating to design. It was the view of Cooper & Shepard (1978) that the mental processes utilised by the subjects in their experiments play a major role in creative thinking and problem solving, and in fields such as **design, architecture, engineering,** physics and stereochemistry in

which spatial relations are central. However, their research did not tend to explore these fields. They merely revealed an understanding of the loose connection. In her more recent work Cooper (1989);(1990) & (1991), using engineering students, sought to investigate if synthesis can and does occur in the mental construction of images, views, or objects, which have not been previously experienced.

Cooper (1989); (1990) & (1991) had revealed aspects of synthesis in mental manipulation. The basic question she sought to answer, was: Do constructed mental representations of objects embody information about three-dimensional structure that is specific to a particular point of view, or is the accessible information in such representations more general, in the sense of being view–independent? In essence, can different views of an object be synthesised to create a three-dimensional mental representation.

The basic experiment conducted by Cooper (1991) involved asking subjects to solve problems about the structure of objects from disconnected, two-dimensional views of the structures. Then via a surprise recognition test, it was believed that the nature of three-dimensional object structure in mental representations generated during problem solving would be revealed in that the subjects' need to generate a three-dimensional representation that was constructed from the initial views. The method of depicting objects was orthographic projection. To ensure that subjects would have the facility to understand these forms of projection, they were selected from undergraduate students undertaking an introductory course in mechanical engineering.

The subjects were shown a series of problem slides. An initial slide was presented consisting of two orthographic views of an object along with a "placeholder", showing the position of an intended third view. The subjects had to solve the missing view (illustrated in Slide 1 of Figure 12 below). They were shown a possible third view in a second slide (Slide 2 in Figure 12 below) and were asked if all the views could be combined to make a possible three-dimensional object.

ISOMETRIC RECOGNITION TASK

PROBLEM SOLVING:

SLIDE 1   SLIDE 2
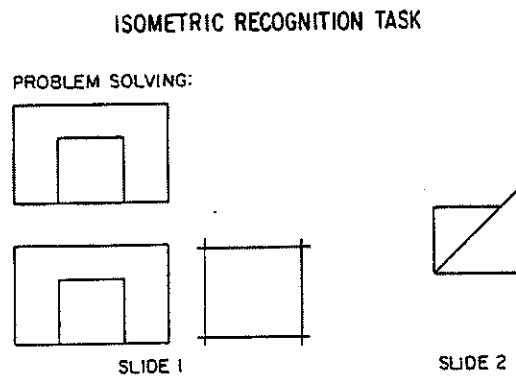
FIGURE 12: ISOMETRIC RECOGNITION TASK 1 [COOPER 1991]

Then via a surprise recognition test they were shown two isometric views of objects, an example of which is illustrated in Figure 13 below. They were to select the object that corresponded to the same object they were shown in the preceding problem solving set of orthographic projections.

RECOGNITION:

TARGET ISOMETRIC   DISTRACTOR ISOMETRIC
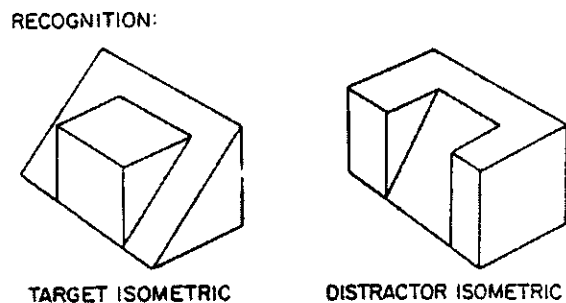
FIGURE 13: ISOMETRIC RECOGNITION TASK 2 [COOPER 1991]

Cooper's basic finding was that the rate of isometric recognition is very high overall (almost 90 percent) even though the task is to discriminate between structures that the subject has never seen before in the form provided at the time of recognition. This result suggests that people solved the original "orthographic compatibility" problems by **synthesis,** or **constructing** an internal representation of a three-dimensional object, with that mental model being used for subsequent recognition, even though the original problems had been presented as and could have been solved on the basis of separated, flat views of individual sides of the objects.

If it is possible for a person to construct/create a new mental image of an object, which can later be used for recognition purposes, then it may be possible to use this ability to mentally generate new objects, as suggested in the design literature. However, the subjects in Cooper (1991) created a new mental image by visually reasoning the synthesis of views, they did **not create a new object.** The object the subjects mentally developed by using the three orthographic views could only lead to one specific object that was **predictable and predetermined,** and therefore is not associated with being a creative act.

While the systematic research discussed above has revealed that empirical investigations of visual imagery and synthesis can be conducted, they are based on the recognition of predictable and predetermined forms or parts. In general, once the subjects mentally synthesise parts, generating a form, they are required to match the resultant form to an existing predetermined form. They do not generally explore **creative mental synthesis,** which can result in outcomes that are not predetermined.

As expressed earlier, design thinking is essentially a creative endeavour, which tends to emphasise **imagery, synthesis, creativity and discovery.** The systematic ~~discoveries in~~ approaches used in the research above fall short of encompassing these issues in one methodology, consequently, they were determined to be inappropriate for this study.

2.4 Creative Mental synthesis

2.4.1 Introduction

A suggested in the previous section, creative mental synthesis would require the subject to use visual imagery to imagine the assembly of a final part made from component parts with the final part having been determined by the imagination of the subject. It would not be a predictable or predetermined object, and it may or may not be creative, thus providing an opportunity for the newly generated object to be judged as creative. Further investigations of the literature in cognitive psychology which appeared to relate to issues within design and centred on mental synthesis, revealed a very appropriate methodology, which was selected for this study and described below.

2.4.2 Creative Mental synthesis (2D)

Recognising that the previous literature in mental synthesis [Thompson & Klatzky (1978); Glushko & Cooper (1978)] required only recognition skills in mental synthesis, Finke & Slayton (1988) sought to investigate **creative mental synthesis.** What set their work apart from previous research in mental synthesis was the core idea of visual **"discoveries"** in imagery. The previous mental synthesis research required the subjects to simply verify that certain parts could be combined to make a

particular object or shape (recognition of predictable and predetermined forms or parts). They claim this restricted the subjects' abilities to make **creative** discoveries in the imagined mental synthesis.

Finke & Slayton (1988) sought to investigate how often naive untrained subjects could produce a two-dimensional recognisable pattern using designated parts. They used undergraduate psychology students as subjects and judges. The subjects were presented with a group of fifteen forms to be used in mental synthesis. Three forms out of the fifteen forms were randomly selected for each trial. The subjects had to complete eight trials. For example, in one trial they could be given the letter L, a square, and a circle. As soon as the parts were named the subjects were to close their eyes and attempt to mentally assemble a recognisable figure. At the end of two minutes they were to open their eyes and write down the name of the figure and then draw it. For example, as illustrated in Figure 14 below, they could have turned the letter L upside down, placed the square under the horizontal leg of the L and then shrunk the circle, placing it in the square and called it **a flag**.
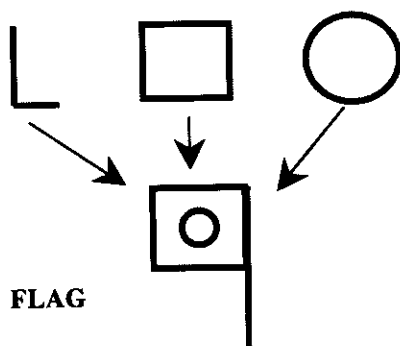
FIGURE 14: 2D CREATIVE MENTAL SYNTHESIS

After the subject had completed the series of trials, as a way of investigating what their subjects thought they were doing, Finke & Slayton (1988) administered a questionnaire. They asked the subjects to select the one thinking strategy which they mostly used. They were to select from the following four possibilities:

1) " I tried combining the parts by trial and error in my image until I happened to recognise a shape"
2) " I first thought of a possible shape, then I tried to combine the parts in my image to see whether the particular shape could be made out of the parts"
3) " I did not form an image at all, but just thought about how the parts might be combined in a more abstract way"
4) " I used some other strategy"

Finke & Slayton (1988) analysed the results in the following way, using a scale of 1 to 5, the responses were judged on how well the name/description corresponded to the image drawn. These scores were then averaged and if the average score of the judges was 4 or higher, a response was determined as being of high correspondence. In addition, if the responses were deemed to have a high correspondence (4 or 5), they were then judged in terms of how creative they were, using a binary scale (creative or not creative). If the majority of judges determined a response creative, it was considered creative.

These findings appear to show that creative discoveries in imagery can be reliably induced in laboratory conditions where mental synthesis is unrestrained. In their work Finke & Slayton (1988) make the distinction between using imagery as a convenient representational medium for recalling visual features that are already in memory and using imagery for discovering novel configurations of visual features. As there are two-dimensional designers [graphic designers], this investigation parallels design work in that the subjects were required to use two-dimensional visual imagery and

mental synthesis to create/discover a new object or form which could not be predicted or predetermined.

2.4.3 Creative Mental Synthesis (3D)

The mental synthesis abilities investigated by Finke & Slayton (1988) involved flat two-dimensional forms. In his later work Finke (1990) sought to advance the research in mental synthesis by investigating three-dimensional mental synthesis. He felt the flat two-dimensional forms to be of little practical value to three-dimensional thinkers such as engineers or inventors. In his three dimensional mental synthesis experiments he again used undergraduate psychology students as subjects and two of the judges from the previous two-dimensional experiments. However, instead of giving the subjects two-dimensional shapes they were given drawings of three-dimensional shapes and a category. For example, as illustrated in Figure 15 below, they could have been given a sphere, a rectangular block and a cylinder, and then given the category Toys & Games. A subject could put the sphere on top of the cylinder and place the block one-third up the cylinder and say it was a pogo stick.
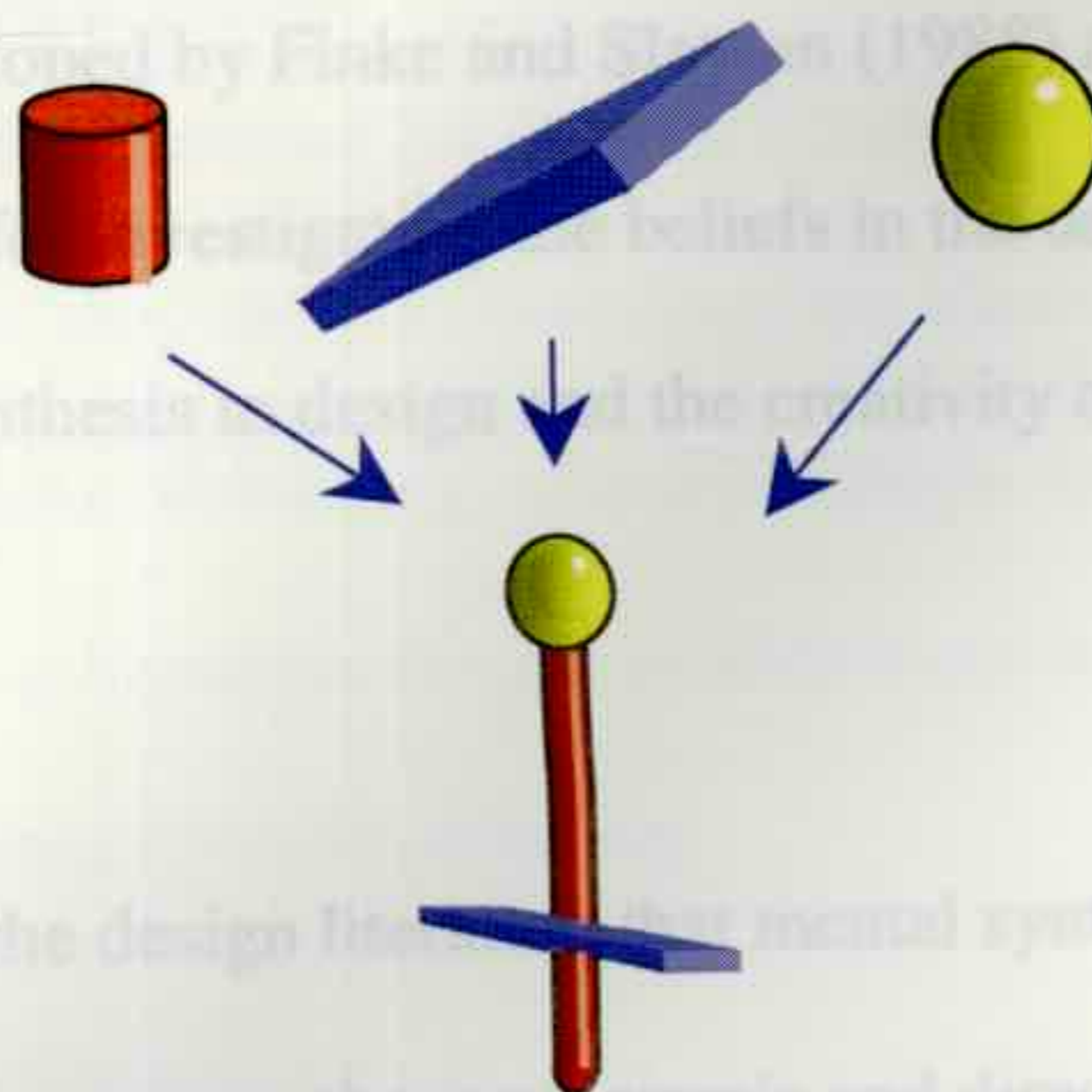
FIGURE 15: 3D CREATIVE MENTAL SYNTHESIS

As was the case in the experiments of Finke & Slayton (1988), the subjects in Finke (1990) were asked to develop their ideas with their eyes closed using only mental synthesis to create their inventions. Finke (1990) analysed the results in the following way: using two scales of 1 to 5 the responses were judged on how practical the inventions were and how creative they were. In addition, after the subjects had completed the series of trials, as a way of investigating what the subjects thought they were doing, a questionnaire similar to the one used in Finke & Slayton (1988) was administered.

As there are three-dimensional designers [e.g. industrial designers], this investigation parallels design, in that the subjects were required to use three-dimensional visual imagery and mental synthesis to create/discover a new object or form that could not be predicted or predetermined.

In the collective work of Finke & Slayton (1988) and Finke (1990), the tasks given to their subjects clearly involve mental synthesis, as participants were asked to close their eyes and combine forms to create new forms using 'mental imagery'. It can be argued that the tasks developed by Finke and Slayton (1988) and Finke (1990) provide a possible model for investigating the beliefs in the design literature about both the role of mental synthesis in design and the creativity of the results of such mental activities.

Given the basic belief in the design literature that mental synthesis and creativity play a central role in the design process, the most simple and direct test of this idea using the creative mental synthesis task would be to compare and contrast the performance

of designers and non-designers on the tasks. Furthermore, since the tasks given to the subjects in the collective work of Finke & Slayton (1988) and Finke (1990) focused on two-dimensional and three-dimensional creative mental synthesis respectively, coupled with the fact that there are two-dimensional designers [e.g. graphic designers] and three-dimensional designers [e.g. industrial designers], it would be appropriate to compare and contrast all three groups within one experiment [2D designers, 3D designers & non-designers].

If creative mental synthesis is one of the core aspects of the design process then there should be differential performance on the two versions of the task between graphic designers and industrial designers. Graphic designers should perform better on the measures of correspondence and creativity using the 2D forms than the industrial designers while the reverse should occur with the 3D version of the task. Both types of designers would, however, be expected to perform better than the non-designers. There clearly exists a method for empirically exploring creative mental synthesis in design, by comparing the performance of designers and non-designers.

2.4.4 Mental Synthesis & Drawing

The experiments discussed in sections 2.4.2 and 2.4.3 above investigated creative mental synthesis. However, they did not investigate the views of the design literature regarding the need for the use of drawing, which is thought to be fundamental in the design process in order to aid creative mental synthesis and assist in the discovery of new forms thought to emerge from the drawings.

While Finke & Slayton (1988) and Finke (1990) did not investigate drawing per se, the subjects were required to draw after they had mentally developed solutions. The

subjects did not use drawing for discovery, which is considered to be important in the design literature. Their work did provide however a methodology that could be used to explore drawing and creative mental synthesis. Developing an object may cause a high cognitive load. It is possible that drawing while thinking and developing a creative solution may lighten the cognitive load on the subject. In order to test the importance of drawing in creative mental synthesis, Anderson & Helstrup (1993) conducted experiments modelled after Finke & Slayton (1988). They were interested in how people create patterns by using mental imagery with and without pencil and paper support. While developing their 2D forms on some trials the subjects were encouraged to draw to develop their forms (offering an opportunity for discovery in the drawings), and on other trials they were instructed to develop the forms mentally.

Their experiments resulted in the finding that there was no difference between using only internal visual imagery and using external visual imagery as support for generating patterns of good correspondence. Further, there was no difference in the number of creative patterns generated. Both the experimenters and the subjects held the **belief** that using pencil and paper to help construct patterns should be easier or more effective than using mental imagery alone, however, the results were **contrary** to that belief. This is a surprising result as a consistent theme represented in the design literature is that drawing is a fundamental part of visual reasoning and creative mental synthesis. The literature in cognitive psychology does not necessarily support this.

It must be remembered that the subjects used in the experiments of Anderson & Helstrup (1993) were psychology students, who were neither trained in nor practiced

at using drawing to solve problems, and not design students who are trained in and practiced at using drawing to solve problems. However, Verstijnen (1997) used design students as subjects and found no differences between the sketch condition and the non-sketch condition to support creative mental synthesis. In addition, it should be noted that she did not compare the results generated by designers to the results generated by non-designers. Verstijnen (1997) concluded that contrary to the anecdotal evidence, memory restrictions are not the motivating factor for sketching as an aid in creative mental synthesis tasks. She found that the motivating factor is the expected emergence or discovery of novel shapes and forms.

The work of Anderson & Helstrup (1993) offers a methodology for investigating drawing and creative mental synthesis in design. However, their research did not consider various strategies, which may or may not aid in the development of a creative solution in a mental synthesis task. The following are some possible strategies for using drawing:

- **Drawing to clarify and develop ideas:** While the subjects in Anderson & Helstrup (1993) were instructed to 'doodle' to develop their ideas, the subjects may not have been practiced in the use of drawing. As there are different types of drawing, including detailed drawings, they may not have been practiced in using detail drawings to clarify their thoughts.

- **The emergence of ideas from drawings, or how the drawings may stimulate a new idea based on an old idea or drawing:** A consistent theme within the design literature regarding the use of drawing is one of emergence, in that new forms or ideas can be developed.

- **Mental rotation or transformation of drawn forms and drawing to rotate forms to develop ideas:** A common exercise in a drawing class is to attempt to imagine and draw an object upside-down in order to develop a new perspective, which may in turn assist in the emergence of new ideas.

● **Mental formation of ideas, then the formation of embodiments of those ideas, which are then expressed via drawings:** As suggested in the work of Mathias (1993), there are differences in the way expert designers and novice designers use drawing. Central issues revolve around how and when experts use drawings. They tend to think first, developing ideas, and then they use drawing to assist in embodying those ideas.

It is not difficult to see how the strategies and issues discussed above would be problematic within the context of the investigations of Anderson & Helstrup (1993), as they merely instructed their subjects to 'doodle' to develop ideas. Consequently, instructions which allow an investigation of the issues of how and when to use drawing become important, given the act of drawing is thought to be fundamental in the design process.

2.4.5 Restructuring / Reinterpretation

Earlier in the design literature and in the preceding section, a consistent theme was revealed of the anticipation of the emergence of ideas through the use of drawing. In a sense the concept of emergence was explored in the experiments of Verstijnen (1997).

In the context of her work, the subjects were to discover both implicit and explicit forms [drawings], which were embedded in an initial stimulus form [a drawing]. The implicit and explicit forms were expected to emerge from the drawings. This suggests that parts of drawings and consequently whole drawings can be reinterpreted.

Following on from that, restructuring new drawings based on an old drawing is also conceivable.

In all the creative mental synthesis experiments, drawings were the resultant data.

Therefore, in the context of Finke & Slayton (1988), Finke (1990), and Anderson & Helstrup (1993), the emergence of ideas by restructuring/reinterpreting drawing, can

be demonstrated by adapting the examples of the **Flag** (2D creative mental synthesis) and the **Pogo Stick** (3D creative mental synthesis) from sections 2.4.2 and 2.4.3 above.

Without reconstructing the parts, the Flag illustrated in Figure 16 below can be manipulated and reorientated, thus restructuring and reinterpreting it. Reconstructing would allow for the separation and reconnection of the parts, this is *not* considered restructuring. **Restructuring/reinterpreting** would allow for *scaling, sliding of the parts, stretching, mirroring, and reorientation of the object*, but not the disassembly and reassembly of the parts. The Flag could be turned upside down, and the pole lengthened, thus allowing the **Flag** to be reinterpreted as a **Golf club hitting a golf ball**, as illustrated in Figure 16 below.

Original   **Restructure/Reinterpretation**

Flag   O   Golf Club Hitting a Golf Ball

FIGURE 16: 2D RESTRUCTURING/REINTERPRETING

With respect to the reinterpretation of the **Pogo Stick,** illustrated on the left hand side of Figure 17 below, the rectangular plate could be slid down to the bottom of the

cylinder and the whole object could be scaled down to fit a hand and it could become

a **Potato Masher**, kitchen utensil, as illustrated on the right hand side of Figure 17

below.

Original   **Restructure/Reinterpretation**

Pogo Stick   **Potato Masher**
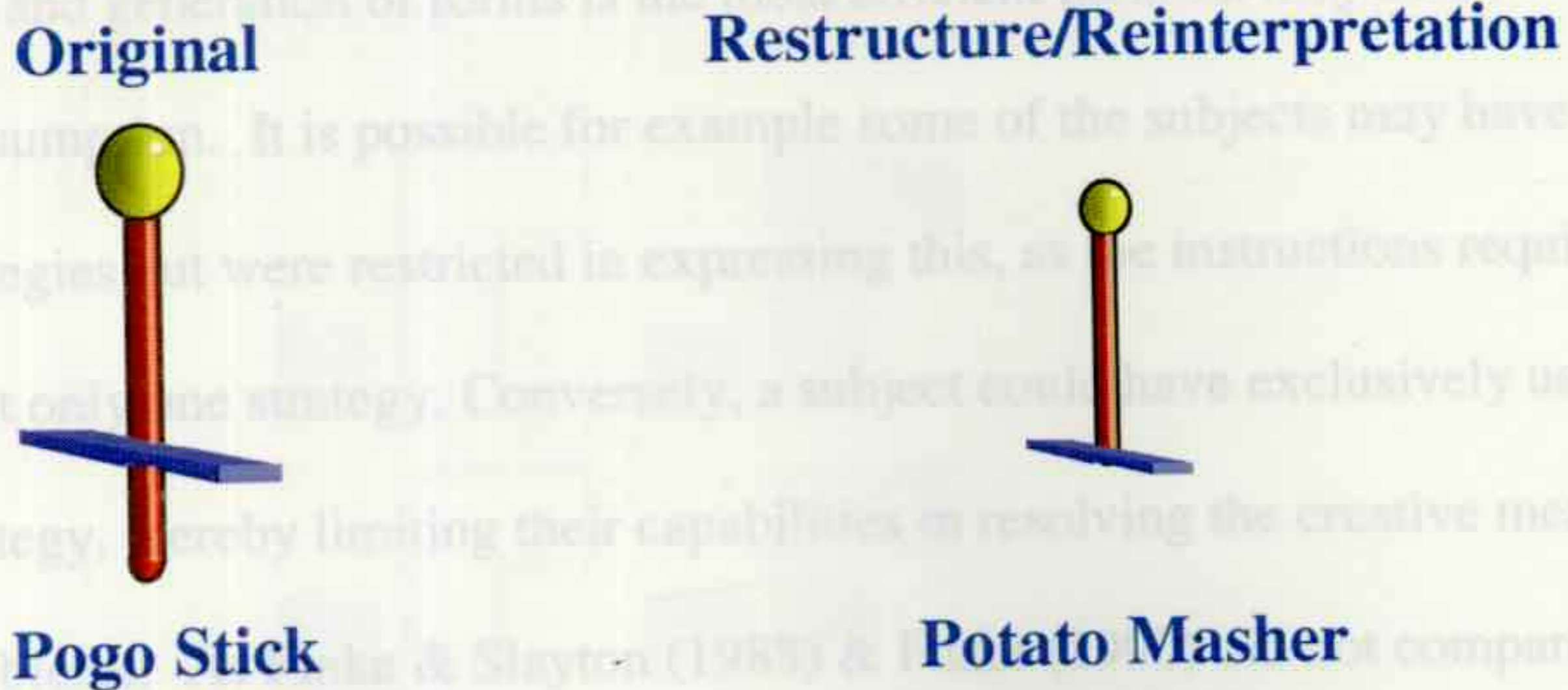
FIGURE 17: 3D RESTRUCTURING/REINTERPRETING

While the interest of Anderson & Helstrup (1993) was not on the role that drawing is

thought to play in design, it is not difficult to see how the creative mental synthesis

tasks can be adopted and adapted to investigate issues such as emergence and

restructuring/reinterpreting drawings. The structure of the creative mental synthesis

task has the capacity to allow a much more careful analysis of drawing, by allowing

quite explicit manipulation of when the drawing activity occurs.

2.5 Thinking Strategies (exclusivity vs. variety)

Earlier [sections 2.4.2 & 2.4.3 above] it was revealed Finke & Slayton (1988) and

Finke (1990) sought to explore the thinking strategies used by their subjects in order

to gain insights into how they resolved the creative mental synthesis problems. While

the subjects did not receive instructions or a suggested strategy to resolve the creative

mental synthesis problems, the researchers were aware of a variety of strategies that

the subject may have used. This is evident from the list of thinking strategies they presented to the subjects in the questionnaire. However, they instructed the subjects to select the one strategy they most used. The subjective impression of Finke & Slayton (1988) & Finke (1990) that the trial-and-error thinking strategy applied to mental manipulation and generation of forms is the most efficient method, may be an inaccurate assumption. It is possible for example some of the subjects may have used multiple strategies but were restricted in expressing this, as the instructions required them to select only one strategy. Conversely, a subject could have exclusively used only one strategy, thereby limiting their capabilities in resolving the creative mental synthesis problems. As Finke & Slayton (1988) & Finke (1990) did not compare and contrast thinking strategies with the empirical results they obtained, this remains unknown. A more detailed investigation may reveal that the ability to vary one's thinking strategy to suit various problems may allow one to perform better in the resolution of creative mental synthesis problems. As creative mental synthesis is important in design, it can therefore be argued that developing an understanding of thinking strategies is important to design.

As a way of investigating thinking strategies, Lawson (1979) conducted an experiment using architecture students and science students as subjects. His experiment sought to integrate the discovery of a structure or solution rules, and production of a solution when subjects had to resolve multidimensional design problems.

In the experiment the subjects were presented with four pairs of coloured blocks, and a rectangular plan on a turntable. The plan had a grid of 3 units by 4 units. Each unit

was a square of 40 mm X 40mm. The blocks were based on these grid units. The top

and bottom surfaces in one pair were white and the other matching pair's top and

bottom surfaces were black. All remaining vertical surfaces were red or blue,

illustrated diagrammatically in Figure 18 below.

Plan view of Blocks
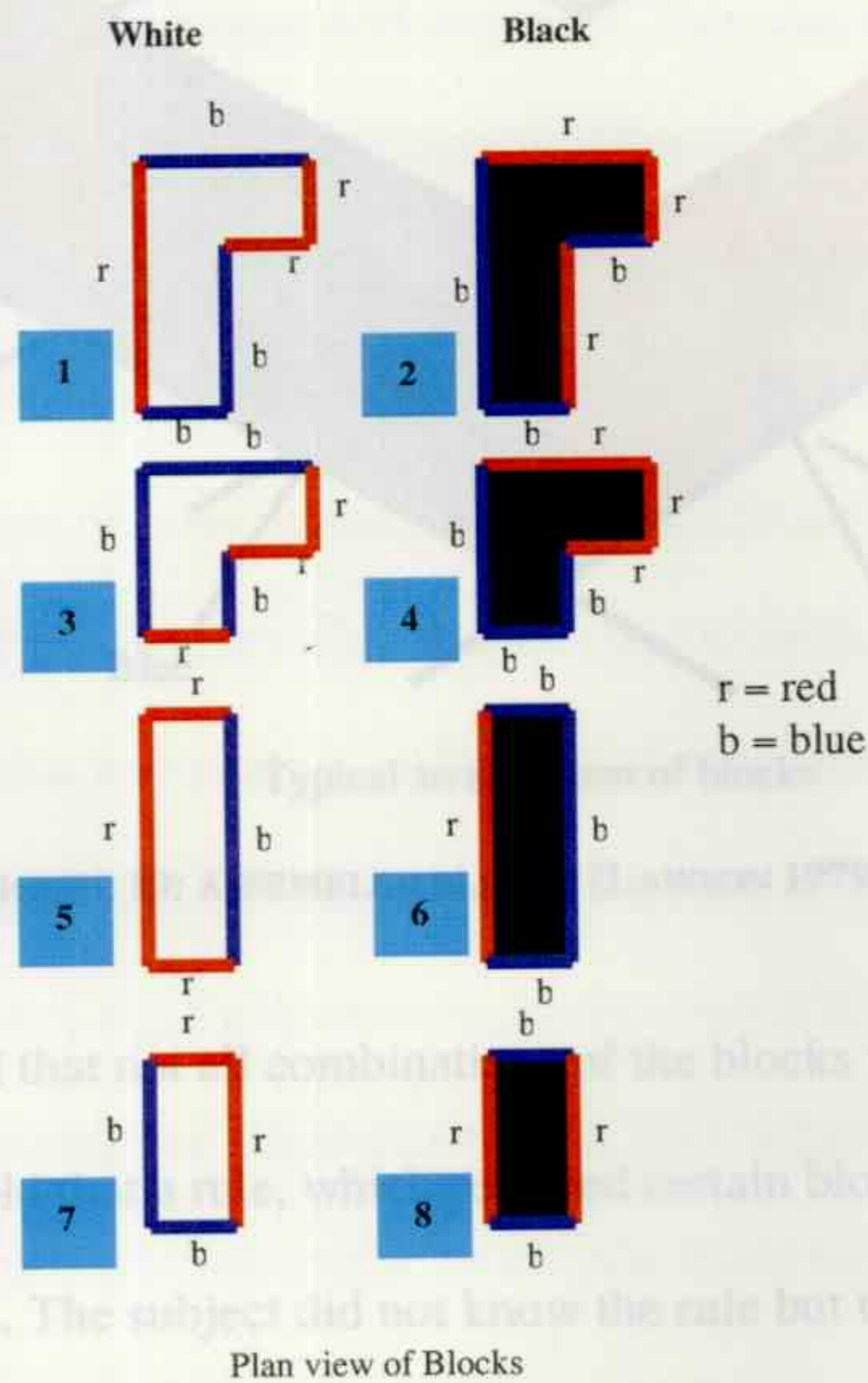
FIGURE 18: BLOCK CONFIGURATIONS [LAWSON1979]

The subjects were to arrange four of the blocks, one from each pair, on the plan so as

to cover all twelve squares. There were to be no blocks projecting beyond the grid

plan. The blocks were to be laid with the black or white surfaces uppermost. In

addition the subjects were to maximise the amount of either the red or the blue

vertical surfaces. Figure 19 represents a typical arrangement of the blocks.

Blue   Red

Typical arrangement of blocks

FIGURE 19: ASSEMBLED BLOCKS [LAWSON 1979]

Subjects were informed that not all combinations of the blocks would be allowed each time. They were also told that a rule, which required certain blocks to be used, would be set for each problem. The subject did not know the rule but they would be allowed to ask if the combination of blocks that they had assembled was acceptable. They would only receive yes or no answers. The subjects were not instructed as to what the rule was but were directed to develop a solution. If the subjects achieved less than optimal colour scores, the subjects' solutions were compared to the optimal solution. A computer capable of solving the problems generated the optimal solution.

The subjects had an opportunity to make what Lawson calls a planning error or a structure error. A planning error is said to be one in which the subject picked the correct blocks but needed to reorganise them in order to maximise their score. A

structure error is said to have occurred when the subject picked one or more

unfavourably coloured blocks. Lawson thought it reasonable to hypothesise that the more spatially able architects would make relatively fewer planning errors than the scientists. This was suggested by the results but not found to be statistically significant. Therefore, a further experiment was needed to explore this difference in planning ability between the architects and scientists. This was done by directing the subjects to plan all sixteen possible combinations of the four pairs of blocks on the grid, once to maximise them for red and once for blue. From the results of the thirty-two combinations a mean colour error score was generated. This score was a planning score because the structure or rules were made explicit. The difference in the error scores was significant. The scientists had a higher error score than the architects. The investigations revealed that architecture students used a solution focusing strategy and the scientists adopted a problem focusing strategy. Lawson was surprised that most of the subjects revealed a very rigid adherence to the strategy of choice. In fact half of each group could not envisage an alternate strategy. This suggests that if the subjects were able to vary their strategy they might have made fewer errors.

The preceding discussion demonstrated that subjects having different categories of experience appeared to use different thinking strategies, which may yield or require different representational hierarchies or strategies. If a designer, or a non-designer for that matter, has the capacity to vary their thinking strategies [use multiple thinking strategies in lieu of using one thinking strategy exclusively], this may equip them to 'run through' their repertoire of strategies, allowing them to develop a number of 'better' solutions to visual reasoning problems [design type problems]. Comparing and contrasting the use of multiple thinking strategies in lieu of using one thinking

strategy exclusively, has yet to be tested in the context of creative mental synthesis

tasks. This research will make these comparisons.

2.6 Summary

The preceding literature review presented a range of themes and issues with a view to

placing creative mental synthesis in a design context. However, two broad themes

emerged in the design literature. The first was that design is essentially a process of

creative mental synthesis. The second was that drawing plays a central role in the

design process. Irrespective of whether the authors were writing about problems with

planning students or the thought processes of architects, industrial designers, or

engineers (see, for example, Lawson 1980; Tovey 1989; Hertz 1992; Ferguson 1993;

Smith & Brown 1993; Goldschmidt 1994; Cunningham 1995) the design literature

strongly supported these two themes.

As was stated earlier in this chapter, when Lawson (1980) was writing about design

thinking in one of the central texts in the field, he stated that: "Design involves a

highly organised mental process capable of manipulating many kinds of information,

blending them all into a coherent set of ideas and finally generating some realisation

of those ideas" (p. 6.) While Lawson here is clearly seeing design as a mental process

involving synthesis, his statement is, however, somewhat vague, and is typical of the

design literature. It could be interpreted as manipulating and synthesising abstract

ideas, concepts, or knowledge to create a design proposal, or manipulating and

synthesising forms to create a new form, or both. In addition, Lawson regards these

acts of mentally synthesising ideas and forms as being strongly associated with

creativity. In his subsequent book (Lawson, 1990) based on interviews with noted

architects, Lawson also documents the belief in the central role of sketching and

drawing in the design process in general and in creative design in particular. However,

in common with much of the other literature in the field Lawson's work is essentially

anecdotal, that is, it is based on designer's thinking and speculating about the design

process on the basis of their own experiences. There are exceptions, for example,

Goldschmidt (1994) and Schon and Wiggins (1992) draw similar conclusions based

on the analyses of protocols of actual design sessions. However these authors' works

are small in number relative to the total amount written about the design process

based on personal experience.

The aim of the research to be reported was to develop an empirical approach that

would allow a more rigorous examination of these beliefs about the role of mental

synthesis and drawing in the design process and in creativity in design. While

Lawson's own work is largely anecdotal, he also points the way towards a possible

area where appropriate empirical methods may be found: cognitive psychology.

For the past thirty years issues related to the reality and functions of mental imagery

have been the focus of considerable debate and research in cognitive psychology. As

revealed in the literature above, a number of empirical methods have been developed

to examine the various issues at the core of the debate. Broadly, these methods can be

divided into three classes. The first addressed questions relating to whether people can

manipulate mental images of objects, in particular whether they can mentally rotate a

given form to determine whether it matches another form [see Shepard & Metzler

(1971)]. Essentially this is a recognition task in that it required the subjects to 'match'

predetermined forms. Consequently, while mental rotation involves mental

manipulation of images of physical forms, it does not involve the synthesis of forms by the perceiver, a core issue of interest in design.

The second broad methodology examined whether people could follow a set of verbally presented instructions to imagine a series of named forms and carry out a series of mental manipulations of those forms. At the end of this process, if the person had successfully followed the instructions, they would have constructed a composite image that corresponded to a new form. The question of interest in this research was whether or not and under what conditions this new form could be recognised. From the design perspective this methodology clearly involved the types of manipulation of imagined forms that are considered to be important in synthesis. However, The mental activities result in a pre-specified form, missing an aspect thought to be important in design, that is, generating a new form.

The third broad methodology explored creative aspects of mental synthesis. Recognising the previous literature in mental synthesis [see Thompson & Klatzky (1978)] required only recognition skills, that is, matching to a previously seen shape or combining shapes to see if they match a predetermined form, Finke & Slayton (1988) and Finke (1990) sought to investigate what they termed creative mental synthesis. What set their work apart from previous research in mental synthesis was the core idea of visual "discoveries" in imagery. They claim that the nature of previous experiments restricted the subjects' abilities to make "creative discoveries" in the imagined mental synthesis.

Finke and Slayton (1988) measured the mental synthesis aspect of the task by having judges numerically rate correspondence between the description of the object and the drawing of the object. In his later work Finke (1990) sought to advance the research in creative mental synthesis by investigating three-dimensional (3D) mental synthesis. He felt the flat two-dimensional forms to be of little practical value to three-dimensional thinkers such as engineers or inventors. With respect to 3D mental synthesis, basically a similar procedure to that of the 2D research was followed.

Finke (1990) used a similar measure for the 3D version of the task. The creativity of the synthesised object was measured by having judges rate the creativity of the objects produced. It is argued here that the task developed by Finke and Slayton (1988) and Finke (1990) provides a possible model for investigating the beliefs in the design literature about both the role of mental synthesis in design and the creativity of the results of such mental activities. The task clearly involves mental synthesis as participants are asked to close their eyes and perform the task using 'mental imagery'. The measures associated with the task then allow an assessment of the success of this synthesis and the extent to which the results are creative. Given the basic belief in the design literature that design involves mental synthesis and creativity, the most simple and direct test of this idea using the creative mental synthesis task would be to compare the performance of designers and non-designers on the tasks. If mental synthesis is one of the core aspects of the design process, then designers should both be better at synthesis and produce more creative output than non-designers. The first experiment to be reported explores this straightforward hypothesis. However, it is important that any results from these experiments be treated with caution in that over simplifications of the design process are not appropriate. It must be acknowledged

that there should be limits in terms of the inferences, which can be made between this research, and design problems that typically confront design professionals. A primary and obvious difference would relate to the time limit subjects are given to complete a design type task. Often professional designers take weeks, months, and at times, years to complete some design projects. In addition, it should be noted the design type tasks within this study remain less complex than those which confront professional designers. Consequently, inferences made to design within this study will be limited.

While the mental synthesis task can be used in this way, it is possible to extend the task to investigate whether or not drawing can influence the synthesis or creativity aspects of the task. While their interest was not on the role that drawing is thought to play in design, Anderson & Helstrup (1993) investigated whether allowing subjects to doodle and draw while they were performing the task affected performance. They argued that developing an object by performing this task mentally may involve a high cognitive load and that drawing while thinking and developing a solution may lighten the cognitive load on the subject by externalising the form being worked with. In order to test the importance of drawing in creative mental synthesis, they conducted experiments modelled after Finke & Slayton (1988). In their procedure, subjects were sometimes encouraged to draw to develop their forms, and other times they were instructed to develop the forms only mentally. The research found no difference between using only internal visual imagery and using external visual imagery (that is drawing with pencil and paper) as support for generating patterns of good correspondence. Further, there was no difference in the number of creative patterns generated, either using pencil and paper support to develop the forms or only mentally developing the forms.

According to the authors this was a surprising result. Both the experimenters and the subjects held the belief that using pencil and paper to help construct patterns should be easier or more effective than using mental imagery alone. It is noteworthy that Verstijnen (1997) found similar results to those of Anderson & Helstrup (1993) using designers as subjects. These results would also appear to bring into question the views expressed in the design literature with respect to drawing as an aid in creative mental synthesis. However, there are a number of reasons why these results should be treated with caution. It is often noted in the design literature that people have to be taught how to draw. Notwithstanding Verstijnen (1997), the participants in these experiments were university students from the general university population. They may not have known how to draw in a way that assists in mental synthesis and creativity. Similarly, they were only instructed to draw while they carried out the task. It could be that drawing is only of use at particular points in the process, for example when the drawing activity follows mental synthesis. However, the structure of the creative mental synthesis task allows a much more careful analysis of drawing, by allowing quite explicit manipulation of when the drawing activity occurs.

The second experiment to be reported investigates the role of drawing in creative mental synthesis by systematically controlling when the drawing activity occurs and by comparing the performance of designers with non-designers. In addition, issues relating to the thinking strategies used by the subjects in both the first experiment and the second experiment were explored. The use of multiple thinking strategies was compared and contrasted, in the context of creative mental synthesis tasks, with the use of one thinking strategy exclusively.

Chapter 3 Experiment 1: Experimental Design (2D&3D)

3.1 Introduction

If the beliefs reflected in the design literature regarding the importance of creative mental synthesis are to be substantiated, empirical methods must be applied in order to investigate the presumed significance of creative mental synthesis in design. The design literature offers very little in the way of empirical methodologies that would assist in such an investigation. However, in the discipline of cognitive psychology much research concerning visual and mental imagery has been conducted for a number of years. The research and research methodologies in the discipline of cognitive psychology are extensive and varied. However, the methodology developed by Finke & Slayton (1988) [with respect to 2D creative mental synthesis] and Finke (1990) [with respect to 3D creative mental synthesis] appears to offer a logical and straightforward way of testing some of the beliefs found in the design literature relating to creative mental synthesis. Therefore, the obvious but necessary first step in the research to be presented here was to adopt and adapt their methods and procedures and place them in a design context by comparing and contrasting designers and non-designers. As there are two-dimensional and three-dimensional designers it is reasonable to compare and contrast these different test subjects by having them solve two-dimensional and three-dimensional creative mental synthesis problems.

The focus of this chapter is centred on the procedural and methodological issues of experiment one, which closely followed those of Finke & Slayton (1988) and Finke (1990). Their experiments explored both two-dimensional and three-dimensional creative mental synthesis respectively. As there were two types of problems

(2D&3D), there were two separate parts of experiment one (2D problem trials and separate 3D problem trials). However, while the procedures were not exactly the same, they were very similar, therefore, it was sensible to group together and report on similar topics in common sections [i.e. types and numbers of subjects used in the experiment; types of stimuli etc...].

3.2 Method & Procedures

3.2.1 Subject Types (2D Problems)

Previously, in both the summary of the literature review [2.6] and introduction of chapter 3 [3.1], it was posited that the most straightforward way of assessing the relevance of the creative mental synthesis task, with respect to design, was to replicate experimental research methods developed by Finke & Slayton (1988). In addition, part one of experiment one compared the performance of different types of designers with non-designers. The type of material and stimuli utilised in their task was of a 2D nature which involving drawings of simple 2D forms. Such forms can be viewed as those typically used by graphic designers. However, there are designers who are trained and practiced in developing 3D forms and representations [thought to be more complex]. Typical 3D designers are industrial designers. A development of the basic hypothesis therefore is that there should be differential performance between graphic designers and industrial designers. Graphic designers should perform better on the measures of creativity and correspondence when using the 2D forms, than the industrial designers. Both types of designers, however, would be expected to perform better than the non-designers given 2D creative mental synthesis problems. An aspect of the experimental design of the first experiment therefore was the use of separate groups of industrial designers, graphic designers, and non-designers. This study did

not randomly select non-designers. Rather, it sought to identify a group who would

contrast with the designers in terms of the types of thought processes involved in their

activities. If design involves the manipulation of representations of physical objects,

then the most appropriate comparison group would be those whose thinking processes

are based on words and abstract concepts. A number of academic disciplines could be

placed in this category, however, the discipline of the law was chosen as the basis for

the comparison group. The pictorial representation below [Figure 20] reflects the

presumed differences in thinking styles [analog/propositional].
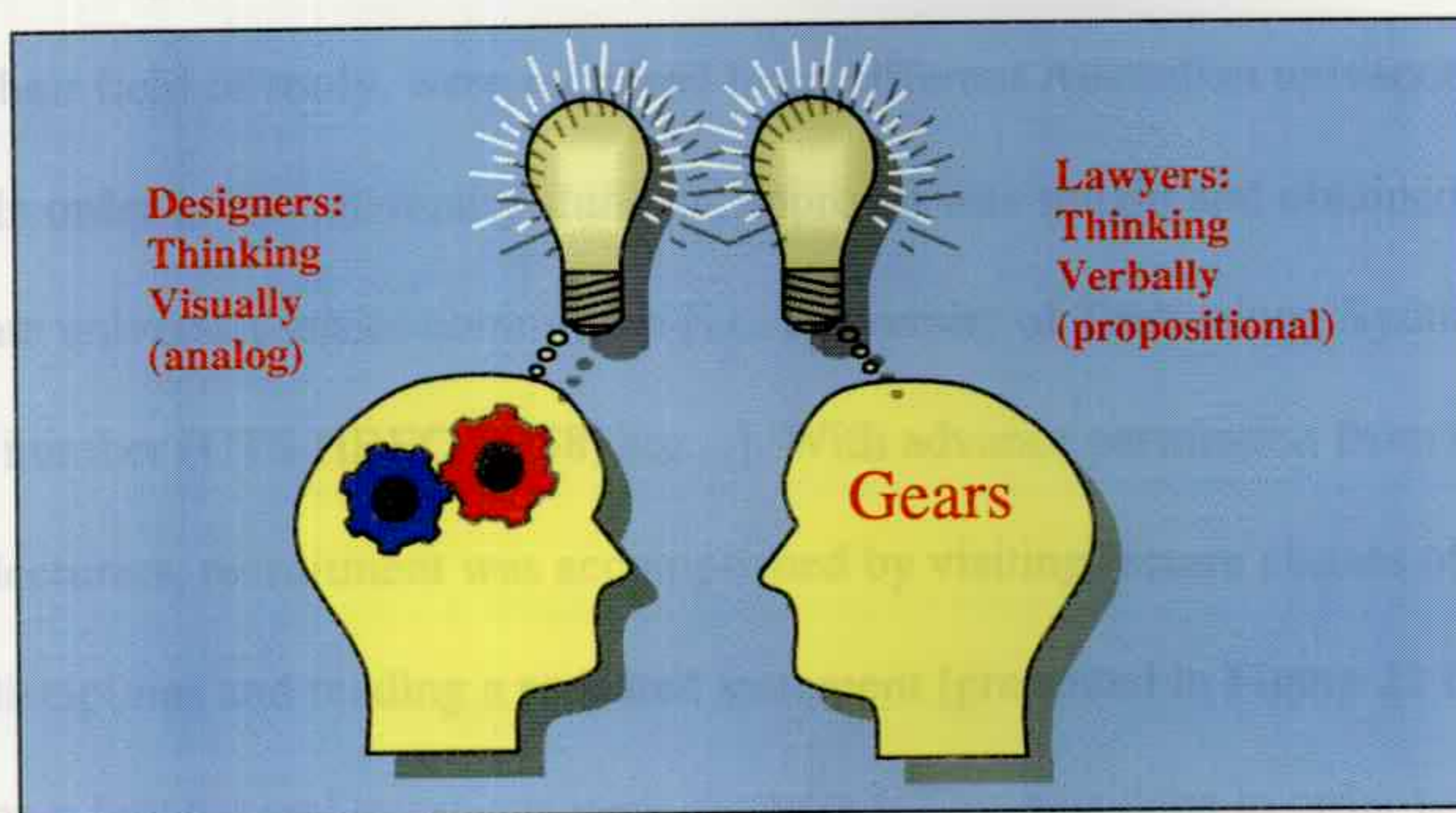
FIGURE 20: THINKING STYLES OF DESIGNERS AND NON-DESIGNERS

3.2.2 Subject Types [3D Problems]

The materials and stimuli in the tasks of Finke (1990) were of a 3D nature, requiring

the subjects to create a practical object. The types of problems Finke (1990) presented

were thought be of value to 3D thinkers. In part two [3D-problem trials] of

experiment one, industrial designers were used as the 3D designers and graphic

designers (visual communications students) as the 2D designers. Law students again

were used as the non-designers. A refinement of the previous basic hypothesis

therefore, is that there should be differential performance of the task between

industrial designers and graphic designers. Industrial designers should perform better

on the measures of creativity and practicality, in contrast to the graphic designers.

Both types of designers would, however, be expected to perform better than the non-

designers. An extension of the experimental design of the first experiment therefore

was the use of separate groups of industrial and graphic designers and non-designers

to solve 3D creative mental synthesis problems.

3.2.3 Subject Recruitment

Volunteer undergraduate university students and private college students in the final

years of their field of study, were recruited from different Australian universities and

schools. In order to use university students, approval was sought and obtained by the

appropriate university ethics committees [i.e. University of Technology Sydney –

approval number (UTS HREC 96/58) etc…]. With advance permission from the

relevant lecturers, recruitment was accomplished by visiting lecture classes of the

various disciplines and reading a prepared statement [presented in Figure 21 below].

In addition a few general questions were answered. This was done in order to

Hello my name is Vasilije Kokotovich.
I am a lecturer in Industrial Design at the University of Technology Sydney. I am working on a PhD.
My research is concerned with issues of mental synthesis.
Mental synthesis is described as imagining the assembly of a final part from component parts.
In creating a design it is believed that designers use mental synthesis in the design thinking process.
My work is a study of designers and mental synthesis. I am looking at Non-designers/2D designers/3D designers.
I am asking for volunteers to participate in my research.
I have some already from the University. However, I need some more volunteers.
It will only take about one hour of your time [Sometime throughout the semester].
I will try to organise the times for you to do the tasks in groups of 4-6.
However, some of the volunteers will be randomly selected as judges. In this case the time commitment will consist of 2 four-hour blocks of time.
In these cases I will organise lunch or something.
Another possibility is that you may be selected to be a judge for one 4 hour block later in the semester.
I would greatly appreciate your participation.
If you are interested in helping me with my research would you please put your name and contact phone number on the sign up sheet I am passing around now.
Are there any questions? In answering your questions I cannot tell you too much, however, I need to tell you enough to entice you to participate.

FIGURE 21: RECRUITMENT STATEMENT

maintain consistency in the recruitment process. The nature of the statement was to

tell the potential subjects enough to pique their curiosity and interest, but not enough

to reveal the details of the research. Interested students placed their name and a

contact telephone number on a sign-on sheet, thus minimising disruption to the

scheduled class. Volunteers were later contacted to confirm their willingness, and to

obtain prospective times to participate in the research.

3.2.4 Subject Numbers [2D Problems]

One aspect of experiment one, which investigated 2D creative mental synthesis, was

that it utilised 60-student subjects in the final years of their degree [20 subjects from

each discipline]. Table 2 below reflects the breakdown by student type:

Subject groups [2D trials modelled on Finke & Slayton (1988)]			
	3D Designers Industrial design students number of subjects	2D Designers Graphic design students number of subjects	non-designers Law Students number of subjects	Total
2D Problems sets (8 trials)	20	20	20	60

TABLE 2: SUBJECT GROUPINGS 2D PROBLEMS

After contacting the subjects, each cohort of 20 students was generally organised into

groups of four to six. Finke & Slayton (1988) had also used small groups in order to

expedite their experiments. These group numbers were large enough to expedite the

experiment, yet small enough so as not to be a distraction for the other subjects within

the small groups. If a subject was unable to meet in a scheduled group, an appropriate

individual time was found.

3.2.5 Subject Numbers [3D Problems]

Part two of the first experiment, which investigated 3D creative mental synthesis,

utilised 60 student subjects in the final years of their degree [20 subjects from each

discipline]. It should be noted that no subjects who assisted in part one [2D problems]

of experiment one, participated in part two [3D problems] of experiment one. Table 3

below reflects the breakdown by student type.

Subject groups [3D trials modelled on Finke (1990)]			
	3D Designers Industrial design students number of subjects	2D Designers Graphic design students number of subjects	non-designers Law Students number of subjects	Total
3D Problems sets (8 trials)	20	20	20	60

TABLE 3: SUBJECT GROUPINGS 3D PROBLEMS

Having contacted the subjects, each cohort of 20 students was again organised into

groups of four to six. Having utilised this group size before, these group numbers

were in fact large enough to expedite the experiment, yet small enough so as not to be

a distraction for the other subjects. This was consistent with Finke (1990), as he

expedited his experiments by dividing his subjects into groups of 4–6 subjects. If a

subject was unable to meet in a scheduled group, an appropriate individual time was

found.

2.2.6 Stimuli [2D Problems]

The subjects were presented with a group of parts, which consisted of fifteen forms

shown in Figure 22 below, as utilised in Finke & Slayton (1988). Three forms of the

fifteen basic forms were randomly selected for each trial of the eight trials all subjects

were required to complete. Finke & Slayton (1988) reasoned that some shapes might

be considered more complex than others. In their work Finke and Slayton (1988) were

concerned that the subjects would consider some of the forms difficult to utilise. So

that the more complex forms were less likely to be used in each separate trial, they

weighted the first ten forms consisting of circle, square, rectangle, triangle, vertical

line, horizontal line, capital letters D, C, L, T, to be three times as likely to be used as

the last five forms (J, 8, X, V, P). The same weighting of the forms was applied in this study. The purpose of this was to minimize the prospect of a triplet of forms for any of the eight trials, being comprised of only more complex forms. That is to say, it is important that a triplet of forms should not consist of three of the forms thought to be more difficult. The selection of triplets of parts to be used in each trial was performed randomly by computer. This was accomplished by attributing a set of code numbers to each figure. The length of the number codes [larger or smaller sets of codes] attributed to the figures was appropriate to effect the weighting ratio 3:1 (i.e. circle = 7–9 whereas letter X = 39–40). A random number generator within the computer selected the triplet codes. The codes were then related back to the forms. Each group within each cohort of subjects had a different set of eight triplets compared with the other groups of subjects. As each cohort of subjects was divided into groups of 4–6, each subject performed the creative mental synthesis task eight times, using three new randomly selected forms in each trial.
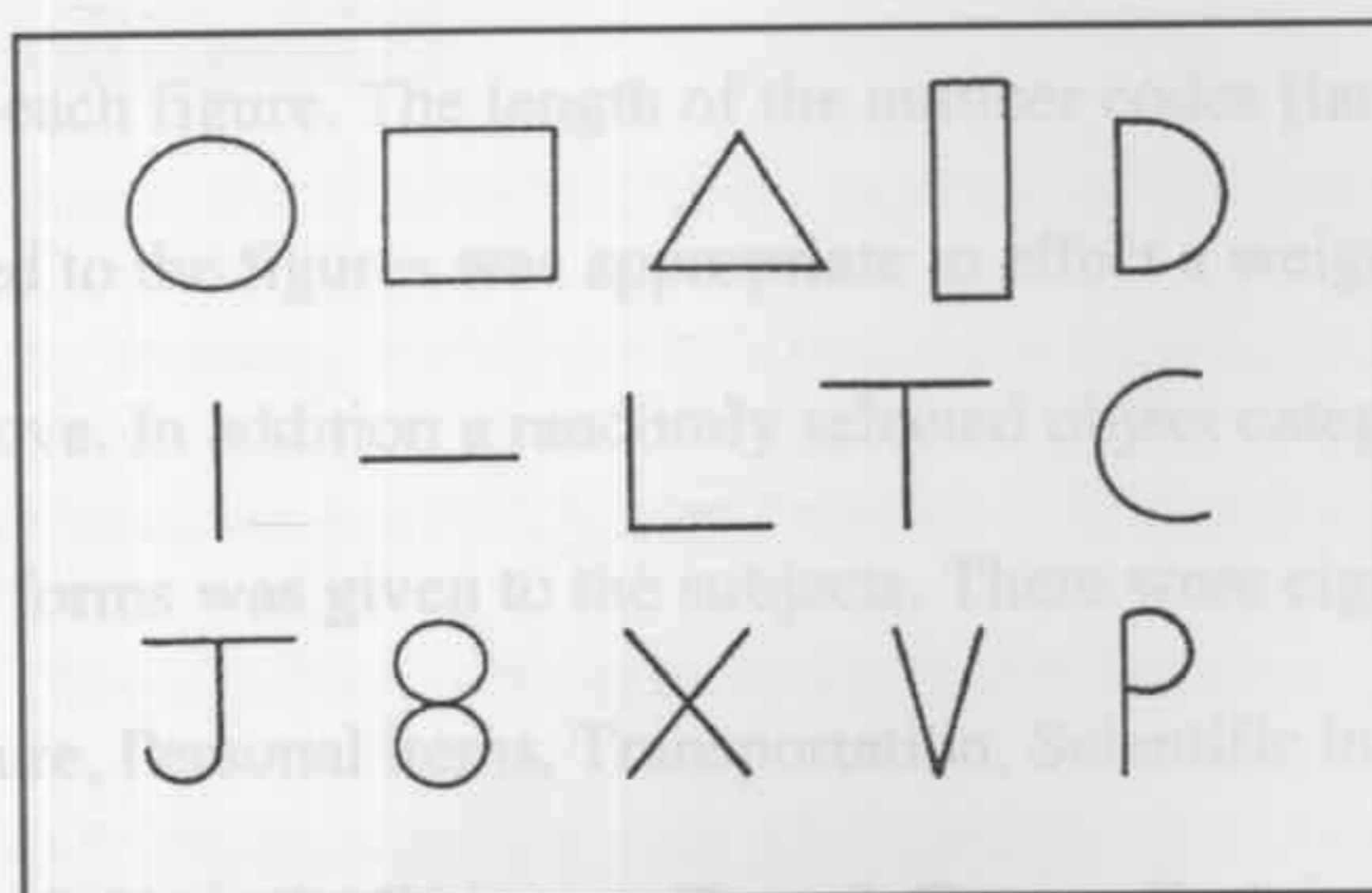
FIGURE 22: STIMULI (2D)

The subjects were presented with a group of parts, which consisted of fifteen forms shown in Figure 23 below, as utilised in Finke (1990). Three forms of the fifteen basic forms were randomly selected for each trial of the eight trials all subjects were

required to complete. Finke (1990) reasoned that some shapes might be considered more complex than others. Consequently, in his work Finke (1990) was concerned that the subjects would consider some of the forms difficult to utilise. Therefore, in this study, as in Finke (1990), the following constraints were applied to the 3D forms of varying complexity so that the more complex forms were less likely to be used in each separate trial:

The sphere, hemisphere, cube, cone, and cylinder had a 50 percent chance of selection. The wire, tube, flat square plate, bracket, and rectangular block had a 33.3 percent chance of selection. The hook, wheels, cross, ring, and handle had a 16.7 percent chance of selection.

This was to minimize the prospect of a triplet of forms for any of the eight trials, being comprised of the more complex forms. As in the 2D trials it was important that a triplet of forms should not consist of three of the more difficult forms. The selection of triplets of parts to be used in each trial was done randomly by computer, utilising the same methods previously described in the selection of 2D triplets, giving a set of code numbers for each figure. The length of the number codes [larger or smaller sets of codes] attributed to the figures was appropriate to effect a weighting ratio following the rules listed above. In addition a randomly selected object category attached to each triplet of 3D forms was given to the subjects. There were eight invention categories, Furniture, Personal items, Transportation, Scientific instruments, Appliances, Tools & Utensils, Weapons, Toys & Games. Each invention category had an equal chance of being randomly selected by the computer, again using the coding methods described earlier.

Each group within each cohort of subjects had a different set of eight triplets coupled with a randomly selected invention category. As each cohort of subjects was divided

into groups of 4–6, each subject performed the creative mental synthesis task eight times in contrast to the six trials in Finke (1990), using a new invention category coupled to each new triplet of forms.
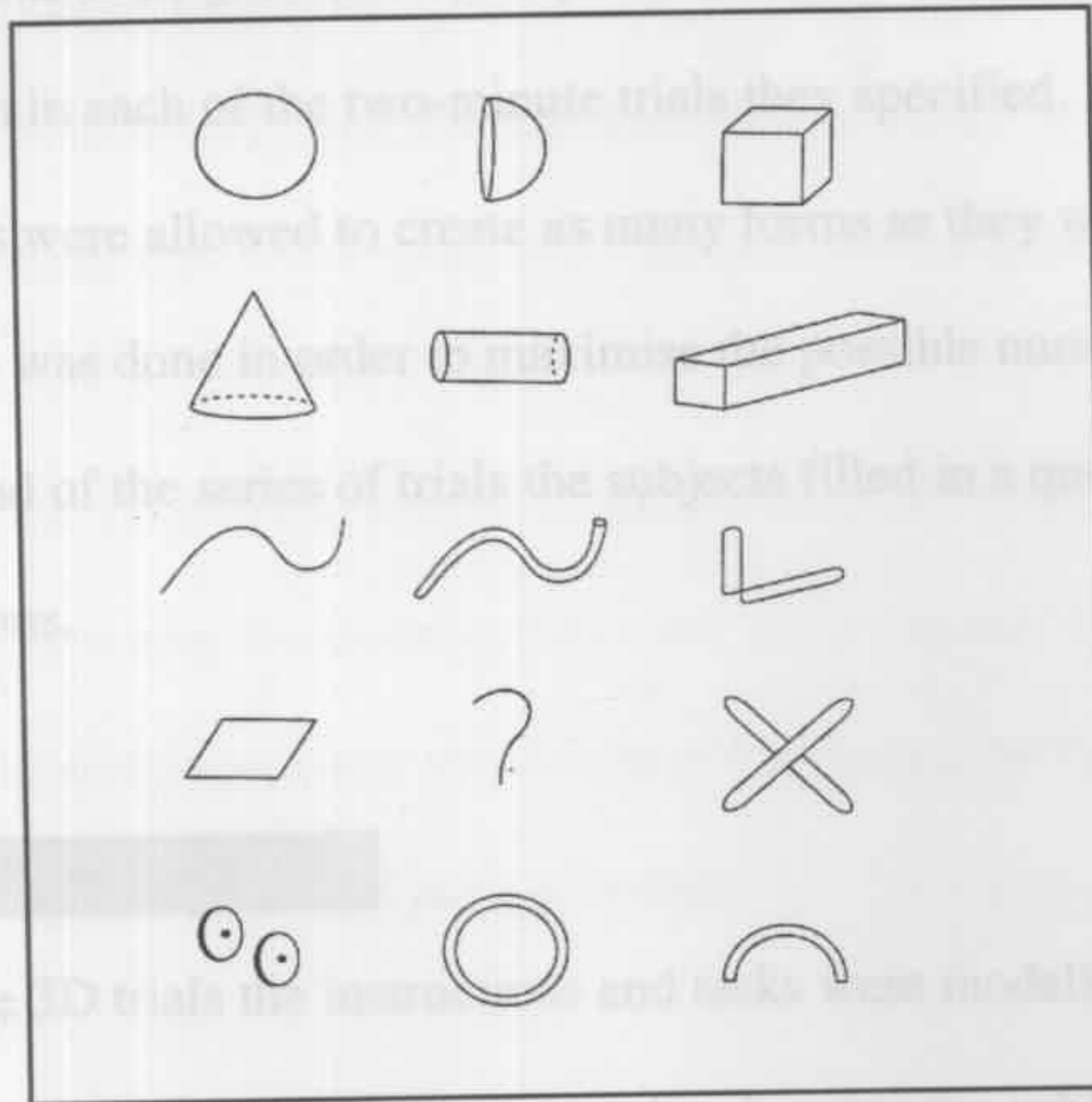
FIGURE 23: STIMULI (3D)

The experimenter was in the room at all times monitoring the sessions. The experiment began by showing the subjects fifteen object parts, as in Finke and Slayton (1988). Three parts were randomly selected for each trial in a series of eight trials presented to the different groups who explored two-dimensional creative mental synthesis. In the 2D trials the subjects were given a copy of a drawing consisting of the fifteen two-dimensional forms from which triplets of parts would be selected. For purposes of consistency, the instructions [refer to Appendix A] were read to the subjects. Prior to the reading of the instructions, information sheets (required by the ethics committees), were read and signed by the subjects. These sheets outlined the

ethical issues relating to time commitment, privacy/publication issues, and contact information should a complaint arise.

In the work of Finke & Slayton (1988) they required the subjects to create only **one** recognisable form in each of the two-minute trials they specified. However, in this study the subjects were allowed to create as many forms as they wished in each three-minute trial. This was done in order to maximise the possible number of forms created. At the end of the series of trials the subjects filled in a questionnaire, detailed subsequent sections.

3.2.9 Procedure [3D Problems]

In conducting the 3D trials the instructions and tasks were modelled on the original work of Finke (1990). The experiment began by showing the subjects fifteen object parts from which triplets of parts would be selected, as described earlier. Three parts and an invention category were randomly selected for each trial in a series of eight trials presented to the 3D problem groups who explored three-dimensional creative mental synthesis. For the purposes of consistency, the instructions [refer to Appendix B] were read to the subjects. Prior to the reading of the instructions, information sheets (required by the ethics committees), were read and signed by the subjects. These sheets outlined the ethical issues relating to time commitment, privacy/publication issues, and contact information should a complaint arise.

In his work concerning 3D mental synthesis, Finke (1990) found a higher percentage of creative responses were generated when subjects were given both the object category and the basic forms to be synthesised. Therefore, in order to maximise the creative output in this experiment, the subjects were given both the object invention

category and the basic forms to be synthesised. In addition to increasing the number of trials to eight [Finke (1990) used six trials], the subjects had three minutes [instead of two minutes in Finke (1990)], to develop as many inventions as they could, to maximise the number of inventions created. In Finke (1990) the subjects were required to try to develop only **one** invention in the time frame given. As in the 2D trials the experimenter was in the room at all times monitoring the sessions.

In addition, as in the 2D trials, at the end of the series of 3D trials the subjects filled in a questionnaire concerning the strategy they used in combining the parts to create a new form. If the subjects made any comments or had questions throughout the experiment, these were noted for future reference.

3.3 Data

3.3.1 Data Collection and Experimenter Bias [2D Responses]

The procedure outlined in section 3.2.8 resulted in a number of individual drawings with corresponding descriptions of different forms being created by each subject. These drawings were considered to be quantitative data. After the drawings were generated they were coded and had judging stickers applied to them. This will be explained in detail in the section on judging.

A difference between this study and the work of Finke & Slayton (1988) was that naive experimenters were not used, contrary to suggestions by Intons-Peterson (1983). Naive experimenters are persons who facilitate the experiment, who, while being trained in the procedures of the experiment, are blind to the major purpose of the experiment.

Finke (1993) contends that this type of research has an advantage, in that a researcher can avoid many of the problems associated with demand characteristics and experimenter bias. A possible reason for this was that the experimenter did not know what the subjects would create, therefore, could not bias them by giving verbal or nonverbal cues. The work of Finke & Slayton (1988) suggested this, as in one of their experiments they instructed the experimenters to guess and predict the results. For the most part they could not accurately predict the forms. Consequently, it can be argued the experimenter giving the instructions could not influence the outcomes.

In this research, the experimenter was in the room at all times monitoring the sessions. As the experimenter did not have previous contact with the vast majority of the subjects participating in this experiment, coupled with the fact that the instructions were consistently read from a pre-printed sheet, it was felt these factors control experimenter bias. The experimenter did have knowledge of the hypothesis, but it was believed this would not present a problem in conducting this research. Research by Intons-Peterson (1983) suggested that in some cases experimenter bias owing to knowledge of an experimental hypothesis can be a factor in predicting and therefore influencing the response of a subject towards the experimenter's hypothesis. Finke & Slayton (1988) used naive experimenters in their mental synthesis research. They found the experimenters could very rarely predict the creative output of the subjects. Since it is difficult to predict a response from a subject in these types of mental synthesis experiments, it is reasonable to believe that an experimenter with knowledge of the hypothesis would also have difficulty in predicting and therefore influencing, the creative output of the subjects or judges in this type of research. In addition, the

subjects had their eyes closed for most of the time and could not pick up on visual

cues from the experimenter's body language. The supporting rationale for not having

naive experimenters is that any questions or concerns raised by the subjects can be

appropriately dealt with, given that the researcher has an understanding of the

complete experiment.

3.3.2 Data Collection Questionnaire [2D Responses]

At the end of the series of trials, as in Finke & Slayton (1988), the subjects filled in a

questionnaire concerning the strategy/strategies they used in combining the parts to

create a new form. The difference was that in Finke & Slayton (1988) the subjects

were to pick the most common (**one**) strategy they used in combining the parts and

did not further explain their strategies. As the subjects were not given a strategy for

solving the problems, the questionnaire was included in order to discover how the

subjects thought they might have actually performed the task. They were told that the

four possibilities 'were not set in concrete' and were only suggestions. The

alternatives were as follows:

1) " **I tried combining the parts by trial and error in my image until I happened to recognise a shape**"

2) " **I first thought of a possible shape, then I tried to combine the parts in my image to see whether the particular shape could be made out of the parts**"

3) " **I did not form an image at all, but just thought about how the parts might be combined in a more abstract way**"

4) " **I used some other strategy**"

They were instructed to circle the strategy or strategies they used to develop their

solutions. If they used more than one strategy they were told to circle all the strategies

used. On the back of the questionnaire, they were encouraged to further enhance the

standard description of the strategies used. In addition, if they had changed strategies

they were to describe when and why they changed. If they used some other strategy not listed then they were to explain the strategy they used. This component of the experiment analysis relates to thinking/reasoning strategies. In addition, if the subjects made any comments, had questions, or instilled thoughts within the experimenter, in any way throughout the experiment, these were noted for future reference and analysis. These questions, comments and thoughts were also considered to be valuable data.

3.3.3 Data Collection and Experimenter Bias [3D Responses]

The procedure outlined in section 3.2.9 resulted in a number of individual drawings with corresponding descriptions of different inventions being created by each subject. These drawings were considered to be quantitative data. After the drawings were generated they were coded and had judging stickers applied to them. This will be explained in detail in a subsequent section on judging.

As the basic procedure for the 3D problems was similar to the 2D problems, the issue of naive experimenters was similar. Therefore, naive experimenters (as in the 2D trials) were not used, contrary to suggestions by Intons-Peterson (1983). As stated and explained earlier, Finke (1993) contends that this type of research has an advantage in that a researcher can avoid many of the problems associated with demand characteristics and experimenter bias, therefore naive experimenters were not deemed necessary. In addition, as before, the supporting rationale for not having naive experimenters was that any questions or concerns raised by the subjects could be appropriately dealt with, given that the experimenter had an understanding of the complete experiment.

3.3.4 Data Collection Questionnaire [3D Responses]

Consistent with Finke (1990) at the end of the series of trials, and as in Finke &

Slayton (1988), the subjects filled in a questionnaire concerning the strategy/strategies

they used in combining the parts to create a new invention. The difference was that in

Finke (1990) the subjects were to pick the most common **(one)** strategy they used in

combining the parts. As the subjects were not given a strategy for solving the

problems, the questionnaire was included in order to discover how the subjects may

have actually performed the task. As with the 2D trials questionnaire, in part one of

experiment one, the subjects were told that the four possibilities 'were not set in

concrete' and were only suggestions. Essentially, the same instructions for responding

to the questionnaire were given to subjects completing the 3D problems as the

subjects given the 2D problems. This component of the experiment provided data for

analysis relating to thinking/reasoning strategies. Consistent with part one [2D trials]

of experiment one, if the subjects made any comments, had questions, or instilled

thoughts within the experimenter in any way throughout the experiment, these were

noted for future reference and analysis. These questions and comments were also

considered as being valuable data.

3.4 Judging Data

3.4.1 Judge Type & Numbers [2D & 3D Responses]

There were three judges used in Finke & Slayton (1988). However, drawing from the

remaining pool of volunteers, this study used five judges from each cohort of students

(Industrial design—Visual communications design—Law), resulting in a total of

fifteen judges, as illustrated in Table 4 below. These judges reviewed the responses

generated by all three cohorts of student subjects. Consequently, each of these judges

reviewed every single response generated by all one hundred and twenty test subjects

[subjects completing the 2D problems, and subjects completing the 3D problems].

	Judge groups			
	3D Designers Industrial design students number of Judges	2D Designers Graphic design students number of Judges	non-designers Law Students number of Judges	**Total**
Number of Student Judges	5	5	5	15

TABLE 4: JUDGE TYPE GROUPINGS EXPERIMENT ONE

Students, who were either subjects or judges, taking a general psychology course, as

in Finke & Slayton (1988), could be from any of a number of disciplines [which may

or may not include design disciplines], and therefore could be considered as being

from a general student population. However, controlling the different cohorts of

judges as well as different cohorts of subjects, allows analysis between and among the

judge types and subject types. The supporting rationale for the increased judge

numbers was that a larger number (greater than two or three) of a mixed group of

judges [designers and non-designers] would allow for flexibility in analysis, yet still

reflect a general student population [as in a general psychology class used in Finke &

Slayton (1988)]. In addition, greater numbers would allow more reliable statistical

analysis of the results.

While there were only two judges used in his work, Finke (1990), these judges had

also reviewed the 2D responses in his earlier work [Finke & Slayton (1988)].

Therefore, the practice of using the same judges for different problem types has been

established. As indicated earlier, the judges used in this study to review the 3D data

sheets were the same judges who reviewed the 2D responses.

3.4.2 Data Coding Conventions [2D & 3D]

In order to ensure that the judges were blind to the background of the subjects, a

coding system was devised for each response generated by each subject. After the

participants generated the responses, the responses were coded, and a rating system

sticker was applied to each response. Once the codes and stickers were applied, fifteen

photocopies of each response sheet were made. Using this coding system it was

possible to generate for each judge, one complete set of 2D responses (photocopies),

appropriately encoded, so that if required a particular response from a particular judge

could conceivably be tracked down later. The legend below is a breakdown of the

coding system acting, as an example for one particular judge from the industrial

design group, viewing one response generated by a particular Law subject:

Judge

1 Law (judge background)
2 Industrial Design (judge background)
3 Vis Com (judge background)
1ˢᵗ judge from the background group
2ⁿᵈ judge from the background group
3ʳᵈ judge from the background group
4ᵗʰ judge from the background group
5ᵗʰ judge from the background group
ND non-designer (subject background)
ID industrial designer (subject background)
VC Visual com designer (subject background)
2D Problem sets
3D Problem sets
Group
X Group number
Subject
X Subject number
Problem
X Problem number
Response
X Response number

J23ND3DG4S1P4R3

Example of a code written on one of the subjects' response sheets to identify the judge, the subject being judged and a particular response from that subject.

3.4.3 Distribution of Responses

In judging either the 2D data sheets or the 3D data sheets, it was important that no ordering effect among the judgements occurred. It may be possible that the order in which responses are presented may change the judge's response due to a number of factors (e.g. Practice, Fatigue, Shifting views or Criterion of the judge, etc…). For example, if it is assumed that a judge is fatigued by the time the last response is reviewed, the judgement of that judge could be affected by fatigue. However, if another judge had judged this particular response earlier, fatigue may not have been a factor. Thus, randomising helps to reduce ordering effects.

After all the copies of the responses had been coded and the rating system applied the stacks of photocopies were randomised to ensure the stack of responses presented to each judge was different between the judges. The diagram below shows how each stack of responses was randomised yet structured enough to investigate any boredom or criterion shift effects if necessary.

Semi-Random Distribution of Responses

The stack of responses for each judge was different than the other judges
Each of these represents a set of photocopies from a particular subject.
For example the first set of responses Judge J12 reviewed were all
from Subject 1 of the non designers. J13 first reviewed a vis-com
subjects responses.

15 different randomised stacks of photocopied responses

J12	J13	J14	J15
NDS1	VCS1	IDS1	NDS1
IDS1	NDS1	VCS1	IDS1
VCS1	IDS1	NDS1	VCS1
VCS2	NDS2	NDS2	IDS2
NDS2	IDS2	VCS2	NDS2
IDS2	VCS2	IDS2	VCS2
NDS3	IDS3	NDS3	VCS3
VCS3	NDS3	IDS3	NDS3
IDS3	VCS3	NDS3	IDS3
IDS4	VCS4	NDS4	VCS4
NDS4	IDS4	IDS4	NDS4
VCS4	NDS4	VCS4	IDS4
NDS5	IDS5	NDS5	VCS5
VCS5	NDS5	IDS5	NDS5
IDS5	VCS5	VCS5	IDS5
NDS6	IDS6	VCS6	NDS6
	NDS6	NDS6	IDS6
	NDS6	NDS6	NDS6
		NDS7	
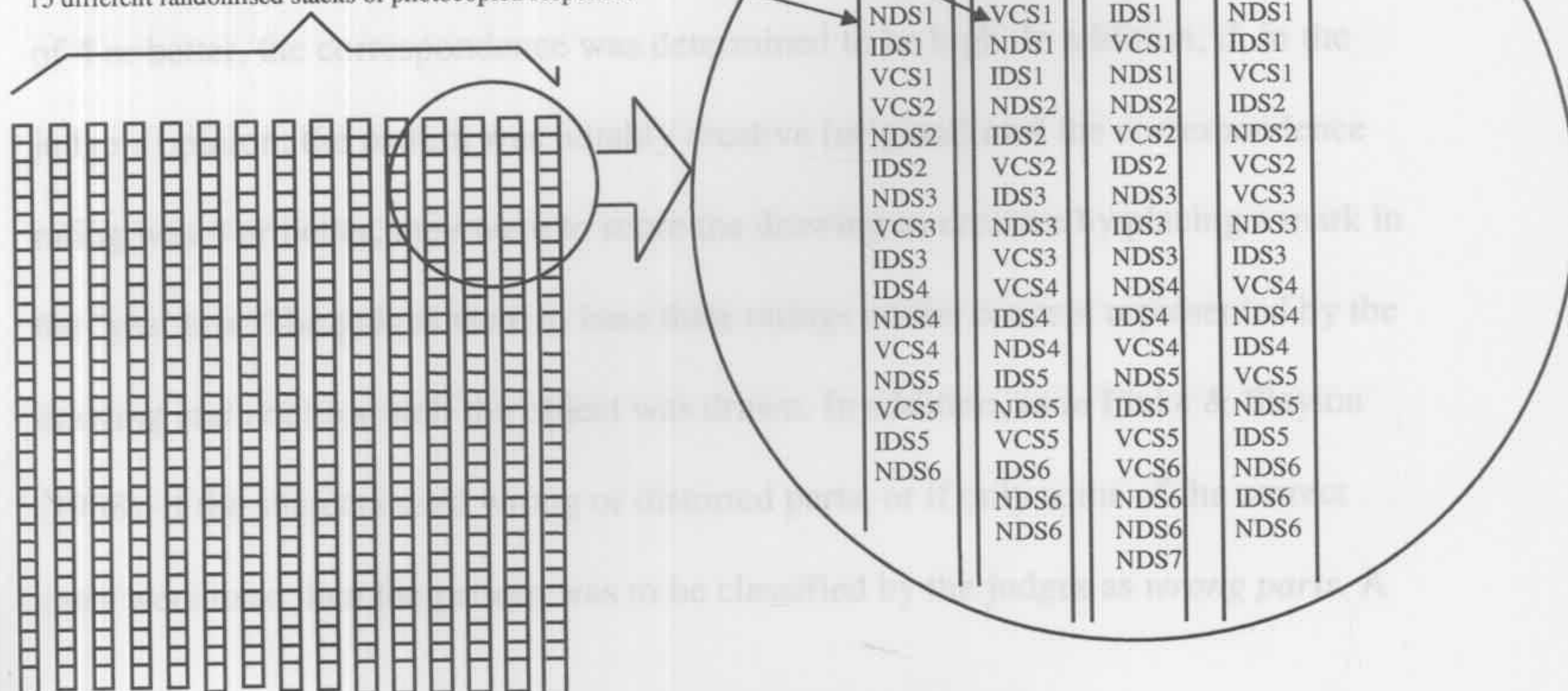
In the diagram above, when stacking the responses for the judges, there were fifteen stacks of data for judging the 2D responses, and fifteen separate stacks of data for judging the 3D responses. Each stack [either 2D or 3D] contained photocopies of all the subjects' responses. Each subject's responses were coded and grouped together.

3.4.4 Scoring Conventions [2D Problems]

As mentioned earlier, the judges were to independently rate how well the names of the forms corresponded to the drawings presented. Following the scoring conventions of Finke & Slayton (1988), the judges were to use a 5-point scale (as shown below). This judgement scale was on each 2D response.

1	2	3	4	5.
Very Poor correspondence	Low correspondence	Modest correspondence	Good correspondence	Very Good correspondence

Is the pattern creative (original) ?

No pattern	Wrong Parts used	YES
☐	☐	☐

The judges were instructed to give a correspondence rating to the drawing by circling a rating number. The correspondence rating acted as a clear indicator of the occurrence of mental synthesis. If the majority of judges gave a correspondence rating of 4 or better, the correspondence was determined to be high. In addition, if, in the judge's opinion, the pattern was notably creative (original) **and** the correspondence rating was 4 or better, they were to score the drawing as creative by placing a mark in the 'yes' box. The judges were to base their ratings on the concept represented by the drawing and not how well the object was drawn. In addition, as in Finke & Slayton (1988), if the subjects used wrong or distorted parts, or if only some of the correct parts were used then the pattern was to be classified by the judges as *wrong parts*. A

no pattern classification refers to a trial in which the subject reported no form. Even if there was no pattern [form] this was considered an attempt and therefore counted, unlike Finke & Slayton (1988) who did not count a non-response.

3.4.5 Scoring Conventions [3D Problems]

As in the work of Finke (1990) the judges were to rate the practicality and originality (creativity) of each invention. They were to use two 5-point scales (as shown below).

1	2	3	4	5.	No Response
Not Practical	Low Practicality	Modest Practicality	Practical	Very Practical	☐

1	2	3	4	5.
Not Original	Low Originality	Modest Originality	Original	Very Original

These different ratings were to be made independent of each other. An object could be practical but not original, original but not practical, or both original and practical. They were to circle a rating for the practicality for each response and an originality rating for each response. If the majority of judges rated an invention with a score of 4 or better for practicality, the invention was counted as being practical. If the majority of judges rated an invention with a score of 4 or better for originality/creativity, the invention was counted as being creative. The judges were to base their ratings on the concept represented by the drawing and not how well the object was drawn. In addition they were to rate the overall design of the object not whether it necessarily contained all of the working parts it actually needed (e.g. If fasteners were missing it should not matter). In addition, if the subjects could not develop an invention in the time allowed (i.e. a blank response) or they used the wrong parts, the judges were to mark the box **No Response**.

As with the 2D responses, a coding sticker was applied to each 3D response. Next fifteen photocopies of each response were made (one for each judge). Using this coding system it was possible to generate for each judge, one stack of 3D responses (photocopies) appropriately encoded so that if required a particular response from a particular judge could conceivably be tracked down later.

3.4.6 Judgement Days [2D & 3D judgements]

Thirteen of the fifteen volunteer judges were gathered together for a full day of judging in a comfortable quiet room. Two judges were unable to attend that session so each was scheduled to judge on another day suited to their schedule. However, the same judging instructions were given to them. They were told that the morning session would be devoted to judging the 2D responses and after lunch they would be judging the 3D responses. The procedure the subjects had been expected to follow was explained to the judges. Then the judges were instructed to score the responses from each subject using the scoring conventions previously detailed in sections 3.4.4 and 3.4.5 above.

3.4.7 Judge instructions [2D]

All the judges received the same basic instructions. After they assembled in the room where the judging was to take place, and prior to the reading of the instructions, information sheets (required by the ethics committees) were read and signed by the judges. Just as the subjects were to be apprised of the ethical issues involved in the research, the judges had to be informed as well. These sheets outlined the ethical issues relating to time commitment, privacy/publication issues, and contact

information should a complaint arise. After they signed the ethics forms, the

instructions were read to them [instructions are located in Appendix C].

The judges were to score the responses sequentially as they were presented to them.

They were not allowed to return and review a previous response. They were not

allowed to compare or rank the responses. Each response was to stand on its own

merits at the time of review. The judges were not allowed to discuss the responses

with each other. No definition of originality or creativity was given. Modelled on the

methods of Finke & Slayton (1988) and Finke (1990), each judge was to use his or her

own criterion. A collective view [consensual agreement] would stand. If the majority

of judges deemed a response to be of high correspondence it would be considered so.

This was also true for the originality or creativity criterion [2D].

3.4.8 Judge instructions [3D]

Upon their return from lunch the original judges who reviewed the 2D responses,

were to judge the 3D responses. However, they were now to review drawings of

inventions. All the judges received the same basic instructions. After they assembled

in the room where the judging was going to take place, instructions were read to them

[instructions are located in Appendix C].

With respect to judging the 3D problems, the judges were to proceed in a similar

manner as they did with the 2D problems, and were to follow the conventions below:

- Score the responses sequentially as they were presented to them
- Were not allowed to return and review a previous response
- Were not allowed to compare or rank the responses
- Were not allowed to talk to each other about the responses
- Each response was to stand on its own merits at the time of review

No definition of originality or creativity was given. Each judge was to use his or her own criterion. A collective view would stand.

Chapter 4 Experiment 1: Judges issues & Results

4.1 Introduction

Once the data [responses] were collected and judged, the result was that fifteen different judges had reviewed each response from each subject. That is to say, any particular response was judged fifteen times. Therefore, a way of reviewing the numerical representations [numbers the judges circled] of any response needed to be organised in such a way as to allow a sensible analysis of the data to occur. The simplest way would be to organise the numerical ratings in a spreadsheet, thus allowing an investigation of the patterns of judgement both between and among the different judge groups and subject groups. This chapter is dedicated to discussing the experimental results.

4.2 Spreadsheet layout [2D]

Once the responses were judged, a spreadsheet was developed in order to prepare the coded data for analysis. Table 5 below summarises the basic construction of the spreadsheet as described in the text of this section.

Response Code	Correspondence				Creativity			
	ID Judge J12	ID judge J??/J??	ID Judge J??/J??	ETC .... J??/J??	ID Judge J12	ID judge J??/J??	ID Judge J??/J??	ETC . J??/J??
ID2DG1S1P1R1	4	3	5	4	0	1	1	0
ID2DG1S1P1R2	2	3	2	5	0	1	1	0
ID2DG1S1P2R1	5	4	5	2	0	1	1	1
ID2DG1S1P3R1	3	5	5	4	1	1	0	0

Row →

TABLE 5: INDICATIVE SPREADSHEET LAYOUT

The row headings in this spreadsheet were represented by a given response code (as described earlier in chapter 3), identifying the responses of the subjects, and the

column headings were represented by a judge code number (i.e. **J12**). Consequently,

the columns of cells represented the correspondence ratings (a number 1–5) and the

creativity ratings (1 or 0) for each judge. Each row of judgements corresponded to the

responses from a number of judges. This allowed for flexibility in analysis of the data.

4.3 Rules of Classification [2D]

The obvious but necessary first step with respect to investigating creative mental

synthesis of designers and non-designers was to model this experiment on the

methods and procedures of Finke & Slayton (1988), including aspects of their analysis

techniques. As described earlier, if in a judge's opinion the pattern was notably

creative (original), **and** the correspondence rating was at least a 4, the judges were to

score the pattern as creative. Another rule of classification was that, if the pattern was

recognisable (having a rating of 4 or 5) and was deemed creative by a majority of

judges, it was classified as a *creative pattern;* otherwise it is deemed a *non-creative*

pattern. A rule with respect to correspondence used by Finke & Slayton (1988), was

that patterns that had an average below 4 were classified as having poor

correspondence. In addition, if a response had a wrong or distorted part, or no

response was created, the response was not utilised.

4.4 Frequency Distribution Tables

A simple and straightforward way of reviewing the data via the spreadsheet and

adhering to the rules of classification of Finke & Slayton (1988) was to generate

frequency tables. Five variant types of frequency tables with respect to the variants of

judge types reviewing the responses of subjects are listed below:

Tables using ALL judges
Tables using only Industrial Design Judges
Tables using only Visual Communications Judges
Tables using only Non-Designer Judges
Tables of each Individual Judge

In reviewing the frequencies which were generated after following the scoring and

judging conventions of Finke & Slayton (1988) and using the spreadsheet described

above, results are summarised in Table 6 below. They are consistent with the

expectation that design subjects would perform better than non-designers with respect

to creativity and correspondence. The Table rows contain the number of responses

deemed to have a correspondence rating of 4 or above and the number of responses

deemed creative with respect to subject type [ID = Industrial Design subjects; VC =

Graphic design subjects; ND = Non-designer subjects].

All Judges		
	Corr	Creative
ID	49	35
VC	51	35
ND	23	25
Total	123	95
	% Corr	% Creative
	9.22	7.12
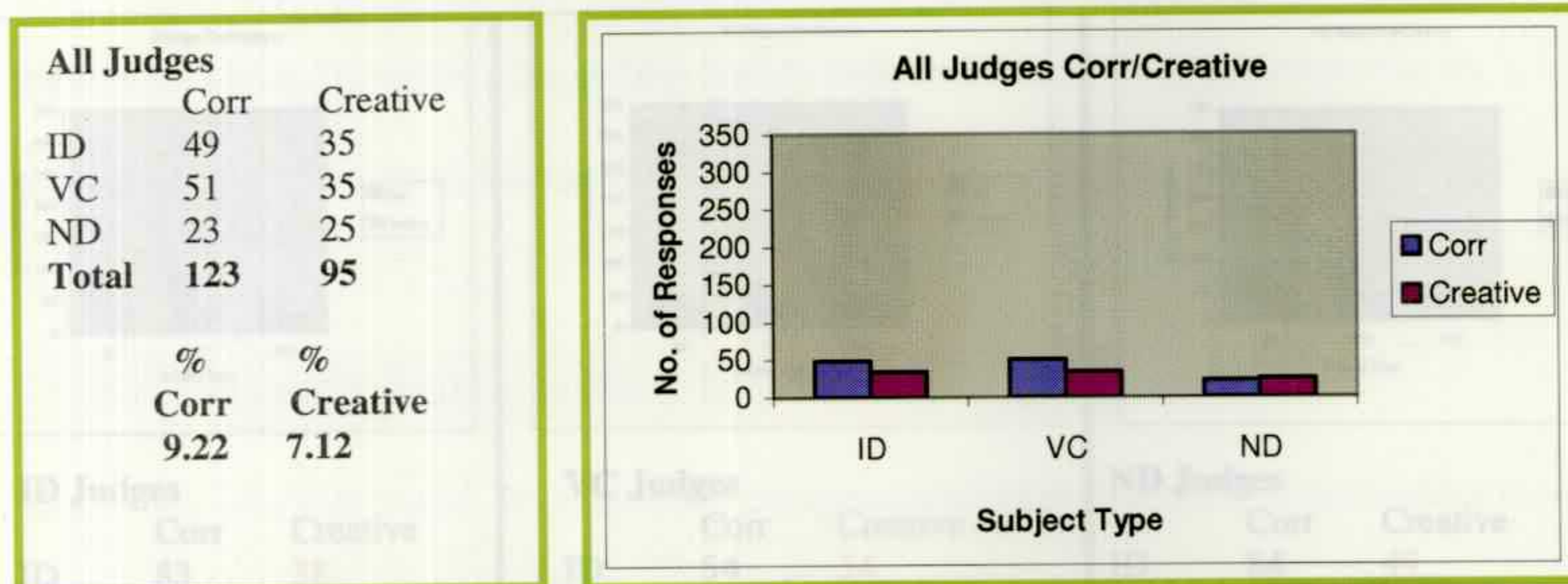
TABLE 6: FREQUENCIES OF RESPONSES USING ALL JUDGES AS ONE COHORT
[HIGH CORRESPONDENCE / CREATIVE]

When contrasting the results in the frequencies above [Table 6] with those of Finke &

Slayton (1988), differences emerge. In their work Finke & Slayton (1988) determined

15 percent of the responses as being highly creative and 38 percent were recognisable

(relatively high correspondence). In this research, when using fifteen judges, who

simulated a general mixed group of judges, [as in Finke & Slayton's (1988) general

psychology class], 7 percent of the responses were determined creative and 9 percent

had relatively high correspondence. In contrast to the work of Finke & Slayton (1988), the percentages in this study were based on the total number of subject responses and not just the recognisable responses. A subsequent section will explain the supporting rationale for this.

When reviewing the frequencies, after separating each cohort of five judges into each discipline, as reflected in the frequencies and charts of Table 7 below, the ID judges and ND judges are similar when their results are contrasted with the results when using all the judges. However, the VC judges found the ID subjects to be the least creative, while the correspondence pattern remains consistent with the results when all judges are combined.
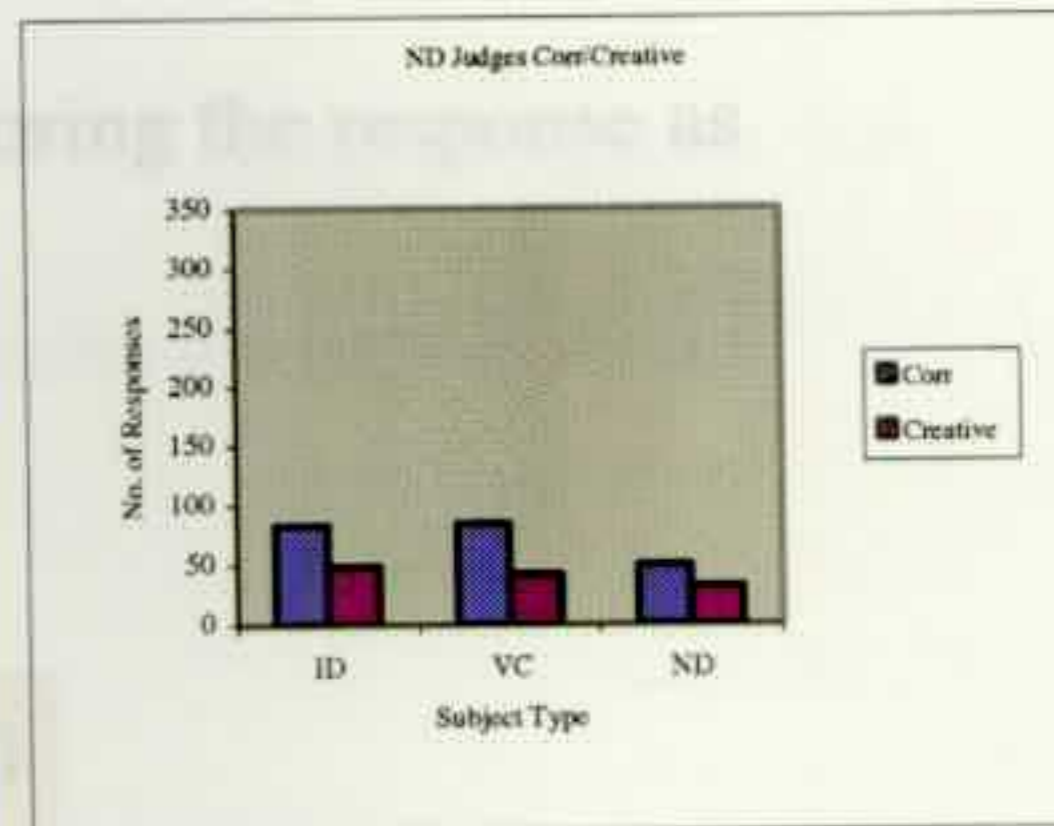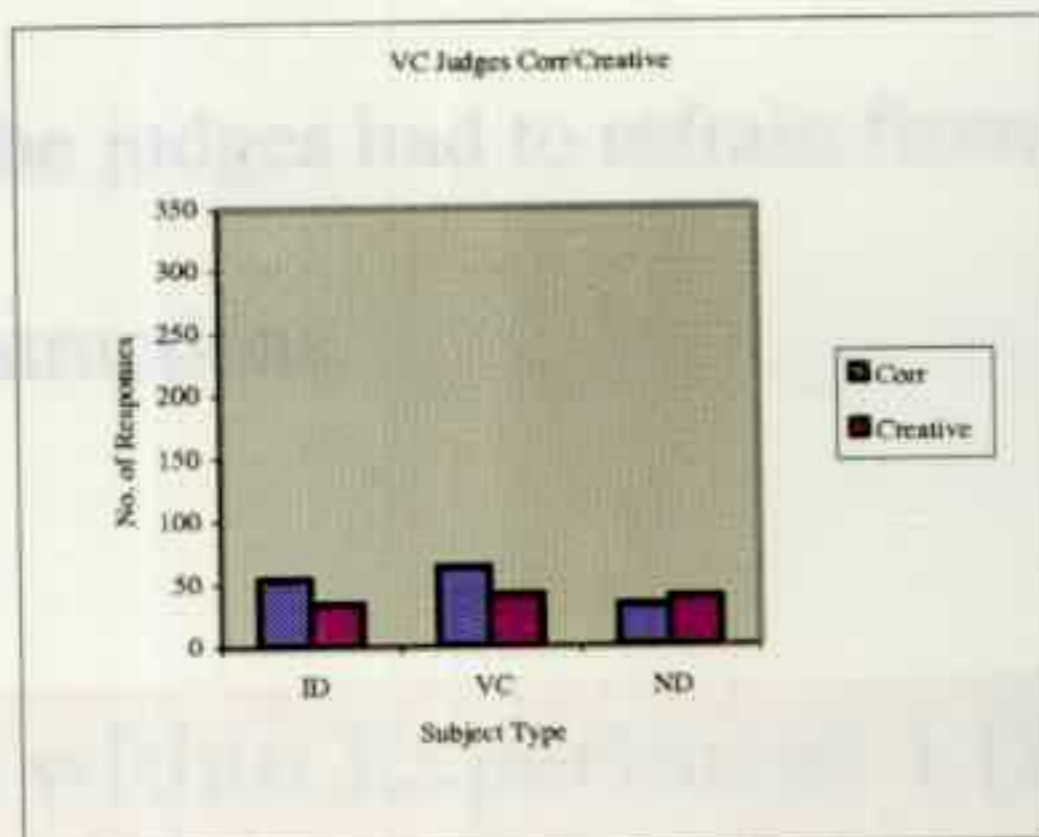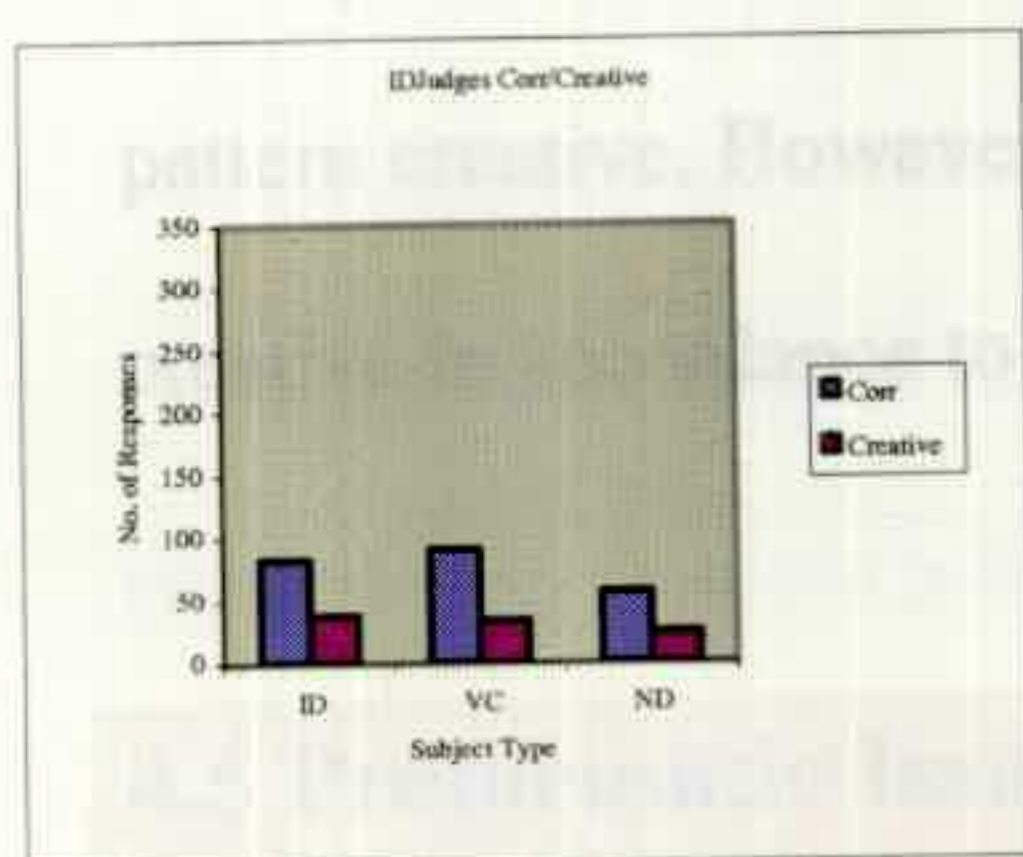
ID Judges		
	Corr	Creative
ID	83	38
VC	91	34
ND	57	25
Total	**231**	**97**

	%	%
	Corr	Creative
	17.32	7.27

VC Judges		
	Corr	Creative
ID	54	34
VC	63	41
ND	33	39
Total	**150**	**114**

	%	%
	Corr	Creative
	11.24	8.55

ND Judges		
	Corr	Creative
ID	84	49
VC	85	43
ND	50	32
Total	**219**	**124**

	%	%
	Corr	Creative
	16.42	9.30

**TABLE 7: FREQUENCIES OF RESPONSES USING SEPARATE COHORTS BY JUDGE TYPE
[HIGH CORRESPONDENCE / CREATIVE]**

The percentages remain relatively low when using the individual cohorts of specialist judges in terms of creativity [ID judges 7%; VC judges 8.5%; ND judges 9%] and in

terms of correspondence [ID judges 17% - VC judges 11% - ND judges 16%]. These

results are not consistent with those of Finke and Slayton (1988).

When reviewing the frequency distributions of the individual judges, a few of the

patterns were not consistent with respect to the other judges, suggesting judging issues

exist. These need to be explored and analysed in detail prior to further analysis. One

issue is that Finke & Slayton (1988) linked creativity to correspondence judgements.

Consequently, the judges were not allowed to separate creativity issues from

correspondence issues. In his later work Finke (1990) instructs the judges differently.

He purportedly allows for the separation of scoring, however, he contradicts this in his

calculations. It is conceivable, in Finke & Slayton (1988), that the average

correspondence score was lower than the set score but the judges still deemed the

pattern creative. However, the judges had to refrain from scoring the response as

creative in accordance to instructions.

4.5 Problematic Issues within Experiment 1 (2D)

This study was interested in comparing designers and non-designers with respect to

creative mental synthesis. Adopting and adapting the experimental methodology of

Finke & Slayton (1988) and controlling the subject type and judge type was thought

to allow the investigation and comparison of designers and non-designers. However,

as suggested in section 4.4 above, this study found problematic issues when closely

adhering to the rules, methodologies and procedures found in Finke & Slayton (1988).

The investigation of Finke & Slayton (1988) focused on two-dimensional creative

mental synthesis and was of a general nature, in that it used subjects and judges from

a general psychology class, drawing students from various disciplines. When comparing the results of designers and non-designers as subjects, while obtaining consensual agreement using designer and non-designer judge types, an expectation would be that the designers would generate greater numbers of responses which are considered to have relatively high correspondence and would generate more responses deemed creative, notwithstanding the judge's background.

Consensual assessment techniques have been employed for a number of years and formally articulated by Amabile (1982). The four studies of Hennessey (1994) found these techniques to be reliable. However, while the techniques may be reliable the number and type of judges [experts and non-experts] used may be important. It is possible that the low number and type of judges used by Finke & Slayton (1988) may have affected their results. Using a greater number and variety of judges suggests that it is harder for them to reach a consensual agreement. Therefore the results of this study would be more robust.

This study used a greater number of judges (15) of three different backgrounds [Industrial design (3D judges), Visual communications (2D judges), Law judges (non-design judges)] in contrast to the three judges used by Finke & Slayton (1988). In addition, Finke & Slayton (1988) linked correspondence ratings and creativity ratings, failing to treat them as separate issues. It is therefore conceivable that judging problems could occur due to this linking. Furthermore, Finke & Slayton (1988) averaged the correspondence scores from the three judges. If the average score was below 4, the response was determined to be of poor correspondence. If the majority of judges determined a response to be of high correspondence and creative it was

considered creative, thus linking correspondence and creativity and mixing averaging of scores with majority rules. The subsequent discussion will tease out these issues.

In this study, after the responses were generated a sticker was applied to each of the response sheets and they were photocopied for the judges to review (see below an example of the sticker).

1	2	3	4	5.
Very Poor correspondence	Low correspondence	Modest correspondence	Good correspondence	Very Good correspondence

Is the pattern creative (original) ?
YES

No pattern   Wrong Parts used

☐   ☐   ☐

When tabulated as the frequency of response (either correspondence or creativity) and the subject type, the results of this study show a very consistent pattern. Judges individually, irrespective of the judge type, generally indicate designers perform better than non-designers, and 2D designers perform better than 3D designers in measures of both correspondence and creativity when given two-dimensional creative mental synthesis tasks. However, collectively, as an aggregate, the judges determined the 3D designers generated slightly more creative responses [i.e. referring to Table 7, section 4.4 above, creativity scores were added using the different judge groups ID 38 + VC 34 + ND 49 = 121]. Table 8 below shows this when all fifteen judges were used while adhering to the judging and scoring conventions of Finke & Slayton (1988).

	2D Problems correspondence responses	2D Problems creative responses
Industrial Designers (Subjects)	221	121
Visual Communications Students (Subjects)	239	118
Non-designers [Law] (Subjects)	140	96
Total Corr/Creative	600	335

TABLE 8: NUMBER OF RESPONSES ATTRIBUTED TO SUBJECT TYPES FOR BOTH CORRESPONDENCE & CREATIVITY USING ALL JUDGES

A possible explanation for 3D designers in this study, performing better is the linking

of creativity and correspondence, which may reduce the number of responses deemed

creative, as a response could be considered to have a moderate or low correspondence

and also be creative. A few of the judges in this study remarked that if they could,

they would have marked a moderate correspondence and deemed some responses

creative (one judge went so far as to write a note to this effect on the response sheet).

The conventions applied by Finke & Slayton (1988) do not allow for this. It is

difficult know how many responses could be considered creative which did not have

either a high correspondence rating [via an individual judge] or a high average

correspondence rating [collective view of the judges].

The judging and scoring conventions of Finke & Slayton (1988) mixed both

averaging and majority rules. The mixture of averaging and majority rules

conventions gives rise to inconsistencies in the results. In this study, using an

aggregate of the judges while following the judging and scoring conventions of Finke

& Slayton (1988), there were instances where the results were misleading. The

example response in Table 9 below indicates an average correspondence rating below

4 [i.e. an average score of 3.6], therefore it must be considered of poor

correspondence. However, it is equally clear the majority of judges [eight judges] felt it to be of high correspondence and creative. As demonstrated by this example, the true representation of the correspondence and creativity is the majority of judges not the average of scores.

Response code: **ID2DG2S2P8R4**

	ID Judge	ID Judge	ID Judge	ID Judge	ID Judge	VC Judge	VC Judge	VC Judge	VC Judge	VC Judge	ND Judge	ND Judge	ND Judge	ND Judge	ND Judge	AVG.
Correspondence	5	5	5	2	0	5	0	5	5	5	3	0	5	5	4	3.6
Creativity	1	1	0	0	0	1	0	1	1	1	0	0	0	1	1	Maj. 8

TABLE 9: INCONSISTENCIES USING AVERAGE SCORES

This suggests that the judging and scoring conventions of Finke & Slayton (1988) do not truly represent the judges' views, and should not be used in this study, therefore, the two-dimensional responses would need to be judged by a new set of fifteen judges using alternate judging and scoring conventions.

In his later work, investigating three-dimensional creative mental synthesis, Finke would change the scale for creativity from a binary scale (creative/not creative) to a five-point scale, with (1) as the lowest rating and (5) as the highest rating. While there was a change in thinking with respect to the scale for creativity, the issue of averaging the scores as opposed to using majority rules remains. In his research of three-dimensional creative mental synthesis, Finke (1990) averaged the practicality and creativity scores. In Finke et al. (1992) it was explained that an object that received an average practicality rating of 4.5 or greater was classified as a practical invention. Further, a practical invention that received an average originality rating of 4 or greater

was classified as a "creative invention." Again two separate measures were linked. On

the one hand, in Finke (1990), ratings were regarded as distinct:

"The two types of rating were to be regarded as distinct. That is, an object could be very practical and not original, or not practical but very original; similarly, an object could be very practical and very original, neither practical nor original." [Finke (1990) Page 43]

However, on the other hand, having said that he links them, he appears to contradict

himself,

"'Creative' inventions were practical inventions that were rated as original; Highly creative inventions received the highest possible rating for practicality and originality." [Finke (1990) Page 45].

4.6 New judgements Experiment 1 (2D)

4.6.1 Judging issues

Due to the problematic issues discussed in section 4.5 above, with respect to Finke &

Slayton (1988), it became apparent that while new data was not necessary, new

judgements and new rules of classification [as in Finke (1990)] would be required in

order to proceed with a more meaningful analysis of the data. Consequently, in order

to review the creativity of the responses independently of the correspondence, a new

set of fifteen judges was obtained [5 from each cohort (ID – VC – ND) reflected in

Table 10 below]. Given new judging instructions, using new scoring conventions, and

a new set of fifteen judges, higher numbers of creative responses and correspondence

responses would be expected. This notwithstanding, it is possible the new set of

judges has a different collective view of creativity and correspondence. However, if

the central concern is the pattern of judgements [i.e. designers performing better than

non-designers] the significance of the differences between the new results and

previous results [in terms of percentage points] is increased because more rigorous

statistical evaluation techniques would be utilised.

Judge groups			
3D Designers Industrial design students number of Judges	2D Designers Graphic design students number of Judges	non-designers Law Students number of Judges	Total
Number of Student Judges 5	5	5	15*

* **NOTE: These new 15 judges only reviewed the 2D responses using new scoring conventions**

TABLE 10: JUDGE TYPE GROUPINGS EXPERIMENT ONE [NEW JUDGES REJUDGING]

4.6.2 Scoring Conventions

Unlike the work of Finke & Slayton (1988) the new judges were to rate the

correspondence and originality (creativity) of each pattern using two 5-point scales (as

shown below). Note that these are similar to the scales used in Finke (1990). New

stickers were applied on top of the original response stickers and fifteen new sets of

photocopies were prepared for the new judges.

1	2	3	4	5.
Very Poor correspondence	Low correspondence	Modest correspondence	Good correspondence	Very Good correspondence

1	2	3	4	5.
Not Original	Low Originality	Modest Originality	Original	Very Original

No pattern ☐   Wrong Parts ☐

These different ratings were to be made independent of each other. A pattern could

have high correspondence but not be original, be original but not have high

correspondence, or have both originality and high correspondence. They were to

circle the rating for the correspondence for each response and an originality rating for

each response. The judges were to base their ratings on the pattern represented by the

drawing and not how well the pattern was drawn. No definition of originality was given; it was up to each judge to determine originality.

As with the previous judging of responses, after all the copies of the 2D responses had been coded and the new rating system applied to each response, they were randomised into different stacks as explained earlier [in section 3.4.3].

4.6.3 Judgement Days

Twelve of the fifteen new volunteer judges were gathered together, in a comfortable and quiet room, for a half-day of judging. Three judges were unable to attend that session so each was scheduled to judge on another day suited to their schedule. The same judging instructions were given to the fifteen new judges with the exception of the new scoring conventions. What the subjects had been expected to do was explained to the judges. Then the judges were instructed in how to score the responses from each subject using the new scoring conventions previously mentioned.

4.6.4 New Judge instructions [2D]

The new judges received similar basic instructions. After they assembled in the room where the judging was going to take place, the instructions were read to them [instructions are located in Appendix D].

4.7 New Spreadsheets

4.7.1 Old Data using new judges and scoring conventions [2D & 3D]

Once the responses were judged again, another spreadsheet was developed to prepare the coded data for analysis. However, it was reasoned this spreadsheet should be

flexible, to accommodate the 3D numerical figures obtained from the first set of

judges, now that the scoring conventions were consistent, as they were both modelled

on Finke (1990).

As a central theme in this research was to compare and contrast three-dimensional

designers, two-dimensional designers and non-designers it was considered necessary

to develop a general spreadsheet (as the scoring conventions were now similar i.e. a

consistent number scale from 1 to 5) which would not only allow empirical analytical

comparisons and contrasts to be made between and among subject type and judge

type, but also problem type. This was done with a view to isolating key factors or

differences in the data, such as problem type, subject type, or even judge type. A

meaningful discussion of the analysis of the data resulting from the new 2D creative

mental synthesis judgments and the previous 3D judgments would then occur.

4.7.2 Spreadsheet layout

After the responses were judged a new spreadsheet was developed to prepare the

coded data for analysis, accommodating both the new 2D judgments [from the new

set of fifteen judges] and the previous 3D judgments. The column headings

[illustrated in Table 11 below] were developed by breaking down the response code

number into a subject type code [ID = 1- VC = 2 - ND = 3], a subject number [1-20],

a problem type [2D = 1 or 3D = 2], a response number, and judge code numbers (e.g.

J61). Each judge had a column of cells, which represented the correspondence or

practicality ratings for each response (a number 1–5), and a column of cells, which

represented the creativity ratings (a number 1–5). Each row of judgments

corresponded to that particular response from a number of judges. This allowed for

flexibility in analysis of the data. Each response could be investigated with respect to issues either between judges, among judges, or subject types. Using this particular spreadsheet layout, any given subject could be traced back without using the long subject code, so consequently, the long code was withdrawn from the spreadsheet.

					Corres/Prac				Creativity			
ID=1 VC=2 ND=3 Subject type (1,2,3)	Subject no. (1-20)	2D=1 3D=2 Problem Type (1-2)	Problem no. (1-8)	Response No.	ID Judge J??/J??	ID judge J??/J??	ID Judge J??/J??	ETC.... J??/J??	ID Judge J??/J??	ID judge J??/J??	ID Judge J??/J??	ETC.... J??/J??
1	1	1	1	1	4	3	5	4	1	5	5	3
1	1	1	1	2	2	3	2	5	3	5	5	5
1	1	1	1	3	5	4	5	2	1	5	5	4
1	1	1	2	1	3	5	5	4	5	4	2	3

TABLE 11: NEW SPREADSHEET LAYOUT

4.8 Frequency Distribution Tables

Presenting the data in a spreadsheet allows the simple generation of frequency tables [as in section 4.4], for the purpose of review and analysis. As before, only the meaningful frequency tables will be presented, therefore, the data can be meaningfully and empirically explored with respect to the variants of judge types and subject types. Since all the data was represented in one large spreadsheet a detailed analysis and presentation of the results could occur.

> Tables using ALL judges
> Tables using only Industrial Design Judges
> Tables using only Visual Communications Judges
> Tables using only Non-Design Judges
> Tables of each Individual Judge

As indicated earlier, averaging techniques and the linking of measures creates an inaccurate view of the judges' decisions. Having a new set of fifteen judges review

the two-dimensional responses, using two 5-point scales along with instructions to treat correspondence and originality as two separate issues while adhering to majority rules conventions, allows for a more accurate unlinked analysis of the data. Consequently, while the numbers of responses determined as having a high correspondence or being creative may differ from the previous results somewhat, the central issue is that of obtaining an accurate pattern of judgments.

The results were very similar to those in section 4.5 of this chapter. A very consistent pattern emerged. Judges individually, irrespective of judge type, generally indicated that designers performed better than non-designers, and 2D designers performed better than 3D designers in measures of both correspondence and creativity when given two-dimensional creative mental synthesis tasks. However, collectively these judges clearly determined the 2D designers to have generated more creative responses, in addition to generating greater numbers of responses deemed to have high correspondence, when compared to the industrial designers or the non-designers, when they were instructed to separate correspondence from creativity. Table 12 below reflects this while adhering to the new judging and scoring conventions adapted from Finke (1990).

	2D Problems correspondence responses	2D Problems creative responses
Industrial Designers (Subjects)	315	235
Visual Communications Students (Subjects)	399	285
Non-designers [Law] (Subjects)	201	169
Total Corr/Creative	915	689

TABLE 12: NUMBER OF RESPONSES ATTRIBUTED TO SUBJECT TYPES FOR BOTH CORRESPONDENCE & CREATIVITY USING ALL JUDGES [2D PROBLEMS]

4.9 Percentage calculations (Correspondence & Creativity)

In their general discussion section Finke & Slayton (1988) said the following:

> *These experiments revealed that people can make creative visual discoveries by imagining novel combinations of simple parts. Of the 353 recognisable parts, 53 were judged as being highly creative. Our subjects, moreover, were neither selected nor extensively trained in how to do the task. [Page 255]*

When deriving percentages from the numbers found in Finke & Slayton (1988), the result is that 15 percent could be deemed creative. However, this percentage could be misleading. Recalling that Finke & Slayton (1988) had linked correspondence and creativity and did not include non-recognisable responses in their calculations, if the question is of the ability of a subject to use mental synthesis to generate a creative response, the figure of 15 percent needs to be queried. The 353 in the data are only the recognisable responses. When considering ability, inability must also be considered. Therefore, any calculations should include the total number of possible responses. Using the reasoning of Finke & Slayton (1988) it may be possible to get a high yet misleading number of responses being deemed creative. The way they calculate percentages may not be as meaningful as first thought. Consider the following:

> Hypothetically, if there were 100 total possible responses and only 10 of those responses were deemed to be recognisable, and 5 of those 10 were deemed to be creative, it could be said that 50% of the recognisable responses were creative. This would be a true statement. However, in terms of total creative mental synthesis abilities, only 5% of the possible responses were creative. For various reasons the other 95% were not.

Returning to the 15 percent figure found in Finke & Slayton (1988), and taking a more conservative approach to calculating the percentage of creative responses, a lower percentage is derived when using every response. In total there were 872 trials

(Exp. 1. [312 forms] & Exp 2. [280 forms + 280 forms]). Dividing the 53 creative responses by the 872 trials yields 6.08 percent deemed creative. This method of calculating percentages is more inclusive. Therefore, this study will derive the percentage calculations using every response.

Since a method of calculating percentages has been determined, the next issue in need of resolution is judging 'expertise'. Finke & Slayton (1988) utilised what could be considered non-expert judges. They used undergraduate psychology students who were neither trained in, nor practised in creative mental synthesis tasks. In addition their subjects could be from any number of different disciplines. As indicated earlier, an expectation would be that the designers would generate greater numbers of responses considered to have relatively high correspondence and would generate more responses deemed creative notwithstanding the judge's background. In order to investigate this issue of judging expertise while investigating issues of subjects' creative mental synthesis abilities, comparisons should be made between the three different judge types used in this study. When Hennessey (1994) discusses the term expert she defines it as being an "appropriate observer". She points out, for example, when asked to rate the creativity of a paper collage, both children and adults from a variety of backgrounds produce highly reliable assessments. When dealing with more specialised fields the range of "experts" would be much narrower. Accordingly, there should be differences between the different judge groups. As the visual communications students are trained and practised in two-dimensional creative mental synthesis, by virtue of their education, they should be considered the "appropriate observers". The results from the other types of judges could then be compared to, and

contrasted with the judgements of the "experts". Table 13 below contains frequency results differentiated by judging group [ID-VC-ND].

Industrial Design judges

	2D Problems Correspondence responses	2D Problems Non-correspondence responses	% Corr	2D Problems Creative responses	2D Problems Non-creative responses	% Creative
Industrial Designers (Subjects)	75	368	17%	99	344	22%
Visual Communications Students (Subjects)	83	441	16%	124	400	24%
Non-designers [Law] (Subjects)	31	336	9%	64	303	17%
Total Corr/Creative	189	1145	14%	287	1047	22%

Visual Communication judges

	2D Problems Correspondence responses	2D Problems Non-correspondence responses	% Corr	2D Problems Creative responses	2D Problems Non-creative responses	% Creative
Industrial Designers (Subjects)	136	307	31%	50	393	11%
Visual Communications Students (Subjects)	174	350	33%	56	468	11%
Non-designers [Law] (Subjects)	105	262	29%	40	327	11%
Total Corr/Creative	415	919	31%	146	1188	11%

Non-Designer judges

	2D Problems Correspondence responses	2D Problems Non-correspondence responses	% Corr	2D Problems Creative responses	2D Problems Non-creative responses	% Creative
Industrial Designers (Subjects)	104	339	24%	86	357	19%
Visual Communications Students (Subjects)	142	382	27%	105	419	20%
Non-designers [Law] (Subjects)	65	302	18%	65	302	18%
Total Corr/Creative	311	1023	23%	256	1078	19%

TABLE 13: FREQUENCY RESULTS 2D PROBLEMS DIFFERENTIATED BY JUDGING GROUP [ID-VC-ND]

In reviewing the row patterns in Table 13 above, while comparing the different judging groups, the pattern remains clear and consistent. The two-dimensional designers generate more creative responses and responses having high correspondence when compared to the other subject types, with the industrial designers generating the next most frequent responses. Non-designers generate the least numbers. Table 13 also reveals the visual communications subjects generally have a higher proportion of their responses deemed creative or having high correspondence. The industrial design subjects follow, leaving the non-designer subjects having the lowest proportion of their responses deemed creative or of high correspondence.

While the visual communications judges ("experts") revealed a judging pattern consistent with the other judge types, they also appear to be more conservative in their judgements with respect to creativity. In contrast, the industrial design judges were more conservative in their judgements of correspondence. When comparing the judge types, the comparative percentages [typically double digits] were generally higher than those of Finke & Slayton (1988) [typically 6 percent when taking into account all responses].

4.10 Set point issue

The criterion (score level) set by Finke & Slayton (1988) was set at 4 for correspondence before a score for originality was allowed. In Finke (1990) an average score of 4.5 or greater for practicality and 4 or greater for originality was set. In Finke et al. (1992) they argued that the major findings of their studies did not depend on where the cut-offs were as they were based on comparisons of relative numbers. With respect to the differences in cut-offs, the supporting rationale was two-fold. First, on

average, the practicality ratings were higher than originality ratings, and second, it made the classification more conservative and weighted towards practicality. This appears to contradict earlier statements that the two types of ratings were to be regarded as distinct. However, this study maintains that the different types of ratings should remain distinct. In addition, it is not unreasonable to investigate what the judging patterns would be like at lower criterion levels (score levels).

When reviewed at the lower score levels of 3 for correspondence and 3 for creativity, the row patterns in Table 14 below remain as consistent as ever. The two-dimensional designers generate more creative responses and responses having high correspondence when compared to the other subject types, with the industrial designers generating the next most frequent responses, with the non-designers generating the least numbers, irrespective of the judge's background.

Industrial Design judges

	2D Problems Correspondence responses	2D Problems Non-correspondence responses	% Corr	2D Problems Creative responses	2D Problems Non-creative responses	% Creative
Industrial Designers (Subjects)	248	195	56%	299	144	68%
Visual Communications Students (Subjects)	308	216	59%	341	183	65%
Non-designers [Law] (Subjects)	147	220	40%	193	174	53%
Total Corr/Creative	703	631	53%	833	501	62%

Visual Communication judges

	2D Problems Correspondence responses	2D Problems Non-correspondence responses	% Corr	2D Problems Creative responses	2D Problems Non-creative responses	% Creative
Industrial Designers (Subjects)	308	135	70%	173	270	39%
Visual Communications Students (Subjects)	386	138	74%	213	311	41%
Non-designers [Law] (Subjects)	236	131	64%	171	196	47%
Total Corr/Creative	930	404	70%	557	777	42%

Non-Designer judges

	2D Problems Correspondence responses	2D Problems Non-correspondence responses	% Corr	2D Problems Creative responses	2D Problems Non-creative responses	% Creative
Industrial Designers (Subjects)	324	119	73%	256	187	58%
Visual Communications Students (Subjects)	375	149	72%	342	182	65%
Non-designers [Law] (Subjects)	253	114	69%	228	139	62%
Total Corr/Creative	952	382	71%	826	508	62%

TABLE 14: FREQUENCY RESULTS DIFFERENTIATED BY JUDGING GROUP [ID-VC-ND] LOWER SET POINT 2D PROBLEMS

The nature of the judgement instructions in Finke & Slayton (1988) did not allow for lower correspondence judgements to be considered original. The judgement system should be more open and unlinked as discussed earlier.

4.11 Experiment 1 (3D)

As with the two-dimensional problems, when tabulated as the frequency of response (either practicality or creativity) and the subject type, the results from the three-dimensional problems show a consistent pattern. Judges individually, irrespective of the judge type, generally indicate that designers perform better than non-designers, and 3D designers perform better than 2D designers in measures of both practicality and creativity when given three-dimensional creative mental synthesis tasks.

Collectively, (adding results of different judge groups) the judges determined the 3D designers generated more creative responses and more practical responses. Table 15 below reflects this when all fifteen judges were used while adhering to the judging and scoring conventions utilising the 5-point scales discussed earlier.

	3D Problems practicality responses	3D Problems creative responses
Industrial Designers (Subjects)	291	137
Visual Communications Students (Subjects)	160	99
Non-designers [Law] (Subjects)	182	53
Total Prac/Creative	633	289

TABLE 15: NUMBER OF RESPONSES ATTRIBUTED TO SUBJECT TYPES FOR BOTH PRACTICALITY & CREATIVITY USING ALL JUDGES

While the industrial design judges for all intents and purposes, are the "appropriate observers" the other judge types revealed a similar and consistent pattern. Table 16 below reflects these results. While the visual communications judges revealed a judging pattern consistent with the other judge types, they again appear to be more conservative in their judgements when compared to the other judges.

Industrial Design judges

	3D Problems Practical responses	3D Problems Non-practical responses	% Prac	3D Problems Creative responses	3D Problems Non-creative responses	% Creative
Industrial Designers (Subjects)	162	207	44%	60	309	16%
Visual Communications Students (Subjects)	78	217	26%	37	258	13%
Non-designers [Law] (Subjects)	83	258	24%	12	329	4%
Total Prac/Creative	189	816	19%	109	896	11%

Visual Communication judges

	3D Problems Practical responses	3D Problems Non-practical responses	% Prac	3D Problems Creative responses	3D Problems Non-creative responses	% Creative
Industrial Designers (Subjects)	46	323	13%	47	322	13%
Visual Communications Students (Subjects)	30	265	10%	34	261	12%
Non-designers [Law] (Subjects)	23	318	7%	20	321	6%
Total Prac/Creative	99	906	10%	101	904	10%

Non-Designer judges

	3D Problems Practical responses	3D Problems Non-practical responses	% Prac	3D Problems Creative responses	3D Problems Non-creative responses	% Creative
Industrial Designers (Subjects)	83	286	23%	30	339	8%
Visual Communications Students (Subjects)	52	243	18%	28	267	10%
Non-designers [Law] (Subjects)	76	265	22%	20	321	6%
Total Prac/Creative	211	794	21%	78	927	8%

TABLE 16: FREQUENCY RESULTS 3D DIFFERENTIATED BY JUDGING GROUP [ID-VC-ND]

4.12 Log linear analysis (2D & 3D)

The simple frequency tables presented in the sections above (both the 2D and 3D results) give a strong indication of the expected pattern of response frequencies, however, other techniques of analysing the data could be used which are seen as being more robust, for example log linear analysis. Essentially, when tabulating [illustrated in Table 17 below] the number of responses determined creative and not creative by the judges, the following was found:

Observed Frequencies		Judge Type	ID	ND	VC		Expected Values			ID	ND	VC
C	2D	ID	99.000	86.000	50.000	C	2D	ID	97.658	87.529	49.814
		VC	124.000	105.000	56.000			VC	118.590	105.860	60.550
		ND	64.000	65.000	40.000			ND	70.752	62.612	35.636
	3D	ID	60.000	30.000	47.000		3D	ID	52.057	37.051	47.893
		VC	37.000	28.000	34.000			VC	37.646	26.686	34.668
		ND	13.000	20.000	20.000			ND	20.297	14.264	18.439
NC	2D	ID	344.000	357.000	393.000	NC	2D	ID	344.759	356.804	392.437
		VC	400.000	419.000	468.000			VC	405.975	418.459	462.566
		ND	303.000	302.000	327.000			ND	296.266	302.737	332.997
	3D	ID	309.000	339.000	322.000		3D	ID	317.527	330.617	321.857
		ND	282.000	275.000	275.000			ND	274.684	282.388	274.928
		VC	304.000	313.000	307.000			VC	302.789	313.996	307.215

Problem Type
Subject Type
Creative/Non-creative
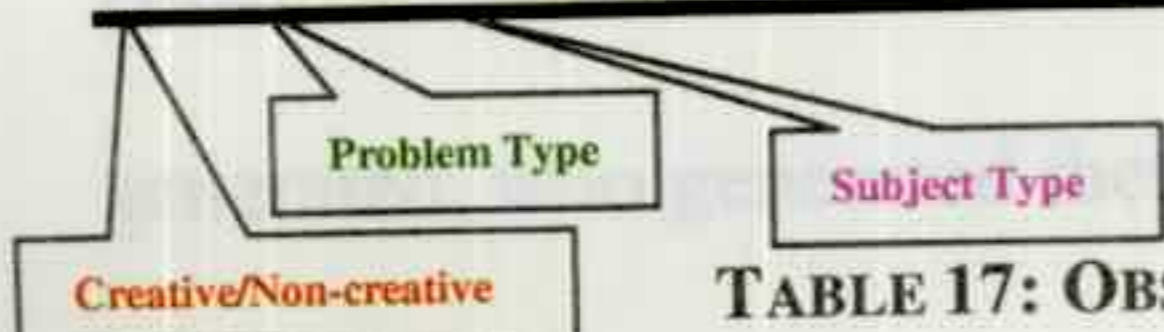
TABLE 17: OBSERVED FREQUENCIES AND EXPECTED VALUES

When using **log linear** analysis, the table of figures on the right of Table 17 above (expected results) can be derived from the table of observed frequencies (table of figures on the left side of Table 17 above). Essentially in this type of analysis, a review of the observed frequencies in the left hand table occurs based on various factors such as those listed below:

Creative / Not Creative   **[C or NC]**
Problem Type   **[2D or 3D]**
Subject Type {in the vertical column}   **[ID,ND, or VC]**
Judge Type {in the top row}   **[ID,ND, or VC]**
Creative – Problems
Creative - Subjects
Creative - Judges
Problems - Subjects
Problems - Judges
Subjects - Judges
Creative - Problems - Subjects
Creative - Problems - Judges

Based on this review, expected values in the table on the right (expected results) are generated. What occurs is that a number of combinations of the factors are analysed, after removing a factor to see if it drastically affects the ability to generate the expected values on the right. This is repeated, continually exploring and removing factors until the combination of factors is found which when removed no longer allows the generation of close expected values to be found. After taking one step back, those factors which if removed do not allow close expected values to be generated, will be the critical factors.

However, as indicated earlier, a central interest is in the number of creative responses generated, who generated them, and who thought they were creative. Therefore, when using only the top portion of Table 17 above, and looking at the number of creative

responses generated, the following possible factors and combination of factors

emerge.

> Problems
> Subjects
> Judges
> Problems - Subjects
> Problems - Judges

A table focusing on these factors was generated, as illustrated in Table 18 below, in

order to focus on these specific issues.

Judge Type

Observed Frequencies			ID	ND	VC
C 2D	ID		99.000	86.000	50.000
	VC		124.000	105.000	56.000
	ND		64.000	65.000	40.000
3D	ID		60.000	30.000	47.000
	VC		37.000	28.000	34.000
	ND		13.000	20.000	20.000

Problem Type   Subject Type

Expected Values			ID	ND	VC
C 2D	ID		97.658	87.529	49.814
	VC		118.590	105.860	60.550
	ND		70.752	62.612	35.636
3D	ID		52.057	37.051	47.893
	VC		37.646	26.686	34.668
	ND		20.297	14.264	18.439

TABLE 18: OBSERVED FREQUENCIES AND EXPECTED VALUES [CREATIVE RESPONSES]

After applying log linear analysis techniques to the values of observed frequencies [in

the left hand table of figures in Table 18 above], by removing the factors [**Problems –**

Subjects] & [**Problems – Judges**] close expected values cannot be generated, therefore,

these factors are critical.

Examining the critical factor of **Problems-Subjects** in terms of percentages, [illustrated

in Table 19 below] the 2D row percents for the different subject types [ID ND & VC]

and problems, reveals that the VC subjects have the highest percentage followed by

the ID subjects and then the non-designers. While this is consistent with earlier

predictions, using the more robust log linear analysis techniques lends stronger

support to this expectation. It is also noteworthy the non-designers are almost half as

creative as the VC subjects with respect to 2D problems.

When looking at the 3D row percents for the different subjects [ID ND & VC] and problems [illustrated in Table 19 below], the ID subjects have the highest percentage creative responses, followed by the VC subjects and then the non-designers. Again, this is consistent with earlier predictions. In contrast with the 2D problems, when given 3D problems the non-designers are less than half as creative as the ID subjects, suggesting the 3D problems are more difficult for them.

When looking at the column percents for the different subjects [ID ND & VC] and problems [revealed in Table 19 below], as a proportion of all the responses generated by the ID subjects, two thirds of the creative responses were the 2D responses. However, as a proportion of all the responses generated by both the VC subjects and the non-designers three quarters of the creative responses were the 2D responses. This adds support to the argument that 3D problems are more difficult than 2D problems for both the 2D designers and non-designers.

Looking At :   **Row percents**
Problem (rows)   **by Subject (columns)**

	ID	VC	ND	Total	N
2D	34.107	41.364	24.528	100	689
3D	47.405	34.256	18.339	100	289
Total	38.037	39.264	22.699	100	
N	372	384	222		978

Looking At :   **Column percents**
Problem (rows)   **by Subject (columns)**

	ID	VC	ND	Total	N
2D	63.172	74.219	76.126	70.450	689
3D	36.828	25.781	23.874	29.550	289
Total	100	100	100	100	
N	372	384	222		978

TABLE 19: ROW PERCENTAGES AND COLUMN PERCENTAGES BY PROBLEM TYPE AND SUBJECT TYPE

When reviewing the results relating to the factors *problems and judges* in terms of percentages, the 2D row percents [illustrated in Table 20 below] for the different judges [columns ID ND & VC], and problems [Row 2D], the VC judges seem to be very conservative in their judgements [i.e. a low 21 percent], whereas the ID and non-designer judges were more liberal in their judgements. However, when looking at the 3D row percents for the different judges [ID ND & VC] and problems, it was found that the ND judges are conservative in their judgements [i.e. a low 27 percent]. When looking at the column percents for the different judges [ID ND & VC] and problems, with respect to how the judges balanced their judgements between the 2D and 3D problems, the VC judges were moving toward balancing their decisions.

Looking At :   **Row percents**
Problem (rows)   **by Judges (columns)**

	ID	ND	VC	Total	N
2D	41.7	37.2	21.2	100	689
3D	38.1	27.0	35.0	100	289
Total	40.6	34.2	25.3	100	
N	397	334	247		978

Looking At :   **Column percents**
Problem (rows)   **by Judges (columns)**

	ID	ND	VC	Total	N
2D	72.3	76.7	59.1	70.5	689
3D	27.7	23.4	40.9	29.6	289
Total	100	100	100	100	
N	397	334	247		978

TABLE 20: ROW PERCENTAGES AND COLUMN PERCENTAGES BY PROBLEM TYPE AND JUDGE TYPE

Previously in other sections within this chapter, it was shown the pattern of responses generated by different subjects was as expected [2D Problems = VC first – ID second – ND last & 3D problems = ID first – VC second – ND last]. This pattern occurs when using raw frequencies and using more robust log linear analysis techniques as above.

Chapter 5 Experiment 1: Questionnaire Results (2D&3D)

5.1 Introduction

Findings in chapter 4 revealed that designers generally perform better than non-

designers when given creative mental synthesis tasks, that two-dimensional designers

perform best when given 2D tasks, 3D designers perform best when given three-

dimensional tasks. However, insights into the thought processes utilised by the

individual subjects has yet to be reviewed. In their research, Finke & Slayton (1988)

and Finke (1990), after the subjects completed the creative mental synthesis tasks,

sought to gain insight into the thought processes of their subjects by having them

respond to a questionnaire asking about the thinking techniques the subjects thought

they used.

It must be remembered no thinking techniques were given to the subjects by Finke &

Slayton (1988) in order to develop ideas during the experiment. It was only after the

mental synthesis tasks were completed that the subjects were issued with the

questionnaire. Subjects were given a list of four possible thinking techniques

conceived of by Finke & Slayton (1988). These are listed below:

> 1) " I tried combining the parts by trial and error in my image until I happened to recognise a shape"
>
> 2) " I first thought of a possible shape, then I tried to combine the parts in my image to see whether the particular shape could be made out of the parts"
>
> 3) " I did not form an image at all, but just thought about how the parts might be combined in a more abstract way"
>
> 4) " I used some other strategy"

In their instructions, Finke & Slayton (1988) required the subjects to pick the most

common (**one**) thinking technique they used in combining the parts and they were not

instructed to give a written explanation of their thought processes. They found a large majority of the subjects [74.4 percent] mostly used thinking technique number 1, a trial and error methodology.

However, it can be argued that the instructions given with respect to selecting one strategy limited the level of enquiry regarding the issues of the thought processes of the subjects. It is possible, for example, that the subjects spread the use of different thinking techniques [i.e. if one did not work they would try another]. The instructions, however, forced them to select only one thinking technique. This limitation placed on their subjects, would appear not to allow comparisons and contrasts to be made between the various thinking techniques used, and success in the creative mental synthesis tasks. Therefore, it is important the thinking strategies overall be investigated in a more open way.

The core issue examined in this chapter compares and contrasts the use of multiple thinking strategies and the exclusive use of one thinking strategy with the level of performance. While the results in the previous chapter related to performance, separate groupings of judges looked at the responses. However, in this instance, in order to generate a picture of the overall performance and avoid double counting, the same criterion of majority rules was applied. However, instead of applying majority rules to the small groups of judges and aggregating the results [as in Chapter 4], majority rules were applied to all fifteen different judges as one group. It should be noted that by changing to one large judging pool, differences in the figures [frequencies] are to be expected when contrasted with treating judges as separate groups and then aggregating their results. This accounts for any differences in

numbers of responses in this analysis in contrast to those found in the earlier chapters of this work. This chapter will present the results of the analysis of the data obtained via the questionnaire relating to the thinking techniques utilised by the subjects when given more open instructions as described earlier. However, it should be noted that upon careful analysis of the results an extremely large and rich data set was revealed. Detailed discussions of a broader range of qualitative issues would have substantially lengthened this thesis. Consequently the discussions in this chapter are intentionally limited.

5.2 Data

5.2.1 Coding of the questionnaire data and results [2D]

Once responses to the questionnaires were completed they were coded for analysis. This was accomplished by using the number/numbers from the list of possible thinking techniques found on the questionnaire [one, two, three, four] as a code, representing that technique/techniques for each individual subject. A subject, who may have used multiple techniques for example, could be coded as using techniques [one, two]. Alternatively, a subject who used only one particular technique, for example, could be coded as using technique [two]. Using this technique of numbering the thinking techniques found on the questionnaire allows information to be coded into a file for each subject.

In addition, other information regarding subject responses was coded into the file. Utilising the thinking technique code numbers described earlier, a file for each subject was created which contained numerical information regarding the thinking technique/techniques that a subject used to solve the creative mental synthesis

problems, the number of responses [drawings] determined to be of high

correspondence, and the number of responses [drawings] determined to be creative. A

typical example was the information regarding subject **ID2DG1S1.** The following

information was placed in their file:

Number of High Correspondence responses [drawings] = 5
Number of Creative responses [drawings] = 4
Thinking techniques/techniques used: <u>four</u>

Note: this designation signifies that the subject used only one thinking technique, **number 4**, and not four different thinking techniques. If they had used four different thinking techniques, the designation would have been as follows: [<u>one</u>, <u>two</u>, <u>three</u>, <u>four</u>].

Combining the two types of numerical data [drawing data and questionnaire data],

allows the thinking techniques to be compared and contrasted with creativity and

correspondence, unlike the work of Finke & Slayton (1988). If the central rationale

for the use of the questionnaire in Finke & Slayton (1988) was to investigate the

thinking techniques of the subjects, then it seems unusual they would limit the

response capabilities of the subjects [i.e. select the **one** thinking technique most used]

and not develop a way of comparing and contrasting the thinking techniques used

with the success of a subject, as measured by the frequency of either creative and/or

correspondence responses. The information in a subject's file, as shown above, allows

such investigations. However, it makes sense first to investigate the issue of which

thinking techniques were most frequently utilised, and then to investigate the issue of

successful thinking techniques, with success measured in terms of correspondence and

creativity.

Using the files of the individual subjects, frequency tables of the responses to the

questionnaire were generated. For example, a frequency table of all subjects, listing

thinking technique type with the number and percentage of subjects who used a

particular type or combination of types of thinking techniques was generated, as in

Table 21 below. If the view of Finke & Slayton (1988) were correct, a reasonable

expectation would be that the majority of subjects in this research would use thinking technique one [using trial and error to develop an idea]. This did not appear to occur.

All subjects													Totals
Thinking Techniques	One	two	three	four	one two	one two three	one two three four	one four	one three	two three	three four	one three four	
% of Subjects	16.7%	6.7%	6.7%	8.3%	21.7%	6.7%	0%	6.7%	15%	5%	1.7%	5%	100%
No. of Subjects	10	4	4	5	13	4	0	4	9	3	1	3	60 Subjects

TABLE 21: FREQUENCY TABLE CONTRASTING THINKING TECHNIQUES AND SUBJECT FREQUENCIES

When reviewing the columns in the Table 21 above, which refer to the thinking techniques used, only 16.7 percent of the subjects exclusively used technique one [trial & error]. As stated earlier [Section 5.1] in their experiment, with their instructions, Finke & Slayton (1988) found 74.4 percent of the subjects utilised type one (1) thinking technique [trying to combine the parts by trial and error in their image until they happened to recognise a shape]. However, it must be remembered that the instructions of Finke & Slayton (1988) asked for the *most* used thinking technique. In a sense, it is possible that the results of Finke & Slayton (1988) could have been similar to the results here but were disguised owing to the specificity of their instructions. Nevertheless, if the view is taken that irrespective of exclusive use of thinking technique one, or the multiple use of different thinking techniques, which include thinking technique one, it can be argued that the results here are similar to those of Finke & Slayton (1988). When adding up the percentage of subjects whose thinking technique/techniques included technique one, then 71.8 percent of the subjects used thinking technique one. This similarity notwithstanding, it is still unknown if thinking technique one is first among equals [when using multiple techniques] or used occasionally along with the other thinking techniques. While

approximately 40 percent [38.34 percent] of the subjects used a single thinking technique, the dominant single thinking technique was technique number one. Conversely, the remaining approximately 60 percent of the subjects used multiple thinking techniques in some combination. At its most basic level, while adhering closely to the Finke & Slayton (1988) methodology, the view that thinking technique one is the preferred, and therefore the optimal thinking technique, cannot be supported.

These results are interesting in that only a little under 17 percent of the subjects exclusively used thinking technique *one* and that more subjects [approximately 22 percent] exclusively used some other thinking technique. When the percentage of subjects who exclusively used a *single* thinking technique are added, the result is that approximately 39% of the subjects persisted in using a single thinking strategy, excluding other thinking strategies. While it is possible that the 39 percent of the subjects who used a single thinking technique generated the majority of the high correspondence and highly creative responses, it seems unlikely.

Based on the suggestions revealed in the literature review [Chapter 2] the use of differing strategies [Strategy variety] should be of great benefit when utilised in visual problem solving. It can be argued the subjects who used multiple thinking strategies should do 'better' than subjects who exclusively used one thinking strategy. Consequently, frequency tables that reflect this information were necessary.

5.2.1.1 Linking Thinking techniques and Correspondence [2D]

The central interest in earlier chapters investigating 2D creative mental synthesis was

to differentiate between and among various subject types and various judge types, by

trying to observe patterns in frequency distributions. Consequently, the differences in

the number of high correspondence and/or creative responses [pattern of responses]

held more significance than the exact number of responses. In addition, those chapters

could not relate an understanding of the thinking techniques utilised by the subjects.

However, as suggested above in section 5.2.1, while the results regarding thinking

techniques were interesting, and different from those of Finke & Slayton (1988), they

did not relate thinking techniques and effectiveness in resolving creative mental

synthesis tasks with respect to either correspondence or creativity.

This section will compare and contrast thinking techniques and frequencies of high

correspondence responses. It should be remembered that while the subjects were

encouraged to generate as many responses as they wished, not all responses

[drawings] could be considered to have high correspondence. As correspondence is

seen as a measure of the occurrence of mental synthesis, a subject who was able to

generate one or more responses [drawings] judged to be of high correspondence,

becomes important. Therefore, the thinking techniques utilised in order to generate the

successful response becomes important as well. At this point it is not known which

thinking techniques were effectively used by those subjects, with effectiveness being

measured by the frequency of correspondence responses from a particular subject.

Once a file was created for each individual subject, a general frequency table, based

on all subjects [60 in total], was generated. Table 22 below demonstrates, for

example, that when reading across the row entitled *No. of subjects* seven subjects

[11.7 percent of the subjects] were able to generate only one response, out of each respective individual's total number of responses, judged to have high correspondence. That is to say, seven people generated only one response with high correspondence.

Correspondence Table 2D Problems																
Number of responses of high correspondence	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
% of Subjects	8.3%	11.7%	13.3%	16.7%	11.7%	13.3%	5%	3.3%	5%	0%	8.3%	0%	0%	1.7%	0%	1.7%	100%
No. Of Subjects	5	7	8	10	7	8	3	2	3	0	5	0	0	1	0	1	60 Subjects

TABLE 22: PERCENT OF SUBJECTS WHO GENERATED A GIVEN NUMBER OF HIGH CORRESPONDENCE RESPONSES [2D PROBLEMS]

A simple and straightforward way of comparing and contrasting subjects who utilised multiple thinking strategies in resolving the creative mental synthesis problems, with those subjects who utilised one particular thinking strategy exclusively, as a function of the high correspondence responses versus non-correspondence responses, was to generate a two-dimensional contingency table [illustrated in Table 23 below].

	Single Thinking strategy	Multiple Thinking strategies	Totals
Correspondence	84	171	255
Non-correspondence	427	652	1079
Totals	511	823	1334

TABLE 23: TWO WAY CONTINGENCY TABLE – SINGLE STRATEGY AND MULTIPLE STRATEGIES VS. CORRESPONDENCE AND NON-CORRESPONDENCE

In Table 23 above, the frequencies in the rows were represented by Correspondence and Non-correspondence respectively. The column headings are represented by

Single thinking strategy and Multiple thinking strategies headings respectively. The results from the application of a Chi-squared test on the frequencies above, to determine whether there was a relationship between frequencies of high correspondence and preference for using a single or multiple thinking strategies, indicated there was a statistically significant difference between using either a single thinking strategy exclusively or using multiple thinking strategies. The obtained value of 3.84 was derived after using the frequencies above and applying them in a Chi-squared test. The value of a one-tailed X^2 at the 0.05 level with one df=2.71. Since the obtained value [3.84] was greater than 2.71 the results were determined to be statistically significant.

5.2.1.2 Linking Thinking techniques and Creativity [2D]

The previous section discussed the results of the questionnaire data by comparing and contrasting the thinking techniques used by the subjects with the results of the responses judged to be of high correspondence. The next important and logical step would be to compare and contrast the questionnaire data regarding the thinking techniques used by the subjects with the results of the responses judged to be creative. It is not known which thinking techniques were used effectively by the subjects, with effectiveness measured by the frequency of creative responses from a particular subject.

As suggested earlier once a file was created for each individual subject, a general frequency table based on all subjects [60 in total] was generated. The table below [Table 24] demonstrates, for example, that ten subjects [equalling 16.7 percent of the subjects] were able to generate two creative responses [the frequency of creative

responses] each, from their respective pool of responses. Marked differences exist in the number of subjects who generated a larger number of creative responses exists.

Creativity Table 2D Problems																		
Number of Creative responses	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
% of Subjects	15%	16.7%	16.7%	10%	11.7%	13.3%	3.3%	1.7%	3.3%	0%	1.7%	1.7%	1.7%	0%	1.7%	0%	1.7%	100%
No. of Subject	9	10	10	6	7	8	2	1	2	0	1	1	1	0	1	0	1	60 Subjects

TABLE 24: PERCENTAGE OF SUBJECTS WHO GENERATED A GIVEN NUMBER OF CREATIVE RESPONSES [2D PROBLEMS]

Consistent with section 5.2.1.1 above, it was appropriate to generate a two-dimensional contingency table [see Table 25 below] in order to compare and contrast in a simple and straightforward way, subjects who utilised multiple thinking strategies in resolving the creative mental synthesis problems with those subjects who utilised one particular thinking strategy exclusively, as a function of the creative responses versus non-creative responses.

	Single Thinking strategy	Multiple Thinking strategies	Totals
Creative	83	121	204
Non-creative	428	702	1130
Totals	511	823	1334

TABLE 25: TWO WAY CONTINGENCY TABLE – SINGLE STRATEGY AND MULTIPLE STRATEGIES VS. CREATIVE AND NON-CREATIVE RESPONSES

In Table 25 above, the frequencies in the rows were represented by Creative and Non-creative responses respectively. The column headings were represented by Single thinking strategy and Multiple thinking strategies headings respectively. The results from the application of a Chi-squared test on the frequencies above indicated there was no statistically significant difference between using either a single thinking strategy exclusively or using multiple thinking strategies. The obtained value of 0.58 was derived after using the frequencies above and applying them in a Chi-squared test. The value of a one-tailed X^2 at the 0.05 level with one df=2.71. Since the obtained value [0.58] was less than 2.71 the results were determined not to be statistically significant.

5.2.2 Questionnaire Data [3D]

The previous sections reviewed issues relating to 2D problems and thinking techniques. The next few sections will discuss issues relating to 3D problems and thinking techniques. Not unlike the 2D trials, at the end of the series of 3D trials, the subjects filled in a questionnaire concerning the thinking technique they used in combining the parts to create a practical invention. The methodology essentially was consistent with that utilised by Finke (1990). No thinking techniques were given to the subjects in order to develop ideas, however, after the mental synthesis tasks, the subjects were given a questionnaire which listed the four possible thinking techniques [described earlier].

5.2.2.1 Treatment of the questionnaire data and results [3D]

Once responses to the questionnaires were completed they were codified for analysis in the same way as the 2D questionnaire data. Using the files of the individual

subjects, frequency tables of the responses to the questionnaire were generated. For example, a frequency table of all subjects listing thinking technique type with the number and percentage of subjects who used a particular type or combination of types of thinking techniques was generated, as in Table 26 below. In his research Finke (1990) found that a majority of his subjects completing 3D creative mental synthesis tasks, had mostly used a trial and error thinking technique to resolve the problems. If the view of Finke (1990) were correct [subjects mostly use trial and error], a reasonable expectation would be that the majority of subjects in this research would use thinking technique one [using trial and error to develop an idea]. This did not occur.

All subjects																Totals
Thinking Techniques	zero	one	two	three	four	one two	one two three	one two three four	two three	one three	two four	three four	one two four	one four	two three four	
% of Subjects	1.7%	18.3%	13.3%	5%	5%	10%	8.3%	13.3%	3.3%	5%	5%	3.3%	1.7%	3.3%	3.3%	100%
No. Of Subjects	1	11	8	3	3	6	5	8	2	3	3	2	1	2	2	60 Subjects

TABLE 26: FREQUENCY TABLE CONTRASTING THINKING TECHNIQUES AND SUBJECT FREQUENCIES [3D PROBLEMS]

When reviewing the columns in Table 26 above, which refer to the thinking techniques used, only 18.3 percentage of the subjects exclusively used technique one [trial and error]. As stated earlier, with his instructions, Finke (1990) found a majority of the subjects utilised type **one** thinking technique [trying to combine the parts by trial and error in their image until they happened to develop an invention]. However, the instructions of Finke (1990) asked for the *most* used thinking technique. In a sense, it is possible that the results of Finke (1990) could have been similar to the results here but were disguised owing to the specificity of his instructions.

Nevertheless, if the view is taken that irrespective of exclusive use of thinking

technique one or the multiple use of different thinking techniques, which include

thinking technique one, it can be argued that the results here may be similar to those

of Finke (1990). When adding up the percentage of subjects whose thinking

technique/techniques included technique one, then 51.6 percent of the subjects used

thinking technique one. This is not consistent with Finke (1990), as approximately

half of the subjects using thinking technique one is not a realistic majority. This

notwithstanding, it is still unknown if thinking technique one is first among equals

[when using multiple techniques] or used occasionally along with the other thinking

techniques. Approximately 40 percent [41.6 percent] of the subjects used a single

thinking technique [remarkably similar to the 38.34 percent result in the 2D

problems]. However, the dominant single thinking technique was technique number

one. Conversely, the remaining approximate 60 percent of the subjects used multiple

thinking techniques in some combination. At its most basic level, while adhering

closely to the Finke (1990) methodology, the view that thinking technique one is the

preferred, and therefore suggested as being the optimal thinking technique, cannot be

supported, as only half of the subjects thought it to be useful and only 18.3 percent

thought it to be exclusively useful.

While the results above were interesting, in that they were significantly different from

what was presented in Finke (1990). In addition, he does not compare and contrast

thinking techniques with either practicality or creativity. The work of Finke (1990)

was blemished in that it could not allow such comparisons and contrasts. Therefore,

slight modifications to the instructions and method of numerical analysis were

required. Consequently, frequency tables, which reflect the linking of this

information, were necessary.

5.2.2.2 Linking Thinking techniques and Practicality [3D]

Comparing and contrasting the use of either single or multiple thinking techniques as

a preferred effective method of resolving three-dimensional creative mental synthesis

tasks with either practicality or creativity was important in that the use of multiple

thinking techniques may be of greater benefit. This was suggested by the design

literature earlier. While the core methods of Finke (1990) were sound, allowance for

such comparisons and contrasts was non-existent.

The central interest of the earlier chapters investigating 3D creative mental synthesis,

was to differentiate between and among subjects, as well as judges. Frequency tables

presented in earlier chapters did not depict the frequencies of practical inventions,

which were drawn from an individual subject's respective pool of responses. This is

important so links can be identified between thinking techniques and frequency of

practical inventions for a given subject. It is possible those subjects who generated

greater numbers of practical inventions were using multiple thinking techniques. At

this juncture, for example, it is not known what percentage of the subjects were able

to generate only one invention judged to be practical and which were able to generate

six practical inventions each. Therefore, this section will compare and contrast

thinking techniques and frequencies of practical inventions.

It should be remembered that while the subjects were encouraged to generate as many

inventions as they wished, not all responses [drawings] could be considered practical.

As practicality is seen as a measure of the occurrence of creative mental synthesis, a subject who was able to develop inventions judged to be practical became important. Hence, the thinking techniques utilised in order to generate the successful practical inventions became important as well.

Earlier frequency tables in previous chapters did not indicate what percentage of the subject population generated practical inventions, based on majority rules using the full cohort of fifteen judges. In addition, at this point it was not known which thinking techniques were effectively used by the subjects, with effectiveness being measured by the frequency of practical inventions from a particular subject. Once a file was created for each individual subject, a general frequency table, based on all subjects [60 in total], was generated. Table 27 below reflects, when reading across the row *No. of subjects* for example, that six subjects [10 percent of the subjects] were able to generate six practical inventions from each of their respective pool of inventions.

Practicality Table 3D Problems											
Number of Practical responses	0	1	2	3	4	5	6	7	8	9	10	
% of Subjects	20%	16.7%	10%	16.7%	11.7%	6.7%	10%	3.3%	1.7%	1.7%	1.7%	100%
No. Of Subjects	12	10	6	10	7	4	6	2	1	1	1	60 Subjects

TABLE 27: PERCENT OF SUBJECTS WHO GENERATED A GIVEN NUMBER OF PRACTICALITY RESPONSES [3D PROBLEMS]

Consistent with previous discussions, a simple and straightforward way of comparing and contrasting subjects who utilised multiple thinking strategies in resolving the creative mental synthesis problems, with those subjects who utilised one particular thinking strategy exclusively, as a function of the practical responses verses non-

practical responses, was to generate a two-dimensional contingency table [illustrated in Table 28 below].

	Single Thinking strategy	Multiple Thinking strategies	Totals
Practical	68	109	177
Non-practical	316	512	828
Totals	384	621	1005

TABLE 28: TWO WAY CONTINGENCY TABLE – SINGLE STRATEGY AND MULTIPLE STRATEGIES VS. PRACTICAL AND NON-PRACTICAL

In Table 28 above, the frequencies in the rows were represented by Practical and Non-practical responses respectively. The column headings are represented by Single thinking strategy and Multiple thinking strategies headings respectively. The results from the application of a Chi-squared test on the frequencies above, to determine whether there was a relationship between frequencies of practical responses and preference for using a single or multiple thinking strategies, indicated there was no statistically significant difference between using either a single thinking strategy exclusively or using multiple thinking strategies. The obtained value of 0.00 was derived after using the frequencies above and applying them in a Chi-squared test. The value of a one-tailed X^2 at the 0.05 level with one df=2.71. Since the obtained value [0.00] was less than 2.71 the results were determined not to be statistically significant.

5.2.2.3 Linking Thinking techniques and Creativity [3D]

The previous section discussed the results of the questionnaire data by comparing and contrasting the thinking techniques used by the subjects with the results of the inventions judged to be practical. The next logical step would be to compare and

contrast the questionnaire data regarding the thinking techniques used by the subjects with the results of the inventions judged to be creative.

As in the previous sections, once a file was created for each individual subject, a general frequency table, based on all subjects [60 in total], was generated. The table below [Table 29] reflects for example that 32 subjects [53.33 percent of the subjects] were not able to generate any creative inventions. Marked differences exist in the number of subjects who generated creative inventions and those who did not. This is consistent with the earlier suggestions [in previous chapters] that 3D creative mental synthesis problems may be more difficult than 2D creative mental synthesis problems, at least with respect to creativity. In addition, perhaps a large number of non-creative responses [with respect to 3D problems, invention] may be non-designers.

Creativity Table 3D Problems							
Number of Creative responses	0	1	2	3	4	5	
% of Subjects	53.3%	21.7%	5%	10%	6.7%	3.3%	100%
No. of Subjects	32	13	3	6	4	2	60 Subjects

TABLE 29: PERCENTAGE OF SUBJECTS WHO GENERATED A GIVEN NUMBER OF CREATIVE RESPONSES [3D PROBLEMS]

Consistent with section 5.2.2.2 above, it was appropriate to generate a two-dimensional contingency table [illustrated in Table 30 below] in order to compare and contrast, in a simple and straightforward way, subjects who utilised multiple thinking strategies in resolving the creative mental synthesis problems with those subjects who utilised one particular thinking strategy exclusively, as a function of the creative responses verses non-creative responses.

	Single Thinking strategy	Multiple Thinking strategies	Totals
Creative	27	36	63
Non-creative	357	585	942
Totals	384	621	1005

TABLE 30: TWO WAY CONTINGENCY TABLE – SINGLE STRATEGY AND MULTIPLE STRATEGIES VS. CREATIVE AND NON-CREATIVE RESPONSES

In Table 30 above, the frequencies in the rows were represented by Creative and Non-creative responses respectively. The column headings were represented by Single thinking strategy and Multiple thinking strategies headings respectively. The results from the application of a Chi-squared test on the frequencies above indicated there was no statistically significant difference between using either a single thinking strategy exclusively or using multiple thinking strategies. The obtained value of 0.62 was derived after using the frequencies above and applying them in a Chi-squared test. The value of a one-tailed X^2 at the 0.05 level with one df=2.71. Since the obtained value [0.62] was less than 2.71 the results were determined not to be statistically significant.

5.3 Discussion: Questionnaire Data [2D & 3D]

Using empirical data and accepted statistical tools [Chi-squared tests] to compare and contrast creative mental synthesis responses with the exclusive use of a single thinking technique and the use of multiple thinking techniques, revealed with respect to 2D creative responses, 3D creative responses, and 3D practical responses there was no statically significant difference between the exclusive use of a single thinking technique and the use of multiple thinking techniques. This finding was contrary to the suggestions found within the design literature as discussed in Chapter 2 where strategy variety was thought to have advantages. However, the result relating to 2D

correspondence responses revealed there was a statically significant difference between the exclusive use of a single thinking technique and the use of multiple thinking techniques and appears to support the argument for the use of multiple strategies. This result notwithstanding, it is possible that the results are less a reflection of the thinking strategies and are more related to individual differences and the capabilities of individual subjects.

Chapter 6: Rejudging Experiment 1 (2D2 &3D)

6.1 Introduction

In experiment one, the judges were from different disciplines, however, the pattern of their judgments remained consistent. It could be argued the judgements may be atypical and peculiar to those judges. In order to investigate this, it was reasoned that a new set of judges should review the drawings, making new judgements. If as Amabile (1982) and Hennessey (1994) suggest, creative responses determined via consensual agreement by "appropriate observers" is reliable, then it is a reasonable hypothesis that the judgements of a new set of judges would have a high degree of

correlation when compared to the first set of judges. Therefore, the reason for rejudging the drawings from experiment one is to observe if the subjects who generated drawings determined as being creative by the first set of judges are also determined as having a similar creative output by new judges. It is expected that this would be the case for both the two-dimensional and three-dimensional problems. In order to investigate this, the first step was to eliminate outlying judges, and then isolate responses deemed creative by the remaining judges. Next, distracter responses needed to be mixed with the creative responses.

6.2 Elimination of judges

6.2.1 Outlying judges

Aberrant judges whose judgements were inconsistent, with respect to creativity/originality when compared to the other judges, would not be used. As the central focus of the rejudging relates to creative responses, thereby relating this work

to the views of Amabile (1982) and Hennessey (1994), the correspondence/practicality scales are not seen as central. This, however, does not suggest that they should not be used in the selection process, they are merely secondary. The argument is that although the scales are not linked, in that the judgements do not depend on each other, consideration should be given to both when eliminating skewed judges. In addition investigations of correspondence or practicality may be interesting. Consequently it would be best to eliminate judges who skew both scales. In this way another set of new judges does not need to be found for the purpose of judging correspondence/practicality responses.

In order to optimise the use of the new judges, the amount of papers they review could be reduced compared to the original set of judges. The idea is to reduce the numbers of judgements, but to have a sufficient total number of responses to mask the responses deemed creative among distracter responses. A response, (after the elimination of outliers), is selected as being original/creative when a majority of judges determine it to be creative. Consequently, an odd number of judges were needed. If an even number of judges was used it would be possible for a response to be declared undecided (deadlocked). This should not be allowed to happen. The central issue when deciding which judges were to be eliminated was whether the pattern of their judgements stood out from the other judges sufficiently enough to warrant their exclusion. There were a number of techniques that might be used to look at the pattern of judgements relating to frequencies of score levels (i.e. number of times a judge scored responses at a level of 5, 4 or 3 etc…). A few example techniques were: visual inspection of frequency tables; visual inspection of frequency

charts and using factor analysis. As it is a more rigorous technique, factor analysis as outlined below, was the primary technique used in this study.

6.2.2 Factor analysis

When using the basic principal components model of factor analysis, a list of component loadings was generated. In reviewing these loadings, patterns can be observed in the numbers with respect to which judge is responsible for a pattern. Typical examples and patterns of the loadings of the two-dimensional problems can be found in Table 31 below:

	Comp Loading 1	Comp Loading 2	Comp Loading 3	Comp Loading 4	Comp Loading 5
IDJ44IDCo	0.995	0.046	0.034	-0.079	0.025
IDJ44VCCo	0.985	0.067	-0.004	-0.156	-0.011
IDJ44NDCo	0.892	0.286	-0.222	-0.118	0.245
IDJ44ID2Cr	0.992	0.083	0.05	-0.054	0.057
IDJ44VC2Cr	0.971	0.234	-0.01	0.054	0.02
IDJ44ND2Cr	0.889	0.303	-0.216	-0.07	0.258
VCJ61IDCo	0.955	0.014	0.078	-0.271	-0.09
VCJ61VCCo	0.956	-0.033	0.106	-0.272	0.009
VCJ61NDCo	0.93	0.273	0.032	-0.222	0.101
VCJ61ID2Cr	0.873	0.484	-0.017	0.034	-0.037
VCJ61VC2Cr	0.893	0.429	-0.062	0.1	-0.071
VCJ61ND2Cr	0.883	0.444	0.011	-0.109	0.109
NDJ51IDCo	0.884	0.144	0.042	-0.431	-0.106
NDJ51VCCo	0.929	0.108	0.032	-0.327	-0.134
NDJ51NDCo	0.883	0.265	-0.032	-0.368	-0.119
NDJ51ID2Cr	0.935	0.171	-0.012	-0.262	-0.166
NDJ51VC2Cr	0.953	0.105	0.038	-0.215	-0.181
NDJ51ND2Cr	0.95	0.212	-0.11	-0.112	-0.164

TABLE 31: FACTOR ANALYSIS COMPONENT LOADING PATTERNS

Table 31 above is a representative sample of three of the judges (1 Industrial design judge [IDJ], 1 Visual communications judge [VCJ], and 1 Law judge [NDJ]).

Below is how the codes on the left of Table 31 are deciphered:

Type of Judge	Judge type number	Subject type	Scale type
ID = Industrial design		ID = Ind design	CO= Correspondence
VC = Vis Com		VC = Vis Com	CR= Creativity
ND = Law		ND = Law	PR = Practicality

$$\overline{IDJ}\ 44\ \overline{ID}\ \overline{CO}$$

The rows of each code represent the results of component loading. In reviewing the percentage of total variance explained (2D problems), Component 1 was approximately 63 percent Component 2 was approximately 20 percent, and Component 3 was approximately 10 percent. This indicates that the greatest explained variance resides in the first three components. Therefore these should be the main focus in observing the patterns of judgements.

Some basic patterns were found. Three different techniques were used in looking at patterns in the loadings. The first utilised a coding system of plus signs, zero and minus signs; the second was a visual inspection of the frequency tables and their corresponding frequency distribution charts and the third was by searching for outliers in a cluster analysis. The table below [Table 32] indicates how the +, - and 0 are used to reflect the loadings in a simple fashion.

High positive significance		High negative significance	
Symbol ++ Loading .75 to .99		Symbol - - Loading -.75 to -.99	
Significant but not High		**Moderate negative significance**	
Symbol + Loading .25 to .75		Symbol - Loading -.25 to -.75	
Chance		**Chance**	
Symbol 0 Loading .25 to -.25		Symbol 0 Loading .25 to -.25	

TABLE 32: GRAPHIC CODING OF COMPONENT LOADINGS

Using the system of +,- and 0 the loadings can be simplified. As an example, the list

below shows how the system was applied using the example loading symbols shown

above. Various patterns were identified and given pattern numbers [i.e. pattern 1,

pattern 2, etc...]. Pattern 1 [shown in Table 33 below] was typical of the majority of

the judges.

	Comp Loading 1	Comp Loading 2	Comp Loading 3	Comp Loading 1	Comp Loading 2	Comp Loading 3	
IDJ44IDCo	0.995	0.046	0.034	++	0	0	Correspondence
IDJ44VCCo	0.985	0.067	-0.004	++	0	0	**Pattern 1**
IDJ44NDCo	0.892	0.286	-0.222	++	+	0	
IDJ44ID2Cr	0.992	0.083	0.05	++	0	0	Creative
IDJ44VC2Cr	0.971	0.234	-0.01	++	0	0	**Pattern 1**
IDJ44ND2Cr	0.889	0.303	-0.216	++	+	0	
VCJ61IDCo	0.955	0.014	0.078	++	0	0	Correspondence
VCJ61VCCo	0.956	-0.033	0.106	++	0	0	**Pattern 1**
VCJ61NDCo	0.93	0.273	0.032	++	+	0	
VCJ61ID2Cr	0.873	0.484	-0.017	++	+	0	Creative
VCJ61VC2Cr	0.893	0.429	-0.062	++	+	0	**Pattern 1**
VCJ61ND2Cr	0.883	0.444	0.011	++	+	0	
NDJ51IDCo	0.884	0.144	0.042	++	0	0	Correspondence
NDJ51VCCo	0.929	0.108	0.032	++	0	0	**Pattern 1**
NDJ51NDCo	0.883	0.265	-0.032	++	+	0	
NDJ51ID2Cr	0.935	0.171	-0.012	++	0	0	Creative
NDJ51VC2Cr	0.953	0.105	0.038	++	0	0	**Pattern 1**
NDJ51ND2Cr	0.95	0.212	-0.11	++ 0	0	0	

TABLE 33: COMPONENT LOADING PATTERNS

The rows in Table 33 above, represent the loading figures of a judge reviewing a type

of subject. The first three columns [Comp Loading 1, 2, & 3] represent the loading for

a judgment. The last three columns indicate the symbols attributed to a particular

component loading. A review of the symbols, in Table 33 above, reveals a consistent

pattern of judgements typical of the majority of judges. However, the symbol patterns

of Non-design judge 53 [NDJ53] and Vis-Com judge 65 [VCJ65], found in Table 34

below, were very different from that of the majority of the judges [Component 1 = ++,

Component 2 = 0 or +, Component 3 = 0]. When comparing the symbol patterns in

the list below with the symbol patterns typical of most judges reflected in the list above, these judges [NDJ53 & VCJ65] should be considered as outlying judges.

	Comp Loading 1	Comp Loading 2	Comp Loading 3	Comp Loading 1	Comp Loading 2	Comp Loading 3	
VCJ65IDCo	0.306	-0.744	0.423	+	-	+	Correspondence
VCJ65VCCo	0.35	-0.696	0.432	+	-	+	Pattern 4
VCJ65NDCo	0.505	-0.738	0.402	+	-	+	
VCJ65ID2Cr	0.138	0.852	0.373	0	++	+	Creative
VCJ65VC2Cr	0.061	0.813	0.461	0	++	+	Pattern 3
VCJ65ND2Cr	0.23	0.858	0.303	0	++	+	
NDJ53IDCo	0.516	-0.738	0.285	+	-	+	Correspondence
NDJ53VCCo	0.377	-0.819	0.347	+	- -	+	Pattern 3
NDJ53NDCo	0.42	-0.836	0.318	+	- -	+	
NDJ53ID2Cr	0.051	0.601	0.771	0	+	+	Creative
NDJ53VC2Cr	0.275	0.529	0.797	+	+	+	Pattern 3
NDJ53ND2Cr	0.025	0.598	0.779	0	+	+	

TABLE 34: ATYPICAL JUDGES BASED ON PATTERNS OF COMPONENT LOADINGS [2D PROBLEM SETS]

Using this technique for identifying the outlier judges from the three-dimensional problems sets resulted in finding two judges who were not as consistent as the other judges. Therefore, they should not be used. They were Non-design Judge 12 [NDJ12] & Vis-Com Judge [VCJ 34]. Their patterns are shown in Table 35 below:

	Comp Loading 1	Comp Loading 2	Comp Loading 3	Comp Loading 1	Comp Loading 2	Comp Loading 3	
NDJ12IDPr	0.767	-0.607	0.056	++	-	0	Practicality
NDJ12VCPr	0.844	-0.525	0.041	++	-	0	Pattern 1
NDJ12NDPr	0.724	-0.657	0.064	+	-	0	
NDJ12ID3Cr	0.631	0.645	-0.3	+	-	-	Creative
NDJ12VC3Cr	0.566	0.727	-0.335	+	-	-	Pattern 4
NDJ12ND3Cr	0.445	0.726	-0.394	+	-	-	
VCJ34IDPr	0.832	-0.539	0.011	++	-	0	Practicality
VCJ34VCPr	0.964	-0.252	0.008	++	-	0	Pattern 1
VCJ34NDPr	0.92	-0.369	0.047	++	-	0	
VCJ34ID3Cr	0.637	0.617	-0.353	+	-	-	Creative
VCJ34VC3Cr	0.677	0.682	-0.225	+	-	0	Pattern 4
VCJ34ND3Cr	0.592	0.681	-0.396	+	-	-	

TABLE 35: ATYPICAL JUDGES BASED ON PATTERNS OF COMPONENT LOADINGS [3D PROBLEM SETS]

6.2.3 Visual Inspection (Frequency Distributions)

There are different ways in which unusual judging patterns can be identified. One way is graphically, by looking at the charts of frequency distributions. The judges IDJ44 and VCJ61, in figure 24 below, illustrate a typical frequency distribution of judgements.
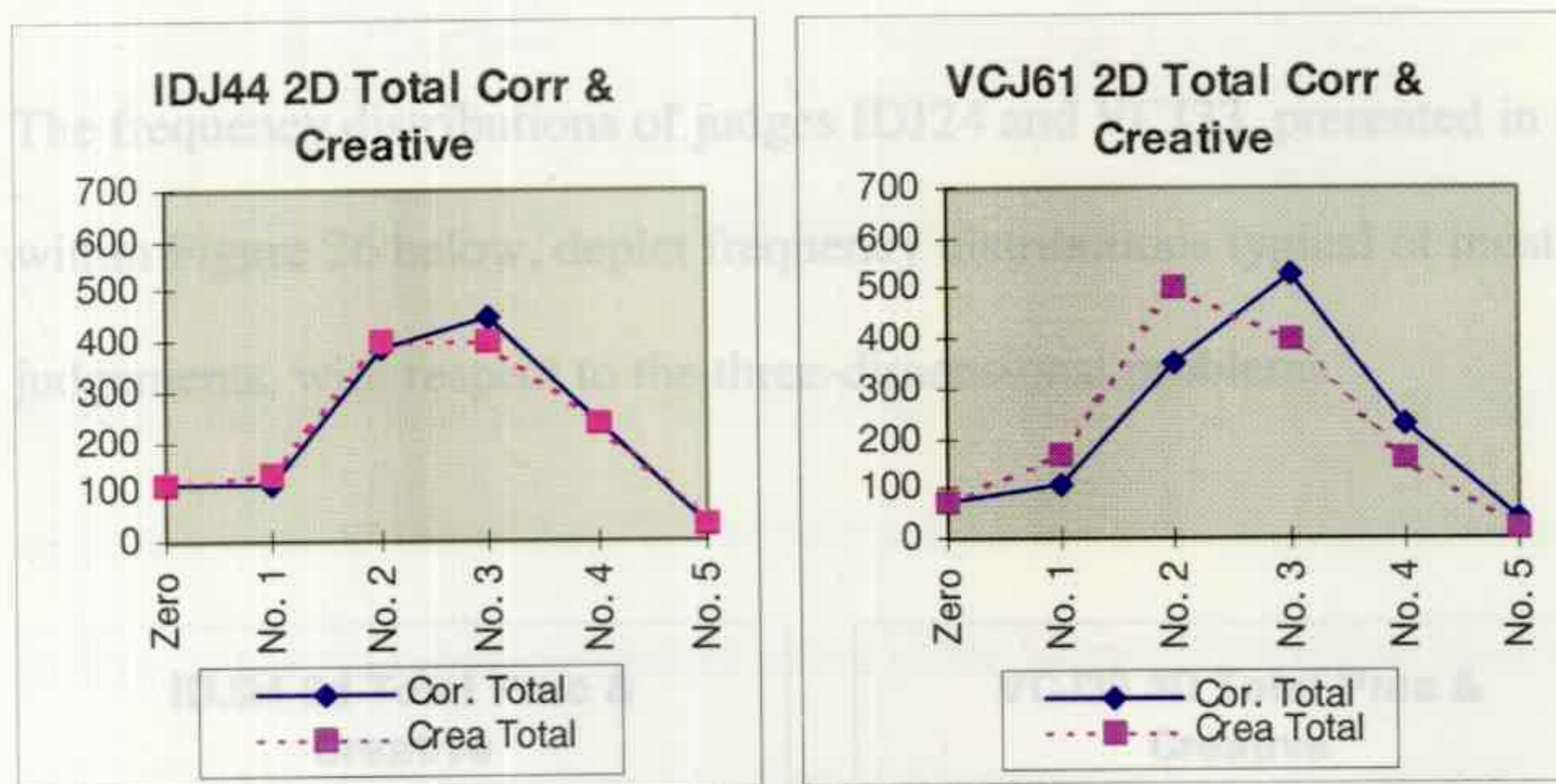
FIGURE 24: TYPICAL JUDGE FREQUENCY DISTRIBUTIONS [2D PROBLEM SETS]

However, the judges, in figure 25 below, were considered to be atypical.
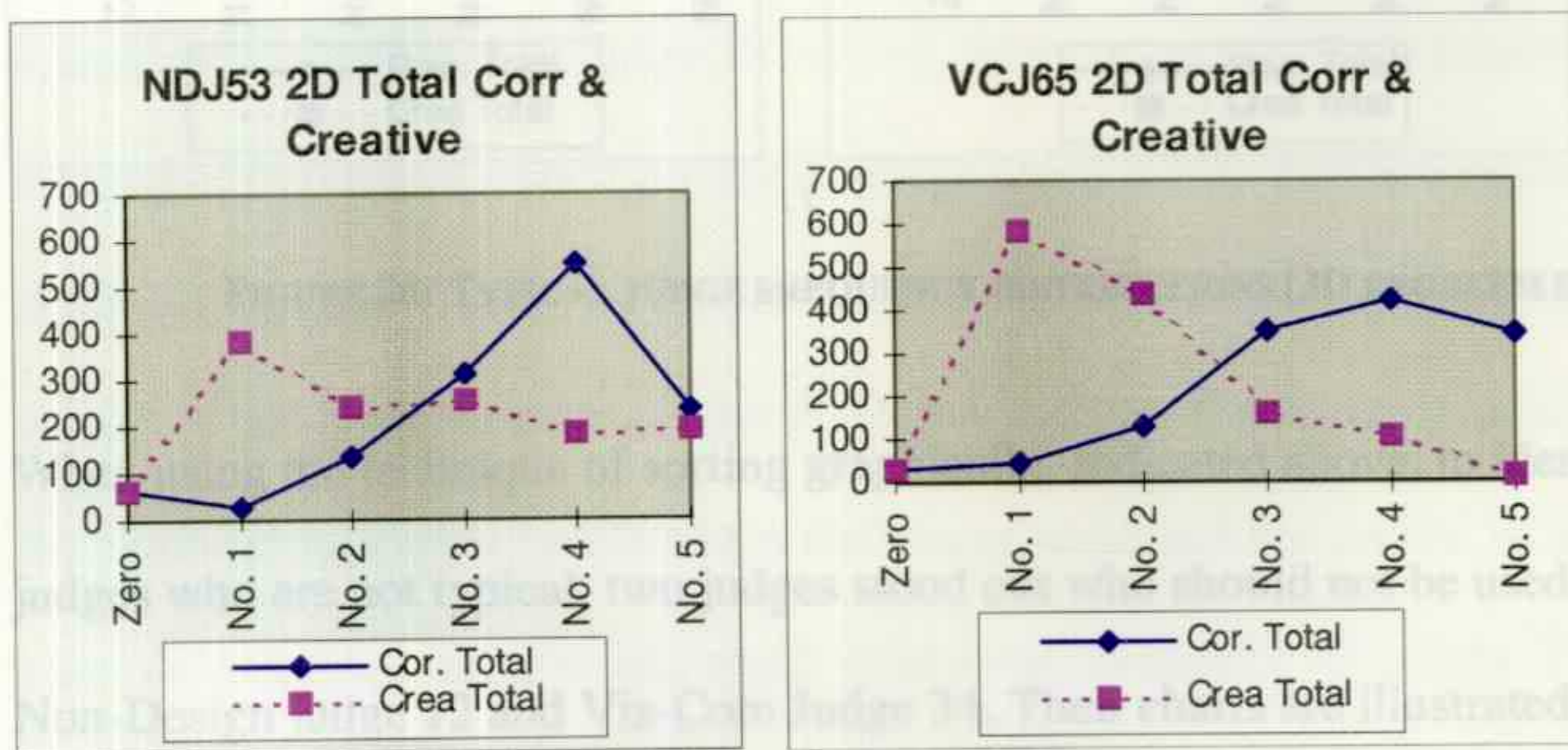
FIGURE 25: ATYPICAL JUDGE FREQUENCY DISTRIBUTIONS [2D PROBLEM SETS]

Note how the peaks of the curves are towards opposite ends of the scales. That is to say, the curves appear [graphically] to be skewed. Creativity appears to be negatively

skewed, while the correspondence curve appears to be positively skewed. These two

judges are not typical with respect to their judging patterns when compared to the

other judges. Therefore, their judgements should not be relied upon and excluded

from use in further analysis. This review confirms what was indicated in section 6.2.2

above.

The frequency distributions of judges IDJ24 and VCJ33, presented in the charts

within Figure 26 below, depict frequency distributions typical of most of the judges'

judgements, with respect to the three-dimensional problems.
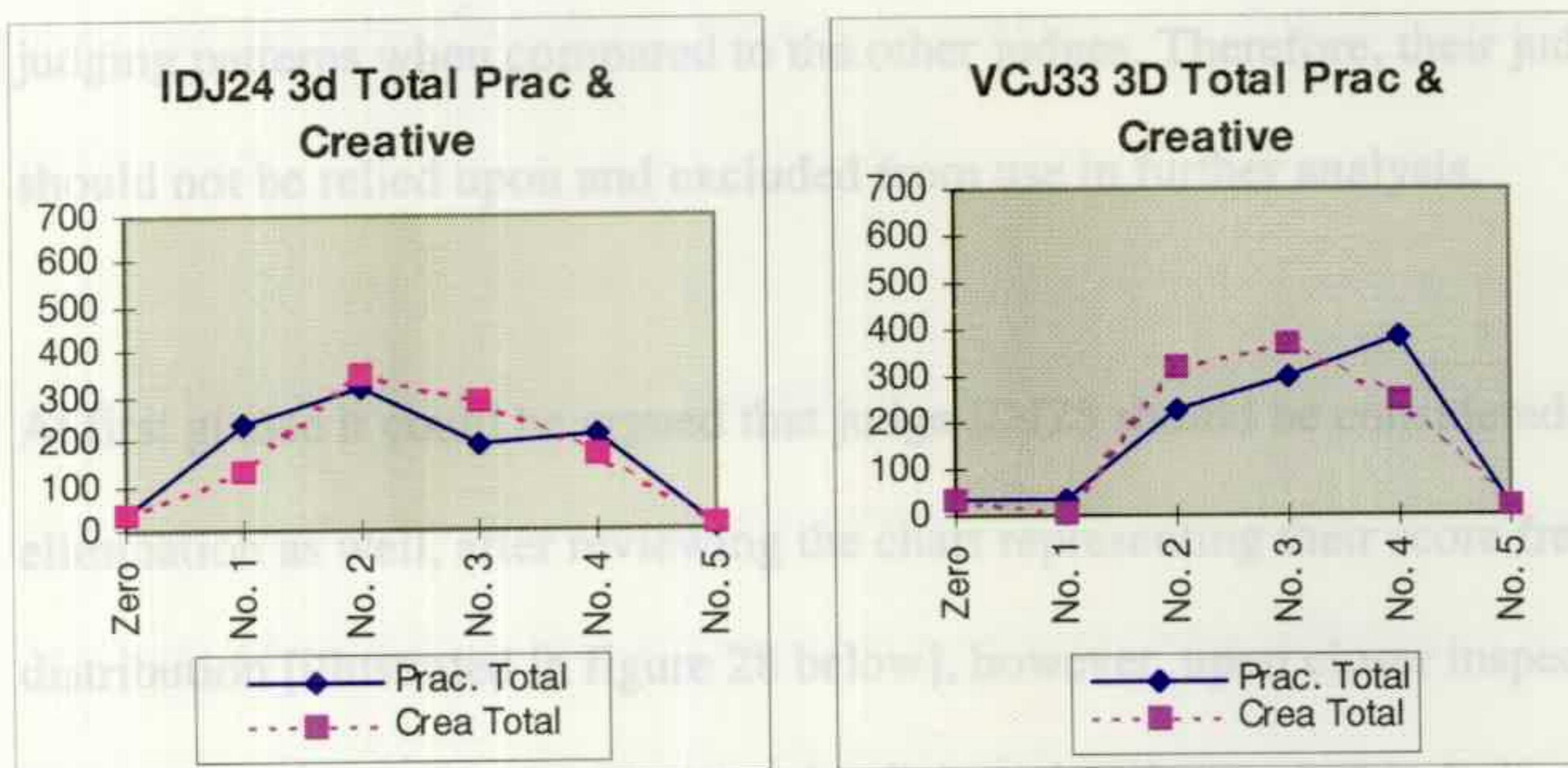
FIGURE 26: TYPICAL JUDGE FREQUENCY DISTRIBUTIONS [3D PROBLEM SETS]

When using the technique of sorting graphically, indicated above, to identify the 3D

judges who are not typical, two judges stood out who should not be used. They were

Non-Design judge 12 and Vis-Com Judge 34. Their charts are illustrated in Figure 27

below.
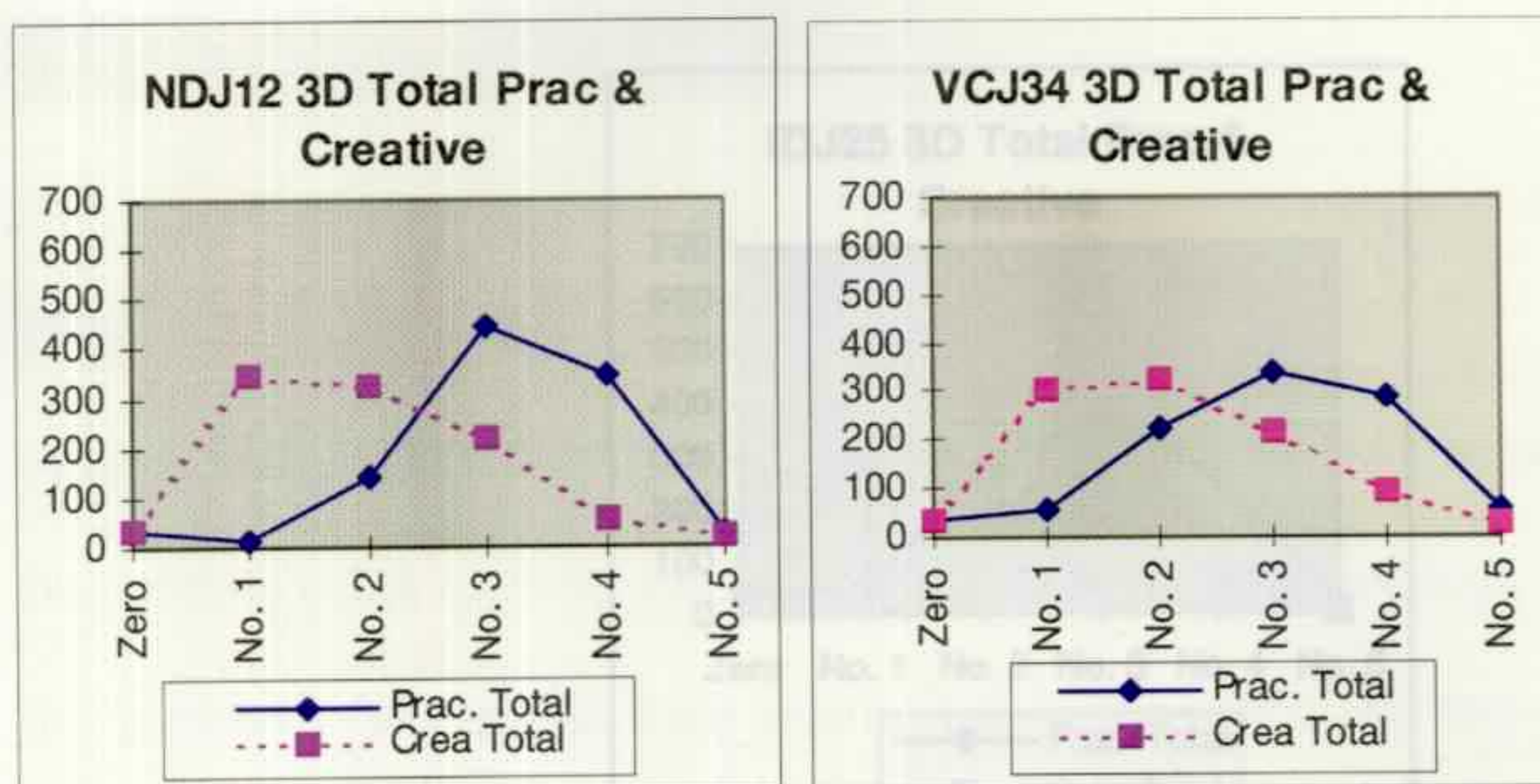
FIGURE 27: ATYPICAL JUDGE FREQUENCY DISTRIBUTIONS [3D PROBLEM SETS]

As with the previous judges, note how the peaks of the curves are skewed towards opposite ends of the scales. These two judges are not typical with respect to their judging patterns when compared to the other judges. Therefore, their judgements should not be relied upon and excluded from use in further analysis.

At first glance it could be argued that judge IDJ25 should be considered for elimination as well, after reviewing the chart representing their score frequency distribution [illustrated in figure 28 below], however, upon closer inspection and after looking at the pattern of component loadings using the +,- & 0 technique [factor analysis] explained earlier as support, IDJ25 can be considered as having a different pattern, when compared with either NDJ12 or VCJ34. However, it should be noted the peaks of the curves, while not in the centre, approach the centre. In addition, the elimination of this judge would result in an even number of 12 judges. This could lead to 'deadlocked' responses, consequently, this judge was retained.
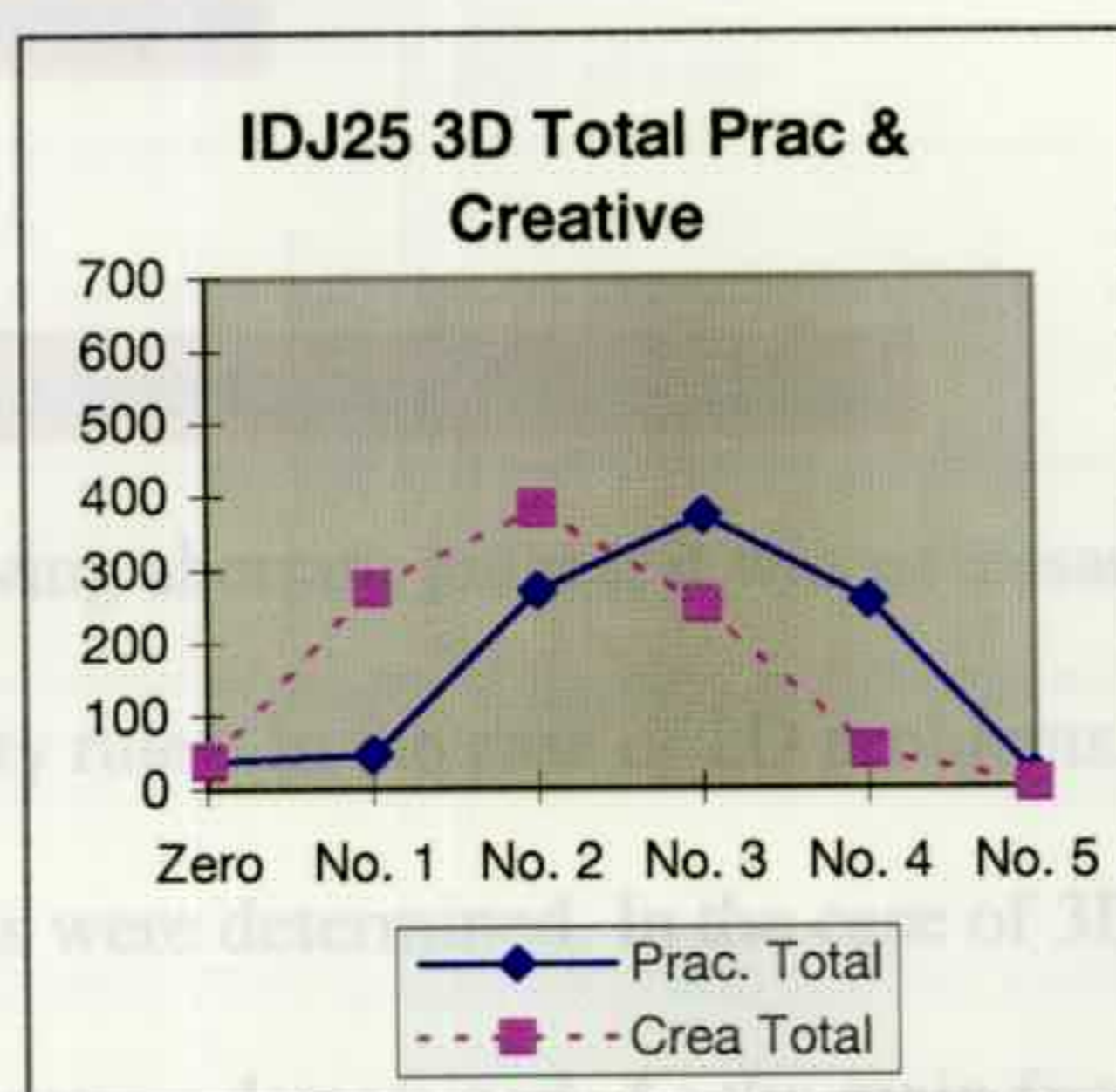
FIGURE 28: CLOSE TO NORMAL JUDGING FREQUENCY DISTRIBUTION

Cluster analysis techniques were also utilised as an alternate way of identifying judges

who were atypical. The similar findings using this technique served to reinforce the

view that the judges indicated above were not typical in their judgements and should

not be used.

After reviewing the pattern of judgements utilising various techniques, (factor

analysis, visual inspection of frequency distribution tables and charts, and cluster

analysis), to identify judges whose judging patterns were determined to be different

enough to warrant eliminating their judgements, two judges from a pool of fifteen

judges reviewing the two-dimensional problems were removed, resulting in an odd

number of thirteen judges. Those removed were Non-design judge NDJ53 and Vis-

Com judge VCJ65. In addition it was found that two judges from another pool of

fifteen judges who reviewed the three-dimensional problems needed to be removed,

resulting in an odd number of thirteen judges. They were Non-design judge NDJ12

and Visual communications judge VCJ34.

6.3 Methods & procedures

6.3.1 Recalculating frequencies using fewer judges

After isolating and removing aberrant judges, it was necessary to recalculate

frequencies using majority rules. In the case of 2D problems, high correspondence

and creativity frequencies were determined. In the case of 3D responses, practicality

and creativity frequencies were determined. As the main focus of rejudging was

creativity, these frequencies dictated which of the response codes to isolate for data

comparison. In addition, owing to the numbers of responses involved and with a view

to increase the time for decisions on the part of the judges, the following ratio for 2D

problems was used to add distracter responses. For every creative response three

distracter responses were drawn from the remaining responses. In the case of the 3D

responses, the ratio was different because of the smaller number of creative responses.

The ratio for 3D problems was five distracter responses were drawn from the

remaining responses for every creative response.

Once the data which was determined as being creative was isolated and the distracters

included, the coded originals could be photocopied and prepared for rejudging by a

new set of fifteen judges.

6.4 Rejudging Data

6.4.1 Judge Type & Numbers for rejudging

In rejudging the data the same number of judges and cohorts of judge types were used

in rejudging. Table 36 below reflects the fact that there were five judges from each

cohort [ID, VC, & ND], resulting in a total of fifteen judges. They reviewed both the

2D responses and the 3D responses.

	Judge groups			
	3D Designers Industrial design students number of Judges	2D Designers Graphic design students number of Judges	non-designers Law Students number of Judges	Total
Number of Student judges	5	5	5	15

TABLE 36: JUDGE TYPE GROUPINGS REJUDGING EXPERIMENT ONE

6.4.2 Data Coding Conventions

In order to ensure that the judges were blind to the background of the subjects, the same coding systems utilised in part one and part two of experiment one were used to code each response. Only the judges' code numbers were altered to reflect the new judges.

6.4.3 Scoring Conventions of the 2D problems

As in experiment one part one (2D) the judges were to rate the correspondence and originality (creativity) of each two-dimensional form. They were to use a 5-point scale for each criterion (as shown below) with 1 being the lowest score and 5 the highest score.

1	2	3	4	5.
Very Poor correspondence	Low correspondence	Modest correspondence	Good correspondence	Very Good correspondence

1	2	3	4	5.
Not Original	Low Originality	Modest Originality	Original	Very Original

No pattern ☐   Wrong Parts ☐

6.4.4 Scoring Conventions of the 3D problems

As in the work of Finke (1990) the judges were to rate the practicality and originality

(creativity) of each invention. They were to use a 5-point scale (as shown below) with

1 being the lowest score and 5 the highest score.

1	2	3	4	5.	No Response
Not Practical	Low Practicality	Modest Practicality	Practical	Very Practical	☐

1	2	3	4	5.
Not Original	Low Originality	Modest Originality	Original	Very Original

6.4.5 Distribution of Responses

The same technique as in experiment one, with respect to randomising the responses

for each different judge, was utilised in arranging the photocopies. This minimised

any ordering effects from occurring and ensured the stack of responses presented to

each judge was different with respect to the other judges.

6.4.6 Judgement Days

The fifteen volunteer judges from the three different cohorts of judges, were gathered

together for a full day of judging. They were told that the morning session would be

devoted to judging the 2D responses and after lunch they would be judging the 3D

responses. The procedure of what the subjects had been expected to do was explained

to the judges. Then the judges were instructed to score the responses from each

subject using the scoring conventions mentioned above.

6.4.7 Judge instructions

As in the judging sessions of experiment 1 parts1&2, the judges were to score the

responses sequentially as they were presented to them. They were not allowed to

return and review a previous response. They were not allowed to compare or rank the responses. Each response was to stand on its own merits at the time of review. No definition of originality or creativity was given. Each judge was to use his or her own criterion. In addition the previous judging rules and instructions applied as before [instructions are located in Appendix E].

Upon their return from lunch the judges (the same judges, who reviewed the 2D responses), were to judge the 3D responses, which were based on Finke (1990). All of the judges received the same basic instructions. After they assembled in the room where the judging was going to take place the instructions were read to them [instructions are located in Appendix E].

6.5 Spreadsheets

6.5.1 Spreadsheet layout

Once the responses were judged again, two spreadsheets were developed in order to prepare the coded data for analysis. The row headings were represented by a given response code as were the column headings similar to the previous spreadsheets generated for experiment one parts one and two (as depicted in Table 37 below). Using the spreadsheets, high correspondence, practical and creative responses could be isolated to allow comparisons between sets of judges.

Response Code	ID=1 VC=2 ND=3 Subject type (1,2,3)	Subject no. (1-20)	2D=1 3D=2 Problem Type (1-2)	Problem no. (1-8)	Response No.	Corres/Prac				Creativity			
						ID Judge I??/I??	ID judge I??/I??	ID Judge I??/I??	ETC .. I??/I??	ID Judge I??/I??	ID judge I??/I??	ID Judge I??/I??	ETC . I??/I??
ID2DG1S1P1R1	1	1	1	1	1	4	3	5	4	1	5	5	3
ID2DG1S1P1R2	1	1	1	1	2	2	3	2	5	3	5	5	5
ID2DG1S1P2R1	1	1	1	1	3	5	4	5	2	1	5	5	4
ID2DG1S1P3R1	1	1	1	2	1	3	5	5	4	5	4	2	3
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓

TABLE 37: SPREADSHEET LAYOUT [REJUDGING]

6.6 Frequency Distribution Tables

Frequency distributions of creative responses and responses of high correspondence

(2D) or practicality (3D) were determined and generated. Frequency tables based on

the spreadsheets allowed data to be reviewed and compared. In addition they allowed

for a comparison of frequencies between and among sets of judges (i.e. original

judges and judges doing the rejudging), and different subject types, thus providing an

opportunity to correlate response judgements.

6.7 Analysis/Results

When comparing judgements made by the sets of judges in experiment one with the

current judgments, it would be expected, given the findings of Amabile (1982) and

Hennessey (1994), that a high correlation should exist between the judging patterns of

the judges. In order to investigate this, correlation tables which listed the ranked

frequencies of responses using all judges, were developed. In order to determine the

degree of association between the judgements rendered by the judges in experiment

one with the judges who rejudged the data, accepted statistical methods were used.

The rank differences correlation formula method, corrected for ties, was the

appropriate tool to use. The supporting rationale for correcting for ties was that

frequently two or more subjects could have the same score on a single variable, an

issue that needed to be addressed. This was accomplished by assigning averages to the

tied scores. To review the tables and calculations refer to Appendix F. In essence this

research tested the null hypothesis that the two variables, ranks of scores by different

sets of judges, would not be associated (H_o: $r_s = 0$). If the value of r_s is *equal to or*

greater than the critical value for a given N, then it is concluded that r_s is significant

(one-tailed) at a *p* level indicated in a *t* distribution table. Table 38 below summarises

the resultant *t* values, with respect to the different judgment criterion, for different *df*

at the 0.05 level.

Using All judges Re-judging (2D)			
Correspondence			
ID subjects	*t* = 8.0	*t* value for *df* (17) @ 0.05 level = 1.740	Reject Null
VC subjects	*t* = 9.0	*t* value for *df* (17) @ 0.05 level = 1.740	Reject Null
ND subjects	*t* = 3.1	*t* value for *df* (13) @ 0.05 level = 1.771	Reject Null
Creativity			
ID subjects	*t* = 2.3	*t* value for *df* (17) @ 0.05 level = 1.740	Reject Null
VC subjects	*t* = 5.68	*t* value for *df* (17) @ 0.05 level = 1.740	Reject Null
ND subjects	*t* = 2.9	*t* value for *df* (13) @ 0.05 level = 1.771	Reject Null
Using All judges Re-judging (3D)			
Practicality			
ID subjects	*t* = 2.85	*t* value for *df* (13) @ 0.05 level = 1.771	Reject Null
VC subjects	*t* = 0.60	*t* value for *df* (12) @ 0.05 level = 1.782	Accept Null
ND subjects	*t* = 5.25	*t* value for *df* (5) @ 0.05 level = 2.015	Reject Null
Creativity			
ID subjects	*t* = 2.3 7	*t* value for *df* (13) @ 0.05 level = 1.771	Reject Null
VC subjects	*t* = 1.6	*t* value for *df* (12) @ 0.05 level = 1.782	Accept Null
ND subjects	*t* = 1.44	*t* value for *df* (5) @ 0.05 level = 2.015	Accept Null

TABLE 38: RESULTS OF CORRELATION ANALYSIS

6.8 Discussion

Consensual agreement patterns in this research tend to support the views regarding

consensual agreement reliability suggested by Hennesey (1994).

As can be noted in Table 38 above, with respect to the 2D problems, both the different

sets of judges demonstrated a similar judging pattern with respect to ranking subjects

who had responses with a high degree of correspondence. In addition, both sets of

judges revealed a similar judging pattern in ranking subjects whose responses were

determined as being creative. While correlation exists in all subject groupings (ID-

VC-ND), the correlations are three times higher for the designers compared to the

non-designers. However, with respect to creativity, the correlation is about two times

greater for the visual communications subjects compared to either the industrial

designers or the non-designers. This tends to suggest that the responses generated by the visual communications subjects can be clearly identified as being creative by different sets of judges.

Differences in the level of difficulty (3D problems are more difficult than 2D problems) suggested by the results from experiment one and as discussed in chapter 4, are supported here, in that the correlations of practicality are lower than those of correspondence. In addition, only with respect to 3D creativity and the industrial design subjects can the null hypothesis be rejected. That is to say, both sets of judges tend to agree on the judging pattern in ranking industrial design subjects whose responses were determined as being creative. However, the null hypothesis must be accepted concerning both the visual communications subjects and the non-design subjects in terms of creativity, with respect to the 3D problems and visual communications subjects in terms of practicality, with respect to the 3D problems.

It might be argued that these results are some affectation of the methodology, perhaps the selection of responses and distracter responses may be weighted towards the subjects who were determined (by the first set of judges) as generating larger numbers of creative responses. However, this is not really sustainable. A subject who generates a large number of responses does not guarantee that they have generated large numbers of creative responses. For example subject VC2DG5S6 generated forty, two-dimensional responses. However, only one of those was determined to be creative by a majority of the judges. On the other hand subject ID2DG1S1 generated only eleven two-dimensional responses and four of those were determined to be creative. As the second judges were blind to who generated which responses (as were the first

set of judges) and it would be impossible for them to know the judging patterns of the first judges, these results are significant in that they lend support to the view that while the number of creative responses is small they remain recognisably creative.

The issue of a small number of creative responses brings the discussion to another point. A low number of non-design subjects generated a significant number of the 3D creative responses (25 percent of subjects generated 75 percent–80 percent of the creative responses). This also appears to be the case for the design subjects. Further research is needed to investigate the backgrounds of the subjects who generated these responses. Perhaps they were the top students in their class.

Chapter 7 Experiment 2: Experimental design (2D&3D)

7.1 Introduction

Revealed in the literature review (chapter 2) the design literature regards creative mental synthesis and therefore creative mental synthesis abilities as important in the design process. Additionally, drawing is seen as playing a central role in that creative process. However, a review of the relevant cognitive psychology literature [see Anderson & Helstrup (1993)] revealed that when empirically investigated, utilising the methods of Finke & Slayton (1988), the use of drawing as an aid in such a task was inconsequential. Notwithstanding the findings of Anderson & Helstrup (1993), it can be argued that drawing may be important in creative mental synthesis tasks, which are clearly related to design tasks. While Anderson & Helstrup (1993) instructed their subjects to sometimes "doodle" or draw, and sometimes to only

perform the creative mental synthesis task mentally, a number of issues arise. To begin with the subjects they had utilised were recruited from a general psychology class and were not thought of as being trained in drawing, as designers are. Another issue open to exploration is that perhaps when and how drawing is used in the creative mental synthesis process is important. If the beliefs reflected in the design literature regarding the importance of drawing and creative mental synthesis are to be substantiated, empirical methods must be applied in order to investigate the presumed significance of creative mental synthesis and drawing in design. The design literature offered no empirical methodology which would assist in such an investigation.

However, the cognitive psychology literature appeared to offer one. The most straightforward way of investigating creative mental synthesis, drawing and design was to adopt and adapt the research procedures and methods of Finke & Slayton (1988), Finke (1990), and Anderson & Helstrup (1993).

While the cognitive psychology literature offered a possible methodology for researching creative mental synthesis and drawing, their findings were not consistent with the views of the design literature. As was suggested earlier, alternate strategies [when and how drawing is used] should be investigated and compared. To that end, in experiment two it was necessary to develop a series of tasks. The tasks were developed to explore a few relevant strategies, derived from the literature review in Chapter 2. Based on the anecdotal evidence found in the design literature, it was predicted that drawing would increase creative output for the design groups relative to their performance when they are not allowed to draw, and that non-designers would not change their level of performance. These two experimental conditions are illustrated below in Table 39 as Strategy A and Strategy B, Task 1.

However, the structure of the creative mental synthesis task allows a more detailed examination of the role of drawing than is implied in this simple comparison. In the design literature there are a number of more specific views about the role of drawing. It is often stated, for example, that design flows from the end of the pencil. This could mean that the activity of drawing simply assists through the type of mechanism suggested by Anderson and Helstrup (1993), of reducing the cognitive load. However this statement is often associated with the idea that drawings that are produced trigger the emergence of new ideas or the re-interpretation of existing ideas (see, for example Goldschmidt, 1994, on emergence and re-interpretation). The basic structure of the mental synthesis task involves the presentation of three randomly selected forms that then have to be recreated in imagery and synthesised to produce a new form. This is then externalised in written and drawn form to allow for the assessment of the results.

Drawing could be introduced while this initial synthesis is taking place. However it would also be possible to introduce a second phase to the task where the normal mental synthesis procedure is carried out but participants are then allowed to go back and work on the forms they have produced either by drawing or by repeating the mental synthesis task during the second phase. In this way the issue of emergence and re-interpretation can be addressed.

The first two Strategies (A and B illustrated in Table 39 below) can therefore be combined with a second phase where drawing is allowed in order to work on the forms produced in the first phase. If drawing is both important during the process of synthesising a form and allows re-interpretation then Strategy A, Task 1 and 2 should produce the highest output for the designers, and if the lack of drawing training is the important factor with the non-designers then the two phase procedure should not change their performance. However, if drawing is only important in terms of the way it facilitates re-interpretation, then creative output should increase in Strategy B, Task 2 and should equal Strategy A, Task 2. It may be, however, that drawing is not important during either Task 1 or 2 and that the important creative activity occurs when forms that have been produced can be mentally manipulated, and that drawing under these conditions is simply a way of externalising the results of these manipulations. This possibility is examined by including a third Strategy where Task 1 involves forms being produced with drawing being allowed and this is followed by a Task 2 condition where participants can use mental imagery to work on the forms produced in Task 1. This combination of Task 1 and 2 is illustrated below in Table 39 as Strategy C.

In his research on expert and novice designers, Mathias (1993) found novice designers often use drawing to focus early on a design solution. For example, when they are given the task of designing a doorknob, the novice would start trying to embody the form early in the design process by drawing doorknobs in general, thus operating a holistic-synthetic strategy in which an overall solution is developed from the outset. However, this then limits the size of their search space. By contrast, experts would use drawing to generate ideas and concepts and not form, at this stage of the process. By operating at the level of abstract ideas and concepts experts develop a complex search space opening up the possibility of innovative and creative outcomes. This would appear to imply that it is better to separate the idea generation stage and the synthesis stage (form generation). This is reinforced by the fact that in the later stages of the design process, Mathias (1993) found that expert designers use drawing and modelling for synthesis to embody the ideas in physical form. Therefore, if conditions are controlled so as to mimic the strategies of expert designers, by forcing subjects to focus on developing ideas (concepts) first and then the embodiment of those ideas, as design experts do, this should result in more creative ideas being generated and offer an opportunity to create forms which are atypical and seen as more creative. Since neither non-designers nor student designers [novice designers] are instructed on how to use drawing for first ideas as experts do, it would be better if the activity of developing first ideas was done only mentally, with basic shapes given later so no embodiments or synthesis could take place. This possibility was examined by providing participants in the mental synthesis task with the name of a category, but not the parts. This combination is illustrated as Strategy D in Table 39 below. If Mathias's views regarding expert designers are correct then the highest level of creative output, for both designers and non-designers, should occur in Task 1 of this

strategy and, if drawing assists the creative process through exploration, then creative

output should increase in the second task where drawing is used to reinterpret the

forms produced in the first task.

In order to investigate the themes described earlier, a series of tasks was developed,

which were divided into four distinct strategies [Illustrated below in Table 39 as

(Strategies ABCD)], and two distinct phases within each strategy [Illustrated below in

Table 39 as Tasks 1 & 2].

Drawing Strategies & Creative Mental Synthesis				
	Strategy A	**Strategy B**	**Strategy C**	**Strategy D**
Phase 1	**Task 1** Using drawing to develop ideas (time limit)	**Task 1** Using mental imagery to develop ideas (time limit), then draw the ideas (no time limit)	**Task 1** Using drawing to develop ideas (time limit)	**Task 1** Mentally develop and name forms (time limit) (no parts given) THEN parts given to develop the previously named forms (no time limit)
Phase 2	**Task 2** Using drawing to rotate and reinterpret forms (time limit)	**Task 2** Using drawing to rotate and reinterpret forms (time limit)	**Task 2** Using mental imagery alone to rotate forms then draw and reinterpret forms (time limit)	**Task 2** Using drawing to rotate and reinterpret forms (time limit)

TABLE 39: DRAWING STRATEGIES AND TASK DESCRIPTIONS FOR EXPERIMENT 2

The focus of this chapter centred on the procedural and methodological issues of

experiment two, which were largely based on those of Finke & Slayton (1988), Finke

(1990). Their experiments explored both two-dimensional and three-dimensional

creative mental synthesis respectively. Additionally, experiment two was based on the

work of Anderson & Helstrup (1993), with respect to drawing issues and creative

mental synthesis. As there were two types of problems (2D & 3D), accordingly, there

were two separate parts of experiment two (2D problem trials and separate 3D

problem trials). However, while the procedures and methods were not exactly the

same, they were very similar, therefore, it was sensible to group sections concerning

similar topics together [i.e. types and numbers of subjects used in the experiment,

types of stimuli etc…]. This chapter is dedicated to explaining the experimental

design.

7.2 Method & Procedures

7.2.1 Subject Types [2D problems]

Previously, in both the summary of the literature review [section 2.6] and introduction

of chapter 7 [section 7.1], it was posited that the most straightforward way of

assessing the relevance of drawing and the creative mental synthesis task with respect

to design, was to adopt and adapt the experimental research methods and procedures

developed by Finke & Slayton (1988), Finke (1990) and Anderson & Helstrup (1993).

This would allow an exploration of the issues relating to mental synthesis, creativity,

and drawing in the context of design if designers were used as subjects. Comparing

the performance of different types of designers with non-designers with respect to

various strategies of utilising drawing, allows such an investigation. The nature of the

material and stimuli in the Finke & Slayton (1988) task was of a 2D nature.

Consistent with experiment one, this experiment (experiment two) recruited both

types of designers [graphic designers (2D) & industrial designers (3D)] along with

subjects having a background in Law [non-designers], as this study sought to

investigate possible differences among designers and non-designers using various

strategies involving drawing to solve creative mental synthesis problems.

7.2.2 Subject Types [3D problems]

One finding of experiment one was that almost three times as many 2D responses

were deemed creative as 3D responses, suggesting the three-dimensional creative

mental synthesis task is somehow more difficult than the two-dimensional creative

mental synthesis task. Subsequently, the issue of using drawing as an aid in the 3D

creative mental synthesis process may be more helpful. While the research of

Anderson & Helstrup (1993) did not involve 3D problems, it is not hard to see how to

adapt their ideas to the work of Finke (1990), as his later work was of a 3D nature,

requiring the subjects to create a practical object. Consistent with experiment one, this

experiment (experiment two) recruited industrial designers (3D designers), graphic

designers (visual communications students) as the 2D designers, and Law students

were again used as the non-designers. As in experiment one, differences were

expected between and among these groups of subjects.

7.2.3 Subject Recruitment

Following on from experiment one, experiment two recruited university students and

private college students in the final years of their degree in their field of study, from

different Australian universities and schools. In attracting new subjects [university

students who had not helped with this research before] the same ethics approvals

previously given by the various institutions [e.g. University of Technology Sydney -

approval number (UTS HREC 96/58) etc...] were utilised, as this research was

considered to be very similar to experiment one with respect to the ethical issues

involved. As before, with advance permission from the relevant lecturers, recruitment

was accomplished by visiting lecture classes of the various disciplines and reading the

prepared statement utilised last time, with the exception of one minor change. The

time involvement for the individual subjects had been extended to approximately one

and a half hours, instead of approximately one hour. Consistent with the previous

recruitment drive, a few general questions were answered after the reading of the

statement. This was done to maintain consistency in the recruitment process. The

nature of the statement was to tell the potential subjects enough to entice them, but not

enough to reveal the details of the research. Interested students placed their name and

a contact telephone number on a sign-on sheet, to be contacted later, thus minimising

disruption to the scheduled class. Volunteers were later contacted to confirm their

willingness, and to obtain prospective times to participate in the research.

7.2.4 Subject Numbers [2D problems]

One aspect of experiment two investigated 2D creative mental synthesis utilising 60

student subjects in the final years of their degree [20 subjects from each discipline].

Additionally, each cohort of subjects was further randomly broken down into four

groups of five subjects, as illustrated in Table 40 below. The further grouping of

student types was necessary to prevent ordering effects. As the subjects were

presented tasks which directed them to use different drawing strategies to resolve 2D

creative mental synthesis problems, it was important that no order effects occurred in

the process. It is possible if all the subjects were given the different strategies in the

same order that a practice effect could be blamed for any increases in performance.

Therefore, each group was given a letter designation (Group A, Group B, Group C, or

Group D), which designated the order in which the different strategies were presented

to the subjects. The details regarding the varied order of strategy presentation within each group will be discussed in a subsequent section.

	Subject groups												
	3D Designers Industrial design students number of subjects				2D Designers Graphic design students number of subjects				non-designers Law Students number of subjects				Total
2D Problems sets [4 strategies]	[20]				[20]				[20]				
	Group				Group				Group				
	A	B	C	D	A	B	C	D	A	B	C	D	
	5	5	5	5	5	5	5	5	5	5	5	5	60

TABLE 40: SUBJECT GROUPINGS FOR EXPERIMENT TWO [2D PROBLEMS]

As with the previous experiment [experiment one] the group numbers (five in each) were large enough to expedite the experiment, yet small enough so as not to be distracting for the other subjects. If a subject was unable to meet in a scheduled group, an appropriate individual time was found. It must be remembered, Finke & Slayton (1988) had used small groups as well, in order to expedite their experiments.

7.2.5 Subject Numbers [3D problems]

A second aspect of experiment two investigated 3D creative mental synthesis utilising 60 student subjects in the final years of their degree [20 subjects from each discipline]. Additionally, as with the 2D problems, each cohort of subjects was randomly placed into four groups of five subjects, as illustrated in Table 41 below. The further breakdown of student type was necessary to prevent ordering effects. As the subjects were presented tasks which directed them to use different drawing strategies to resolve 3D creative mental synthesis problems, it was important that no order effects occurred in the process. As previously stated, it is possible if all the subjects were given the different strategies in the same order that a practice effect could be blamed for any increases in performance. Therefore, each group was given a

letter designation (Group A, Group B, Group C, or Group D), which designated the

order in which the different strategies were presented to the subjects. The details

regarding the varied order of strategy presentation within each group will be discussed

in a subsequent section.

	Subject groups												
	3D Designers Industrial design students number of subjects				2D Designers Graphic design students number of subjects				non-designers Law Students number of subjects				Total
3D Problems sets [4 strategies]	[20] Group				[20] Group				[20] Group				
	A 5	B 5	C 5	D 5	A 5	B 5	C 5	D 5	A 5	B 5	C 5	D 5	60

TABLE 41: SUBJECT GROUPINGS FOR EXPERIMENT TWO [3D PROBLEMS]

As with the previous experiment [experiment one] the group numbers (five in each)

were large enough to expedite the experiment, yet small enough so as not to be

distracting for the other subjects. If a subject was unable to meet in a scheduled group,

an appropriate individual time was found. Finke (1990) had also used small groups in

order to expedite his experiments.

7.2.6 Stimuli [2D problems]

The subjects were presented with a group of parts [as utilised in Finke & Slayton

(1988)] to be used in [2D] creative mental synthesis problems, which consisted of

fifteen forms depicted in Figure 29 below. As with the 2D problems of experiment

one, three forms out of the fifteen basic forms were randomly selected for each trial.

However, in experiment two every subject was required to complete three trials in

each of four different strategies. Following the reasoning of Finke & Slayton (1988),

some shapes might be considered more complex than others, therefore, the subjects

would consider some of the forms to be difficult to utilise. So that the more complex

forms were less likely to be used in each separate trial, the first ten forms, consisting

of circle, square, rectangle, triangle, vertical line, horizontal line, capital letters D, C,

L, T were weighted to be three times as likely to be used as the last five forms (J, 8,

X, V, P). The purpose of this was to minimize the prospect that a triplet of forms, for

any of the twelve trials, would be comprised of the more complex forms. That is to

say, it is important that a triplet of forms should not consist of three of the more

difficult forms. The same selection technique utilised in experiment one, the random

selection of parts [random selection via a computer program], assisted in forming each

of the triplets of parts used in each trial.
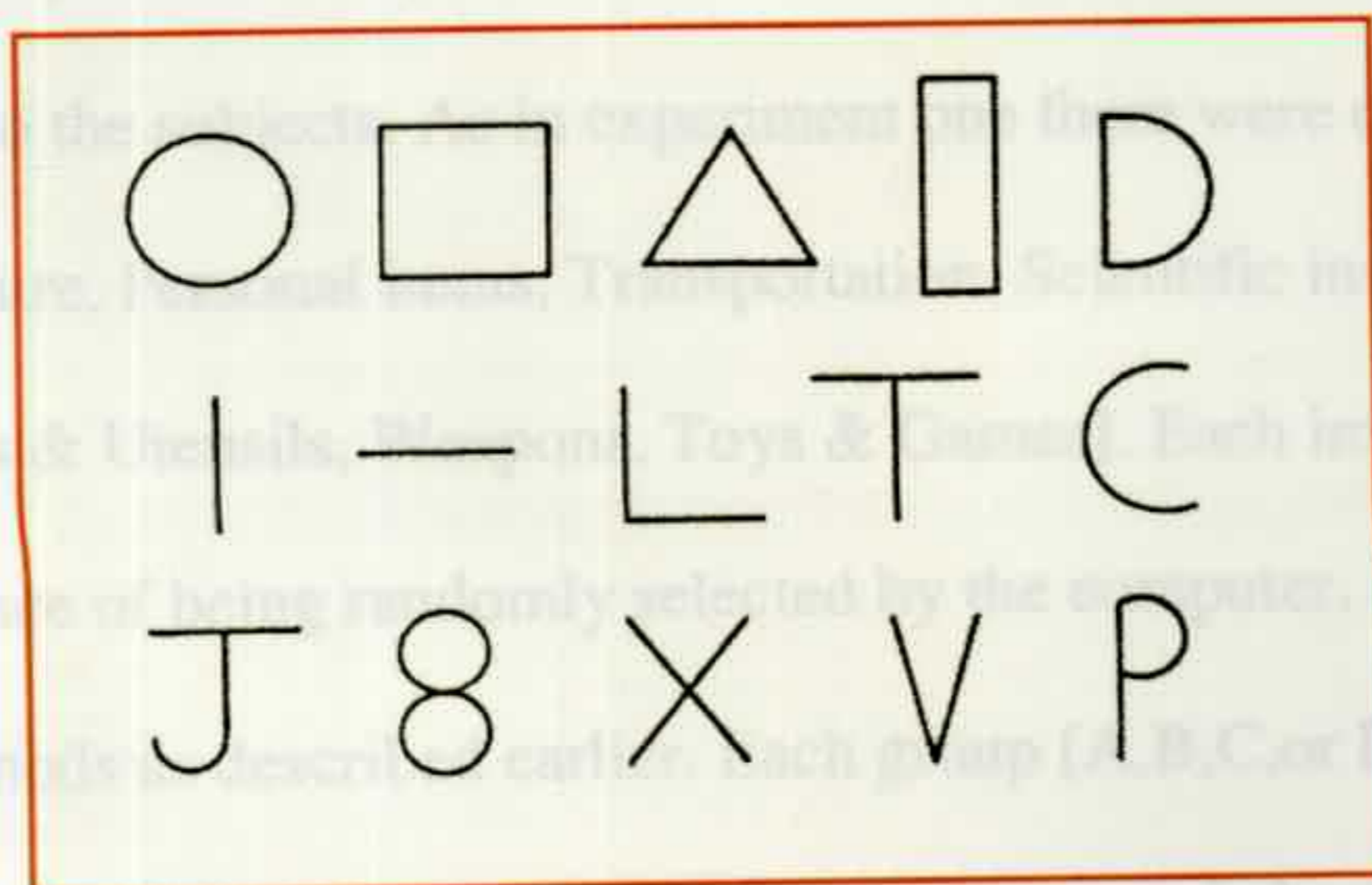
FIGURE 29: EXPERIMENT TWO STIMULI (2D PROBLEMS)

7.2.7 Stimuli [3D]

The subjects were presented with a group of parts [as utilised in Finke (1990)] to be

used in [3D] creative mental synthesis, which consisted of fifteen forms, depicted in

the Figure 30 below. As with the 3D problems of experiment one, three forms out of

the fifteen basic forms were randomly selected for each trial. However, in experiment

two every subject was required to complete three trials in each of four different

strategies. All subjects were required to complete all twelve trials. Following the

reasoning of Finke (1990) some shapes might be considered more complex than

others, therefore, subjects may consider some of the forms to be difficult to utilise.

The following constraints [consistent with Finke (1990) and experiment one of this research], were applied to the forms of varying complexity so that the more complex forms were less likely to be used in each separate trial:

The sphere, hemisphere, cube, cone, and cylinder had a 50 percent chance of selection.
The wire, tube, flat square plate, bracket, and rectangular block had a 33.3 percent chance of selection.
The hook, wheels, cross, ring, and handle had a 16.7 percent chance of selection.

The purpose of this was to minimize the prospect that a triplet of forms, for any of the twelve trials, would be comprised of the more complex forms. The selection of triplets of parts to be used in each trial was performed randomly by computer, utilising the same methods previously described in the selection of triplets in experiment one. In addition, a randomly selected object invention category attached to each triplet of 3D forms was given to the subjects. As in experiment one there were eight invention categories [Furniture, Personal items, Transportation, Scientific instruments, Appliances, Tools & Utensils, Weapons, Toys & Games]. Each invention category had an equal chance of being randomly selected by the computer, again using the same coding methods as described earlier. Each group [A,B,C,or D] within each cohort of subjects, had a different set of twelve triplets coupled with a randomly selected invention category, compared with the other groups of subjects. As each cohort of subjects was divided into four groups of five, each subject performed the first part [task one] of the creative mental synthesis task twelve times [three times in each of the four strategies] in contrast to the six trials in Finke (1990), using a new invention category coupled to each of the three new randomly selected forms in each trial, creating as many forms as they wished in a specified time limit. In the second part of each strategy [task two] the subjects were not given new parts or categories; they were to reinterpret their previous inventions using the parts they were given.

However, they were given the freedom to reinterpret the inventions irrespective of

category. This procedure will be presented in more detail in a subsequent section.
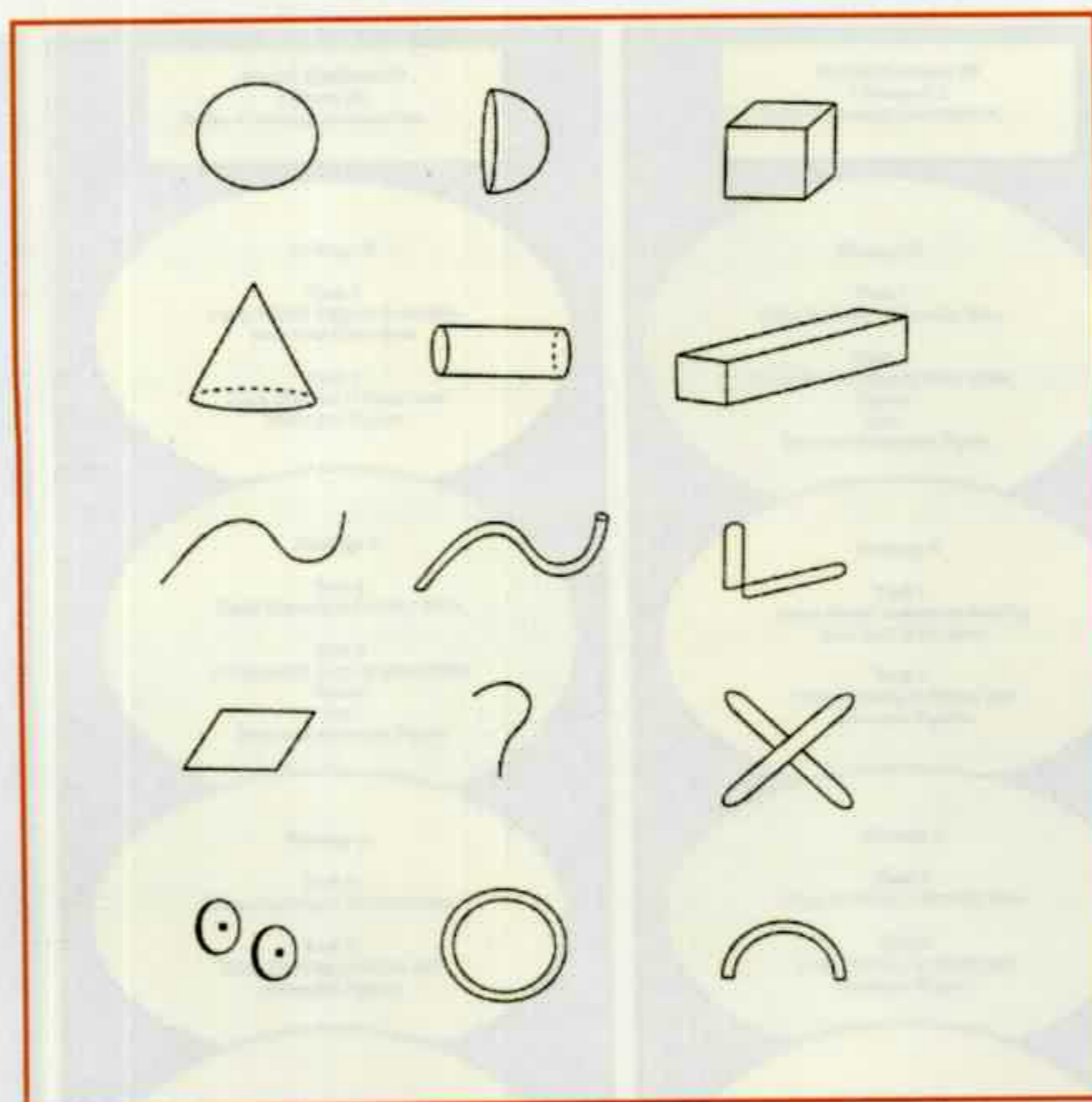
FIGURE 30: EXPERIMENT TWO STIMULI (3D PROBLEMS)

7.2.8 Procedure [2D]

The experimenter was in the room at all times monitoring the sessions. The

experiment began by showing the subjects fifteen object parts as in Finke and Slayton

(1988). Three parts were randomly selected for each trial in a series of trials presented

to the different groups who explored two-dimensional creative mental synthesis. In

the 2D trials the subjects were given a copy of a drawing consisting of the fifteen two-

dimensional forms, from which triplets of parts would be selected. In addition, each

subject was given a paper listing the strategy order of presentation for that particular

group. Each group [A,B,C, or D] had a different strategy order with a view to

minimising any ordering effects as discussed earlier. Figure 31 below illustrates the

different strategy order for each of the groups [Groups A,B,C,&D]. Each subject was

only shown the strategy order list relevant to him or her. It should be noted that

Strategy D was always presented to the subjects last, as it was such a radical departure

from the other strategies.
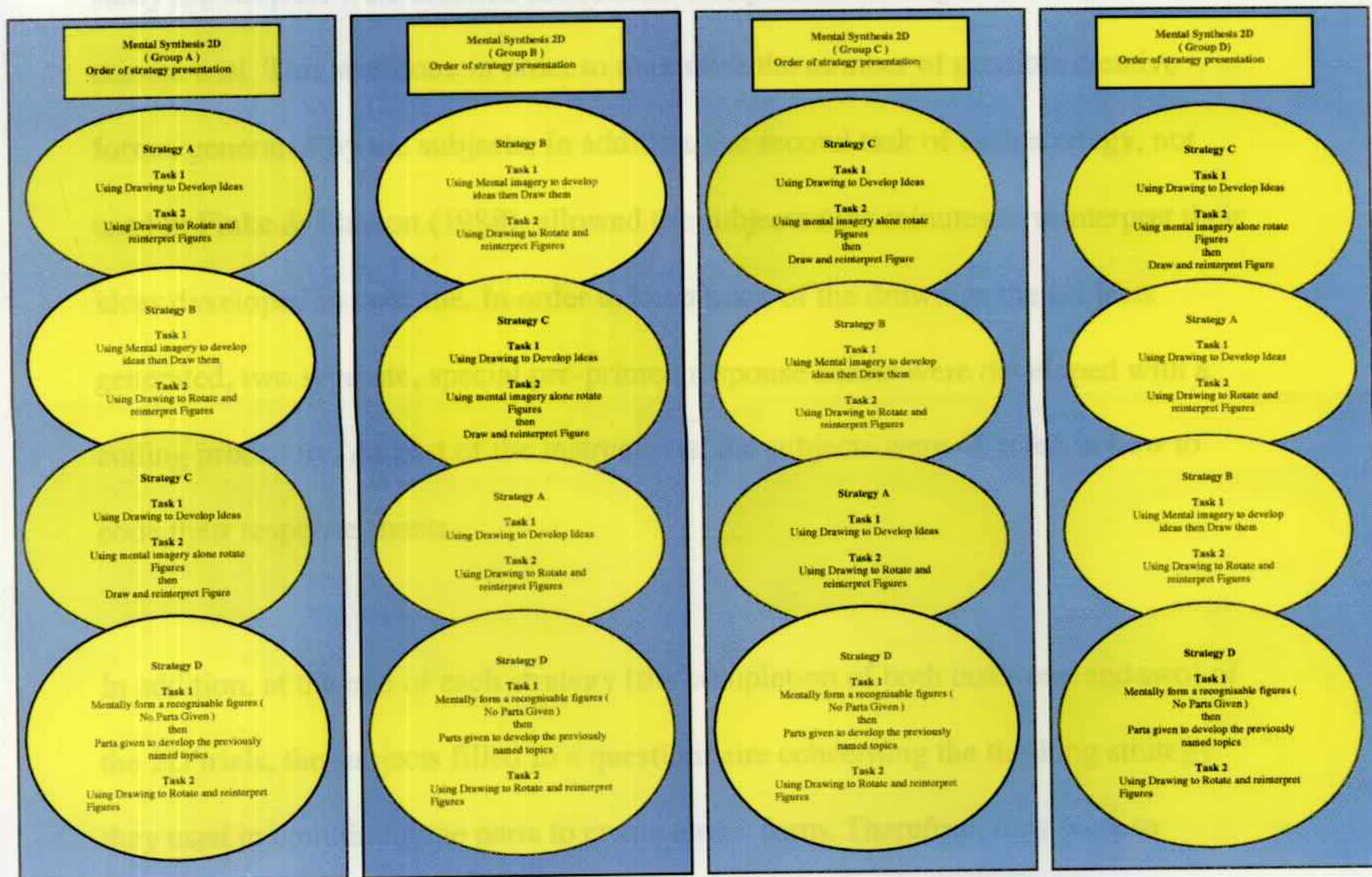
FIGURE 31: DRAWING STRATEGY ORDER FOR GROUPS A,B,C,&D [2D PROBLEMS]

For consistency, pre-prepared instructions were read to the subjects. Owing to their

length the instructions are not presented here. As a reference, detailed instructions for

each group can be found in Appendix G. It is recommended that these be reviewed in

order to gain a clear understanding of the procedures the subjects followed. Prior to

the reading of the instructions, information sheets (required by the ethics committees)

were read and signed by the subjects. These sheets outlined the ethical issues relating

to time commitment, privacy/publications issues, and contact information should a

complaint arise.

In the work of Finke & Slayton (1988) they required the subjects to only create **one** recognisable form in each of the two-minute trials they specified. However, in this study the subjects were allowed to create as many forms as they wished in each three-minute trial. This was done in order to maximise the number of possible creative forms, generated by the subjects. In addition, the second task of each strategy, not used in Finke & Slayton (1988), allowed the subjects nine minutes to reinterpret their ideas developed in task one. In order to keep track of the drawings the subjects generated, two separate, special pre-printed response sheets were developed with a coding procedure. As part of the instructions, the subjects were directed in how to code their response sheets.

In addition, at the end of each strategy [the completion of both tasks one and two] of the 2D trials, the subjects filled in a questionnaire concerning the thinking strategy they used in combining the parts to create a new form. Therefore, they were to complete four questionnaires, one for each strategy. If the subjects made any comments or had questions throughout the experiment these were also noted for future reference.

7.2.9 Procedure [3D]

Consistent with the preceding procedure [the 2D problems], the experimenter was in the room at all times monitoring the sessions. In the 3D trials, the subjects were given a copy of a drawing consisting of the fifteen three-dimensional forms, as in Finke (1990), from which triplets of parts would be selected. Three parts and an invention category were randomly selected for each trial in a series of twelve trials presented to

the different groups who explored three-dimensional creative mental synthesis. In addition, each subject was given a paper listing the strategy order of presentation for that particular group. Each group [A,B,C, or D] had a different strategy order with a view to minimising any ordering effects as discussed earlier. Figure 32 below illustrated the different strategy order for each of the groups [Group A,B,C,&D]. Each subject was only shown the strategy order list relevant to him or her. It should be noted that Strategy D was always presented to the subjects last, as it was such a radical departure from the other strategies.
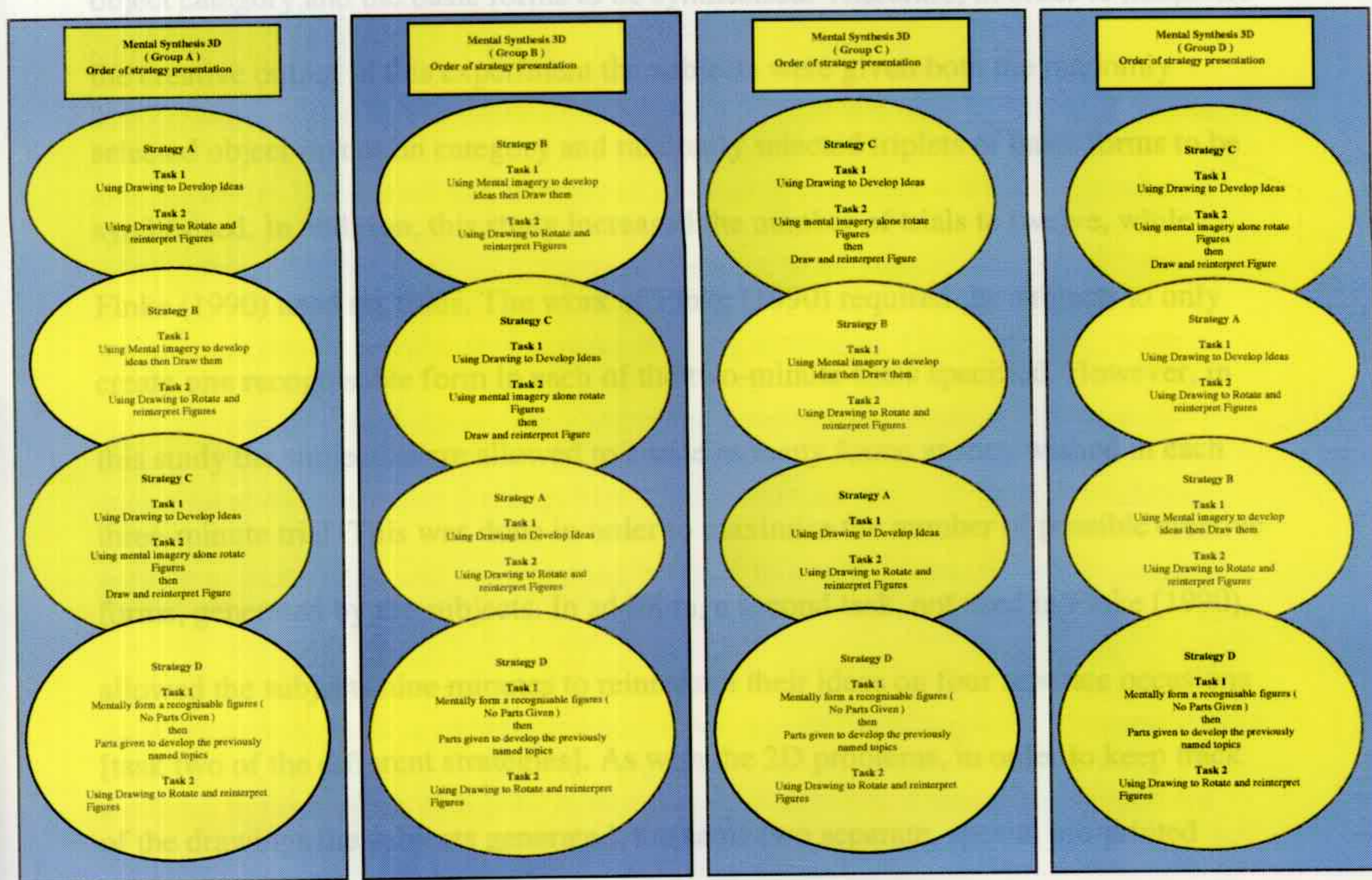
FIGURE 32: DRAWING STRATEGY ORDER FOR GROUPS A,B,C,&D [3D PROBLEMS]

For consistency purposes, pre-prepared instructions were read to the subjects. Owing to their length the instructions are not presented here. As a reference, detailed instructions for each group have been placed in Appendix H. As with the 2D instructions, it is recommended that these be reviewed in order to gain a clear

understanding of the procedures the subjects followed. Prior to the reading of the instructions, information sheets (required by the ethics committees) were read and signed by the subjects. These sheets outlined the ethical issues relating to time commitment, privacy/publications issues, and contact information should a complaint arise.

In his work concerning 3D creative mental synthesis Finke (1990) found a higher percentage of creative responses were generated when subjects were given both the object category and the basic forms to be synthesised. Therefore, in order to maximise the creative output in this experiment the subjects were given both the randomly selected object invention category and randomly selected triplets of basic forms to be synthesised. In addition, this study increased the number of trials to twelve, while Finke (1990) used six trials. The work of Finke (1990) required the subjects to only create **one** recognisable form in each of the two-minute trials specified. However, in this study the subjects were allowed to create as many forms as they wished in each three-minute trial. This was done in order to maximise the number of possible creative forms, generated by the subjects. In addition, a second task, not used in Finke (1990), allowed the subjects nine minutes to reinterpret their ideas on four separate occasions [task two of the different strategies]. As with the 2D problems, in order to keep track of the drawings the subjects generated, the same two separate, special pre-printed response sheets with a coding procedure were utilised in the 3D problems. As part of the instructions, the subjects were directed in how to code their responses on the sheets.

In addition, as in the 2D trials, at the end of each strategy [tasks one and two] in the 3D trials, the subjects filled in a questionnaire concerning the thinking strategy they used in combining the parts to create a new form. Therefore, they were to complete four questionnaires, one for each drawing condition, which included Tasks 1 and 2. If the subjects made any comments or had questions throughout the experiment these were also noted for future reference.

7.3 Data

7.3.1 Drawing Data [2D & 3D]

The procedures outlined in sections 7.2.8 and 7.2.9, presented in detail in Appendix G and Appendix H, resulted in a number of individual drawings with corresponding descriptions of different two-dimensional forms or three-dimensional inventions, which were developed utilising various drawing strategies. These drawings were considered to be quantitative data. During the development process, the subjects coded the drawings. After the drawings were generated they had judging stickers applied to them. This will be explained in detail in a subsequent section on judging.

As discussed in detail in experiment one, since it is difficult to predict a response from a subject in these types of mental synthesis experiments, it is reasonable to believe that an experimenter with knowledge of the hypothesis would also have difficulty in predicting, and therefore influencing the creative output of the subjects or judges in this type of research. Therefore, as in experiment one, naive experimenters were not used, as suggested by Intons-Peterson (1983). An additional supporting rationale for not having naive experimenters is that any questions or concerns raised by the

subjects can be appropriately dealt with, given that the researcher has an

understanding of the complete experiment.

7.3.2 Questionnaire Data [2D & 3D]

At the end of each drawing strategy [which included both tasks one & two], all

subjects [irrespective of which problem sets they were completing – 2D problems or

3D problems] filled in a questionnaire concerning the thinking strategy/strategies they

used in combining the parts to create a new form. The difference was that in Finke &

Slayton (1988) and Finke (1990) the subjects were to pick the most common **(one)**

strategy they used in combining the parts and did not further explain their strategies.

As the subjects were not given a strategy for solving the problems, the questionnaire

was included in order to provide information as to how the subjects may have actually

performed the task. In addition, they were asked to respond to some questions

regarding the difficulties they may have encountered in using the strategy they had

just used. The questionnaire below was presented to all subjects.

Please circle the strategy you have just completed

Strategy   A   B   C   D

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? etc...).

Circle one:

This strategy was easy to use   YES   NO

I typically use this technique to solve problems   YES   NO

I tended to "talk to myself" repeating the names of the parts as I was trying to develop the new form.
                                    YES   NO

Problems I encountered in using this strategy are as follow:

The list below is not "set in concrete". If you used just one of these circle the number. If you used more than one circle the ones you used, then explain on the back of this paper when you used the different techniques, why you changed etc...   Basically use the back of this paper to try and explain the thought process you used as best you can.

Techniques I used in combining the parts to create a new form were :

1) " I tried combining the parts by trial and error in my image until I happened to recognise a shape "

2) " I first thought of a possible shape then I tried to combine the parts in my image to see whether the particular shape could be made out of the parts"

3) " I did not form an image at all, but just thought about how the parts might be combined in a more abstract way"

4) " I used some other strategy " (Please explain on the back)

They were instructed to answer the questions and circle the strategy or strategies they used to develop their solutions. If they used more than one strategy they were told to circle all the strategies they used. On the back of the questionnaire, they were encouraged to further enhance the standard description of the strategies used. In addition, if they had changed strategies they were to describe when and why they changed. If they used some other strategy not listed then they were to explain the strategy they used. This provided questionnaire data [unstructured data] for analysis. In addition, if the subjects made any comments, had questions, or instilled thoughts within the experimenter in any way throughout the experiment, these were noted for future reference and analysis. These questions, comments, and thoughts were also considered to be unstructured data.

7.4 Judging Data

7.4.1 Judge Type & Numbers [2D]

There were three judges used in Finke & Slayton (1988). However, drawn from a pool of volunteers, this study used five student judges from each cohort of students (Industrial design, Visual communications design, Law), as illustrated in Table 42 below. These judges reviewed the responses generated by all three cohorts of student subjects. Consequently, each of these judges reviewed every single response from the 2D problems test subjects.

Judge groups			
3D Designers Industrial design students number of Judges	2D Designers Graphic design students number of Judges	non-designers Law Students number of Judges	**Total**

	3D Designers	2D Designers	non-designers	Total
Number of Student judges	5	5	5	15

TABLE 42: JUDGING GROUPS EXPERIMENT TWO [2D PROBLEMS]

As in experiment one, controlling the different cohorts of judges as well as different cohorts of subjects allowed analysis between and among the judge types and subject types. The supporting rationale for the increased judge numbers was that a larger number (greater than two or three) of a mixed group of judges [designers and non-designers] would allow for flexibility in analysis, yet still reflect a general student population [as in a general psychology class used in Finke & Slayton (1988)]. In addition, greater numbers would allow more reliable statistical analysis of the results.

7.4.2 Judge Type & Numbers [3D]

While there were only two judges used in Finke (1990), they were judges who reviewed the 2D responses in his earlier work [Finke & Slayton (1988)]. There were a number of responses generated in both the 2D and 3D problems. Consequently it would be inappropriate to demand a large time commitment from one set of judges. Therefore, it was necessary to have two sets of judges. To this end a second set of judges was used to review the 3D data sheets. Table 43 below reflects the distribution of judges by judge type and numbers. Essentially there were five student judges from each cohort of students (Industrial design, Visual communications design, Law),

resulting in a total of fifteen judges who were unfamiliar with this research [unlike

Finke (1990)].

	Judge groups			
	3D Designers Industrial design students number of Judges	2D Designers Graphic design students number of Judges	non-designers Law Students number of Judges	**Total**
Number of Student judges	5	5	5	15

TABLE 43: JUDGING GROUPS EXPERIMENT TWO [3D PROBLEMS]

7.4.3 Data Coding Conventions [2D & 3D]

In order to ensure that the judges were blind to the background of the subjects and the

strategy utilised by each subject, a coding system was devised for each response of

each subject. While the participants generated the responses, the responses were

coded, and later a rating system sticker was applied to each response. Once the codes

and stickers were applied, fifteen photocopies of each response sheet were made (one

for each judge). Using this coding system it was possible to generate for each judge

[2D or 3D], one complete set of 2D or 3D responses (photocopies) appropriately

encoded, so if required, a particular response from a particular judge could

conceivably be tracked down later. The legend below is a breakdown of the coding

system and an example for one particular judge from the industrial design group

viewing one 3D response of a particular law subject:

Judge
  1 Industrial Design (judge background)
  2 Vis Com (judge background)
  3 Law (judge background)
       1ˢᵗ judge from the background group
       2ⁿᵈ judge from the background group
       3ʳᵈ judge from the background group
       4ᵗʰ judge from the background group
       5ᵗʰ judge from the background group
          X industrial designer (subject background)
          Y Visual com designer (subject background)
          Z non-designer (subject background)
             2 Problem sets
             3 Problem sets
                Group
                A, B, C, D Group letter
                   Subject
                   1, 2, 3, 4, 5 Subject number
                      Strategy
                      A, B, C, D Strategy letter
                         Task
                         1, 2 Task number
                         (1= mental synthesis
                         2=reinterpretation)
                            Problem
                            X Problem number
                               Response
                               X Response number

J13Z3GBS1SDT2P2R1

Example of a code on one of the subjects' response sheets to identify the judge, the subject being judged and a particular response from that subject:

7.4.4 Distribution of Responses

The same technique of semi-random distribution of responses for judging either the 2D data sheets or the 3D data sheets, as explained and depicted earlier in experiment one, was used here in experiment two. It is important that no ordering effect among the judgements occurred.

7.4.5 Scoring Conventions [2D]

As mentioned earlier the judges were to independently rate how well the names of the forms corresponded to the drawings presented. Following the revised scoring conventions used in experiment one [not the linked instructions of Finke & Slayton (1988)], the judges were to use the two 5-point scales (illustrated below). These

judgement scales were on each 2D response. The judges were blind to who generated

the response, in addition to being blind to the different drawing strategies used by the

subjects.

1	2	3	4	5.
Very Poor correspondence	Low correspondence	Modest correspondence	Good correspondence	Very Good correspondence

1	2	3	4	5.
Not Original	Low Originality	Modest Originality	Original	Very Original

No pattern ☐   Wrong Parts ☐

The judges were instructed to give a correspondence rating to the drawing by circling

a rating number. As in experiment one, the correspondence rating was necessary in

that it suggested a clear understanding or a lack of clarity of the imagined form, and

thereby, indicating whether synthesis had taken place. The judges were also to rate the

originality (creativity) of the responses, independent of the correspondence rating.

The judges were to base their ratings on the concept represented by the drawing and

not how well the object was drawn. In addition, as in Finke & Slayton (1988), if the

subjects used wrong or distorted parts, or if only some of the correct parts were used,

then the pattern was to be classified by the judges as *wrong parts*. A *no pattern*

classification refers to a trial in which the subject reported no pattern. Even if there

was no pattern this was considered an attempt and therefore counted, unlike Finke &

Slayton (1988) who did not count a non-response.

7.4.6 Scoring Conventions [3D]

As in the work of Finke (1990), and experiment one, the judges were to rate the

practicality and originality (creativity) of each invention. They were to use two 5-

point scales (illustrated below). The judges were blind to who generated the response,

in addition to being blind to the different drawing strategies used by the subjects.

1	2	3	4	5.	No Response
Not Practical	Low Practicality	Modest Practicality	Practical	Very Practical	☐

1	2	3	4	5.
Not Original	Low Originality	Modest Originality	Original	Very Original

These different ratings were to be made independent of each other, as in experiment one. Consistent with the views of Finke (1990), an object could be practical but not original, original but not practical, or both original and practical [although he contradicted these views in his writings by linking the criterion]. The judges were to circle a rating for the practicality for each response and an originality rating for each response. The judges were to base their ratings on the concept represented by the drawing and not how well the object was drawn. In addition, they were to rate the overall design of the object, not whether it necessarily contained all of the working parts it actually needed (e.g. If fasteners were missing it should not matter). In addition, if the subjects could not develop an invention in the time allowed (i.e. a blank response) or they used the wrong parts, the judges were to mark the box **No Response**.

7.4.7 Judgement Days [2D & 3D judgements]

The fifteen volunteer 2D judges were gathered together for a full day of judging in a comfortable quiet room. On another day the fifteen volunteer 3D judges were gathered together for a full day of judging in a comfortable quiet room. A large catered lunch, coupled with being supplied with morning/afternoon tea breaks served as remuneration for the judges. In addition, they were given two free movie tickets to relax after a day of judging. They were told that the morning session would be devoted to judging half of the responses, and after lunch they would be judging the

remainder of the responses. The procedure of what the subjects had been expected to do was explained to the judges. Then the judges were instructed to score the responses from each subject using the scoring conventions previously mentioned.

7.4.8 Judge instructions [2D]

After all the judges who were to review the 2D responses assembled in the room where the judging was going to take place and prior to the reading of the instructions, information sheets (required by the ethics committees) were read and signed by the judges. Just as the subjects were to be apprised of the ethical issues involved in the research, the judges had to be informed as well. These sheets outlined the ethical issues relating to time commitment, privacy/publications issues, and contact information should a complaint arise. After they signed the ethics forms, the instructions were read to them [instructions are located in Appendix I].

7.4.9 Judge instructions [3D]

The judges who reviewed the 3D responses were treated in a similar fashion to that of the 2D judges, in that all the judges received the same remuneration as the 2D judges. In addition, prior to the reading of the instructions, information sheets (required by the ethics committees) were read and signed by the judges. After they assembled in the room where the judging was going to take place the instructions were read to them [instructions are located in Appendix J].

The judges were to score the responses sequentially as they were presented to them. They were not allowed to return and review a previous response. They were not

allowed to compare or rank the responses. Each response was to stand on its own

merits at the time of review. No definition of originality or creativity was given. Each

judge was to use his or her own criterion. A collective view would stand. If the

majority of judges deemed a response original/creative it would be considered so.

This applied to the practicality criterion as well.

Chapter 8 Experiment 2 Drawing Strategies Results

8.1 Introduction

After the data from experiment two was collected and judged, the result was that

fifteen different judges had reviewed each response from each of the subjects who

completed the 2D problems. Additionally, fifteen different judges had reviewed each

response from each of the subjects who completed the 3D problems in experiment

two. That is to say any particular response was judged fifteen times. As in experiment

one, the simplest way to review the numerical ratings of the responses, was to

organise the numerical ratings in a spreadsheet, thus allowing an investigation of the

patterns of judgements both between and among the judge types, and subject types as

well, as comparing and contrasting the different strategies used. This chapter is

dedicated to discussing the experimental results.

8.2 Rules of Classification [2D & 3D]

The purpose of experiment one was to model the experiment on the methods and

procedures of Finke & Slayton (1988) [2D] and Finke (1990) [3D], the obvious but

necessary first step with respect to investigating creative mental synthesis of designers

and non-designers. However, inconsistencies were found in their methods. Notably,

these inconsistencies were related to scoring conventions and rules of classification

[as discussed in chapters 3 and 4]. Ultimately, the scoring conventions in experiment

one, for both the 2D and 3D responses, required the responses to be judged along two

similar numerical rating scales. The scales ranged between one and five, with one

being the lowest and five being the highest rating. If a response was notably creative

(original), having been scored 4 or higher by a majority of judges, it was deemed

creative. This was the case for both the 2D and 3D responses. With respect to the 2D responses another rule of classification was that a response having a rating of 4 or 5 by a majority of judges, was deemed to have high correspondence. With respect to the 3D responses, the rule of classification was that an invention was practical, having received a rating of 4 or 5 by a majority of judges. These same scoring conventions applied in experiment two.

8.3 Experiment Two Spreadsheets

8.3.1 Spreadsheet layout

After the responses from experiment two were judged, a new spreadsheet [different from experiment one] was developed [as illustrated in Table 44] in order to prepare the coded data for analysis, accommodating both the 2D judgments and the 3D judgments and allowing for the different strategies used. The column headings were represented by breaking down the response code number into a subject type code [ID = 1- VC = 2 - ND = 3], a subject number [1-20], a problem type [2D = 1 or 3D = 2], a strategy type response number [Strategy A Task1=1 Strategy A Task2=2 Strategy B Task1=3 Strategy B Task2=4 etc…], and judge code numbers (e.g. J121). Each judge had a column of cells, which represented the correspondence or practicality ratings for each response (a number 1–5), and a column of cells, which represented the creativity ratings (a number 1–5). Each row of judgments corresponded to that particular response from a number of judges. This allowed for flexibility in analysis of the data. Each response could be investigated with respect to issues either between judges, among judges, or subject types and strategy types. Using this particular spreadsheet layout, any given subject could be traced back without using the long subject code. Consequently it was withdrawn from the spreadsheet.

ID=1 VC=2 ND=3 Subject type (1,2,3)	Subject no. (1-20)	2D=1 3D=2 Problem Type (1-2)	SAT1=1 SAT2=2 SBT1=3 SBT2=4 etc.. Problem condition no. (1-8)	Corres/Prac				Creativity			
				ID Judge J??/J??	ID judge J??/J??	ID Judge J??/J??	ETC .... J??/J??	ID Judge J??/J??	ID judge J??/J??	ID Judge J??/J??	ETC .... J??/J??
1	1	1	1	4	3	5	4	1	5	5	3
1	1	1	1	2	3	2	5	3	5	5	5
1	1	1	1	5	4	5	2	1	5	5	4
1	1	1	2	3	5	5	4	5	4	2	3

TABLE 44: SPREADSHEET LAYOUT FOR EXPERIMENT TWO

8.4 Frequency Distribution Tables [2D]

Representing the data in a spreadsheet allows the simple generation of frequency tables [as before in experiment one], for the purpose of review and analysis. As before, only the meaningful frequency tables [as listed below] were represented, therefore, the data could be meaningfully and empirically explored with respect to the variants of judge type, subject type, and strategy type. Since all the data is represented in one large spreadsheet a detailed analysis and presentation of the results can occur.

> Tables using ALL judges
> Tables using only Industrial Design Judges
> Tables using only Visual Communications Judges
> Tables using only Non-Design Judges
> Tables of each Individual Judge

As indicated earlier in chapter 4, averaging techniques and the linking of measures offers an inaccurate view of the judges' decisions. Therefore, having the fifteen 2D problem judges review the two-dimensional responses, using two 5-point scales, along with instructions to treat correspondence and originality as two separate issues while adhering to majority rules conventions, allows for a more accurate unlinked analysis of the data. While the numbers of responses determined as having a high correspondence or being creative may differ from the previous results [owing to the

decreased number of trials (three per strategy), but increased number of strategies], the central issue of the pattern of judgments remains.

Again a very consistent pattern emerged. The pattern of results here was very similar to those in chapter 4. Table 45 below [using majority rules and all fifteen judges combined into one cohort] reflects that the judges generally indicate [noting the yellow highlighted totals column on the right side of the table] designers perform better than non-designers in measures of creativity when given two-dimensional creative mental synthesis tasks. Also reflected in Table 45 below [when looking across the rows] the non-designers, with respect to creativity, maintain consistently low numbers irrespective of the strategy used. However, while contrary to expectations of the 2D designers performing better, the end results of the designers, with respect to creativity [ID =63 and VC=61], are very similar, yet the pattern of results is different. The 3D designers [ID subjects] do not appear to be helped when allowed to use drawing to reinterpret their previous drawings [Task 2 Strategies A,B, &D]. The role of Task 2 was to investigate the issue of creative emergence [reinterpretation] from the drawings or reinterpretation mentally [Strategy C Task 2], thought to play a central role in design. However, the 2D designers [VC subjects] appear to be more consistent irrespective of strategy used. It should be noted that for the 2D designers and the 3D designers, all Task 2 results lag behind the Task 1 results, suggesting that drawing to reinterpret or mentally reinterpreting, with the expectation of emergent ideas, is not as strong as the design literature suggests. While Anderson & Helstrup (1993) found no difference between the conditions of drawing to develop ideas [as in strategy A Task 1] or developing ideas mentally among their subjects [non-designers], the results below show Strategy B Task 1 [developing ideas

mentally] to be the strongest strategy in terms of creativity, at least for the designers.

Additionally, this result appears to contradict the design literature, in that the results

of Strategy B Task 1 [mentally developing the forms] are greater that Strategy A Task

1 [developing ideas using drawing]. Additionally, when reviewing the column results

for Strategy D Task 1, illustrated in Table 45 below, the results do not tend to support

the suggestions of Mathias (1993) with respect to the separation of ideas from the

embodiment of those ideas [at least for the 2D problems].

When reviewing the column designated Total Creative, the total creative output 158

of the 3361 responses resulted in 4.7 percent of the responses determined as being

creative [using all the judges as one cohort]. However, while this percentage appears

to be low, comparatively speaking this percentage of creative forms is generally

consistent with that of Finke & Slayton (1988) [typically 6 percent].

Drawing Strategies & Creative Mental Synthesis (Creativity 2D) [all judges]									
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Creative
Industrial Designers	11	2	17	7	9	2	10	5	63
Vis - Com (Students)	7	5	11	5	10	9	8	6	61
Non-designers (Law students)	6	3	5	3	5	2	3	7	34
Total Creative	24	10	33	15	24	13	21	18	158

TABLE 45: NUMBER OF CREATIVE RESPONSES ATTRIBUTED TO SUBJECT TYPE, STRATEGY TYPE AND TASK

While the creativity results are not linked to the correspondence results, similarities

exist. For example, Table 46 below [again using majority rules and all fifteen judges

combined into one cohort] reflects that the judges generally indicate [noting the

yellow highlighted totals column on the right side of the table] designers perform

better than non-designers in measures of correspondence when given two-dimensional creative mental synthesis tasks. Also reflected in Table 46 below [when looking across the rows] the non-designers, with respect to correspondence, maintain consistently low numbers irrespective of the strategy used, with the unusual exceptions of Strategy B Task 1 [mentally developing the forms] and Strategy C Task 1 [drawing to develop the forms]. When reviewing these columns of results, the non-designers were the highest, followed by the 3D designers (ID subjects), with the 2D designers (VC subjects) last. However, when comparing the overall results with respect to correspondence [ID =92, VC=72, and ND=63], the story is different. The 3D designers [ID subjects] generated more two-dimensional forms having high correspondence than either the 2D designers or the non-designers. This pattern is similarly reflected in the results of Strategy A Task 1 [drawing to develop the forms]. Additionally, as in the results of the creative responses, a result that contradicts the design literature is reflected in the results of Strategy B Task 1 [mentally developing the forms]. The total result of this column yielded the highest number of correspondence responses, contradicting the findings of Anderson & Helstrup (1993). While Anderson & Helstrup (1993) found no difference between the conditions of drawing to develop ideas [as in strategy A Task 1] or developing ideas mentally [as in strategy B Task 1], among their subjects [non-designers], the results below show Strategy B Task 1 [developing ideas mentally] to be the strongest strategy in terms of correspondence, for all subjects [including the non-designers]. Additionally, this result appears to contradict the design literature, in that the results of Strategy B Task 1 [mentally developing the forms] are greater that Strategy A Task 1 [developing ideas using drawing].

The design literature suggests that drawing for the purposes of reinterpreting the drawings in anticipation of emergent forms [Task 2 Strategies AB&D], aids creative mental synthesis. The results here do not reflect this. The subjects do not appear to 'see' new forms either via drawing [Task 2 Strategies A, B & D] or mentally reinterpreting [Task 2 Strategy C]. The role of Task 2 was to investigate the issue of emergence [reinterpretation] from the drawings or reinterpretation mentally [Strategy C Task 2], thought to play a central role in design. It should be noted that for the 2D designers and the 3D designers, generally the Task 2 results lag behind the Task 1 results, suggesting that drawing to reinterpret or mentally reinterpreting, with the expectation of emergent ideas, is not as strong as the design literature suggests.

In terms of the total correspondence output, 227 of the 3361 responses resulted in 6.75 percent of the responses determined as having good correspondence [using all the judges as one cohort].

Drawing Strategies & Creative Mental Synthesis (Correspondence 2D) [all judges]								
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Correspondence
Industrial Designers	23	11	20	10	10	4	7	7	92
Vis - Com (Students)	14	8	18	6	8	5	5	8	72
Non-designers (Law students)	10	4	24	2	11	1	4	7	63
Total Creative	47	23	62	18	29	10	16	22	227

TABLE 46: NUMBER OF CORRESPONDENCE RESPONSES ATTRIBUTED TO SUBJECT TYPE, STRATEGY TYPE AND TASK

While comparing the different judging groups [ID Judges, VC Judges, and ND Judges], in reviewing the row patterns reflected in the creativity and correspondence tables [found in Appendix K], the pattern remains clear and consistent. The designers generate more creative responses and responses having high correspondence when

compared to the non-design subjects, who generate the least frequent responses. A result reflected in the tables [found in Appendix K], revealed a judging pattern consistent with results in experiment one that the visual communications judges appear to be more conservative in their judgements with respect to creativity in contrast to the other judges. Conversely, the industrial design judges appeared to be liberal in their judgements. Another consistent result rests in the judging pattern irrespective of judge type. Generally the Task 2 results lag behind the Task 1 results, suggesting that drawing to reinterpret or mentally reinterpreting, with the expectation of emergent ideas, is not as strong as the design literature suggests.

8.5 Frequency Distribution Tables [3D]

Essentially, when tabulating the number of responses [illustrated in Table 47 below] deemed creative and not creative by the judges, the following was found: the row totals, reflected in Table 47 below, represent the number of creative responses produced by each of the subject groups. Given that the 3D task was used, it would be expected, on the basis of experiment 1, that the industrial designers would produce more creative inventions than the visual communication group, with the non-designers performing poorly, and this is clearly demonstrated in the row totals. However, the results are not strictly comparable because the totals are based on a number of different strategies and tasks. The most direct comparison between the two experiments in terms of the task performed involves Strategy B, Task 1 where the results clearly demonstrate the expected pattern.

In many ways the patterns of results within the frequency tables of the 3D problems are remarkably similar to the patterns of results in both chapter 4 and the preceding

section [8.3]. Table 47 below [using majority rules and all fifteen judges combined into one cohort] reflects that the judges generally indicate [noting the yellow highlighted totals column on the right side of the table] designers perform better than non-designers in measures of creativity when given three-dimensional creative mental synthesis tasks. Also reflected in Table 47 below [when looking across the rows] the non-designers, with respect to creativity, maintain consistently low numbers irrespective of the strategy used, with the exception of Strategy D Task 1. The issue of Strategy D Task 1 will be discussed subsequently. Consistent with initial expectations, the 3D designers performed better, with respect to creativity, than the 2D designers who in turn did better than the non-designers [ID =180, VC=121, and ND=40]. In addition, neither the 3D designers [ID subjects] nor the 2D designers [VC subjects] appear to be helped when allowed to use drawing to reinterpret their previous drawings [Task 2 Strategies A, B, &D]. The role of Task 2 was to investigate the issue of creative emergence [reinterpretation] from the drawings or reinterpretation mentally [Strategy C Task 2], thought to play a central role in design. In fact the levels of results reflected in Table 47 below remain consistent. It should be noted that for the 3D designers and the 2D designers, most of the Task 2 results lag behind the Task 1 results, suggesting that drawing to reinterpret or mentally reinterpreting, with the expectation of emergent ideas, is not as strong as the design literature suggests. While Anderson & Helstrup (1993) found no difference between the conditions of drawing to develop ideas [as in strategy A Task 1] or developing ideas mentally, among their subjects [non-designers], the results below show Strategy B Task 1 [developing ideas mentally] to yield higher numbers in terms of creativity, at least for the designers. Additionally, this result appears to contradict the design literature, in

that the results of Strategy B Task 1 [mentally developing the forms] are greater than those of Strategy A Task 1 [developing ideas using drawing].

While the use of Strategy B Task 1 appears to aid the designers in the creative mental synthesis process more than the use of drawing to develop ideas, or reinterpreting them for that matter, it was far from the best strategy. When reviewing the column results for Strategy D Task 1, illustrated in Table 47 below, the results lend support to the suggestions of Mathias (1993) with respect to the separation of ideas from the embodiment of those ideas, after which drawing is used to develop the ideas [at least for the 3D problems]. In fact, the results of the non-designers show that when they used Strategy D Task 1 [mimicking design experts] they greatly increased their creative output.

When reviewing the column designated Total Creative [illustrated on the right hand side of Table 47 below], the total creative output, 341 of the 2331 total responses, resulted in 14.6 percent of the responses determined as being creative [using all the judges as one cohort]. However, while this percentage may appear to be low, comparatively speaking this percentage of creative inventions is generally consistent with that of Finke (1990) [typically 13.6 percent].

	Drawing Strategies & Creative Mental Synthesis (Creativity 3D) [all judges]								
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Creative
Industrial Designers	15	12	36	13	13	11	70	10	180
Vis - Com (Students)	9	8	18	5	10	5	59	7	121
Non-designers (Law students)	2	0	5	3	2	0	26	2	40
Total Creative	26	20	59	21	25	16	155	19	341

TABLE 47: NUMBER OF CREATIVE RESPONSES ATTRIBUTED TO SUBJECT TYPE, STRATEGY TYPE AND TASK

While the creativity results are not linked to the practicality results, similarities between the two exist. For example, Table 48 below [again using majority rules and all fifteen judges combined into one cohort] reflects that the judges generally indicate [noting the yellow highlighted totals column on the right side of the table] designers perform better than non-designers, in measures of practicality when given three-dimensional creative mental synthesis tasks. However, the difference between the 2D designers and the non-designers is marginal. Also reflected in Table 48 below [when looking across the rows] both the 2D designers and the non-designers, with respect to practicality, maintain relatively low results. This is also reflected in the overall results, with respect to practicality [ID =130, VC=66, and ND=65]. The 3D designers [ID subjects] generated more practical three-dimensional forms than either the 2D designers or the non-designers. This pattern of results is similarly reflected in the results of Strategy B Task 1 [mentally developing the forms]. This result [relating to practicality], as with the creative responses, contradicts the design literature, which appears to maintain the view that drawing to develop ideas should lend greater assistance to designers than performing creative mental synthesis tasks unaided by drawing. This result also contradicts the findings of Anderson & Helstrup (1993). While Anderson & Helstrup (1993) found no difference between the conditions of drawing to develop ideas [as in Strategy A Task 1] or developing ideas mentally [Strategy B Task 1], among their subjects [non-designers], the results [illustrated in Table 48 below] show Strategy B Task 1 [developing ideas mentally] to be the strongest strategy in terms of practicality [at least for the 3D designers].

Additionally, the design literature consistently suggests that drawing for the purposes of reinterpreting the drawings in anticipation of emergent forms [Task 2 Strategies A,

B&D], aids creative mental synthesis. The results here do not reflect this. The subjects do not appear to 'see' new practical forms either via drawing [Task 2 Strategies A, B&D] or mentally reinterpreting [Task 2 Strategy C].

When reviewing the column results for Strategy D Task 1 [illustrated in Table 48 below], with respect to practicality, the results do not lend support to the suggestions of Mathias (1993) with respect to the separation of ideas from the embodiment of those ideas, after which drawing is used to develop the ideas [at least for the 3D problems]. In fact, the results show this strategy to be the least effective for any of the subjects.

In terms of the total practical output, 261 of the 2331 responses resulted in 11.2 percent of the responses determined as being practical [using all the judges as one cohort].

| | Drawing Strategies & Creative Mental Synthesis (Practicality 3D) [all judges] | | | | | | | | |
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Practicality
Industrial Designers	10	12	40	17	14	12	6	19	130
Vis - Com (Students)	11	9	11	6	5	12	2	10	66
Non-designers (Law students)	4	5	12	5	18	13	1	7	65
Total Creative	25	26	63	28	37	37	9	36	261

TABLE 48: NUMBER OF CREATIVE RESPONSES ATTRIBUTED TO SUBJECT TYPE, STRATEGY TYPE AND TASK

While comparing the different judging groups [ID Judges, VC Judges, and ND Judges], in reviewing the row patterns reflected in the creativity and practicality tables [found in Appendix L], the pattern remains clear and consistent. The designers generate more creative responses when compared to the non-design subjects, who

generate the least frequent responses. However, the 3D design judges and the non-design judges found the 2D designers generate the least practical responses. A result reflected in the tables [found in Appendix L], revealed a judging pattern consistent with results in experiment one, that the visual communications judges appear to be more conservative in their judgements in contrast to the other judges [at least with respect to practicality]. Another consistent result rests in the judging pattern irrespective of judge type. Generally the Task 2 results lag behind the Task 1 results with respect to creativity [at least for the designers], suggesting that drawing to reinterpret or mentally reinterpreting, with the expectation of creative emergent ideas, is not as strong as the design literature suggests.

Chapter 9 Experiment 2 – Questionnaire Results (2D&3D)

9.1 Introduction

The findings in Chapter 8 revealed a number of issues regarding how and when drawing is best used as an aid to creative mental synthesis, which are contrary to the views revealed in the design literature. These results were important, however, as illustrated in Chapter 5, it was also possible, via the questionnaire, to gain insight into the thought processes of the subjects as they were trying to complete the creative mental synthesis tasks, thus allowing comparisons and contrasts to be made between the different drawing strategies. While the aim of this chapter is to reveal some of these comparisons, it is appropriate to compare and contrast only the strongest 'drawing' strategies revealed in the previous chapter (Chapter 8). The supporting rationale for doing so rests in the argument that while the purpose of the questionnaire was to explore thinking strategies, it makes sense to focus only on the effective drawing strategies. Consequently, this chapter will only discuss **Strategy B** in the case of the 2D and 3D problems, in addition to **Strategy D** in the case of the 3D problems in relation to the questionnaire. Each of these will be discussed, in turn, in separate subsections of this chapter. In addition, as in Chapter 5 the discussions of a broader range of issues relating the to the questionnaire results was intentionally omitted due to the size, complexity, and richness of the data. The addition of such discussion would a have substantially and inappropriately expanded the thesis.

9.2 Data

9.2.1 Questionnaire Data [2D & 3D]

The procedure outlined in section 7.2, relating to creative mental synthesis, resulted in

a number of individual drawings with corresponding descriptions or inventions being

created by each subject. These drawings were considered to be quantitative data, in

that numerical ratings were applied to the drawings, as explained earlier. Previously,

as was illustrated in Chapter 5, questionnaire data [unstructured data] was also

obtained from the subjects. As in experiment one, and as discussed earlier at the end

of the series of creative mental synthesis trials of each drawing strategy in experiment

two, the subjects were also instructed to fill in a questionnaire in order to investigate

their thought processes. However, unlike the questionnaire in experiment one, the

questionnaire in experiment two asked additional questions. They were to answer

questions regarding ease of use of the drawing strategies, typical use of the drawing

strategies, and talking to one's self [enquiring about sub vocalisation]. These were

added as a way of enhancing our understanding about the different drawing strategies,

as it is possible for a drawing strategy to be effective but difficult to use. In addition, it

is possible some subjects may typically use what may be considered and effective

drawing strategy. Consequently the subjects were asked these questions on each

questionnaire they completed for each drawing strategy. In order to investigate issues

relating to talking to ones self [sub vocalisation] the subjects indicated if they did so.

As it can be argued that when confronted with a difficult and complex task instances

of sub vocalisation may increase. Finally, the subjects were to describe their thinking

techniques. The responses to the questionnaire provided unstructured data for

analysis. It must be made clear that these questions relating to thinking techniques

[identical to those used in experiment one] are distinct from the newly added

questions [as discussed above] relating to drawing strategies. As was the case in

Chapter 5, this chapter will compare and contrast the use of multiple thinking

strategies and the exclusive use of one thinking strategy.

After the questionnaires were completed they were transcribed into electronic form,

via a word processor. Then using a computer program called **NUDIST** [*Non-*

numerical Unstructured Data Indexing Searching and Theorizing] the text could be

coded and analysed. The sample data below, from an industrial design subject, depicts

how the data was entered into the NUDIST program.

X2GAS1
Strategy Type: A
Easy to use: yes
Typically use this strategy: yes
Tended to talk to myself: yes
Helps develop the idea clearly in my head
Problems I encountered:
Later visualization and diversity using the shapes. I tended not to develop
many ideas after I had locked onto one idea.

Strategy number/s: 2

Comments: An image or a possible idea of a form would quickly come to me and I then just set about manipulating the parts to create the almost predetermined form.
This is I suppose a fairly single minded approach to the design problem.

Strategy Type: B
Easy to use: yes
Typically use this strategy: yes
Tended to talk to myself: no
Problems I encountered: sometimes hard to think up diverse ideas.

Strategy number/s: 1, 2

Comments: I had used both of the methods to complete the strategy. Sometimes I would just construct the shapes in my head with a recognizable form I created. However,
sometimes a form jumped into my head straight away and I manipulated the parts so that they could construct this shape.

Strategy Type: C
Easy to use: no
Typically use this strategy: no
Tended to talk to myself: yes
Problems I encountered: My first forms were quite abstract so I struggled to do much in task two.

Strategy number/s: 1,3

Comments: In some of the problems the shapes lent themselves to a developed sense of construction. The shapes could be drawn and moved until an image was created.
In other problems the forms were very individual and so I took a more abstract approach.

Strategy Type: D
Easy to use: yes
Typically use this strategy: no
Tended to talk to myself: yes
Problems I encountered: Trying to create signs using not appropriate shapes.

Strategy number/s: 1,3

Comments: Abstract sign usage and logos just popped into my head. When constructing the signs/logos I had to work on the form on paper and also in my head.

9.2.2 Questionnaire Data [2D & 3D Thinking strategies] Drawing Strategy B

Within **NUDIST** an attribute table for all subjects was generated which allowed the

questionnaire data derived from all the subjects to be grouped, tabulated, and

quantified. As stated earlier the *thinking strategies* of the more effective *drawing*

strategies would be investigated. Consequently, the following discussion will focus

on Drawing strategy B. Strictly speaking Strategy B requires the subjects to think first

then draw their ideas after they have developed them, and while drawing is involved

the subjects do not use drawing in the development of ideas, nevertheless it is called a

drawing strategy. This 'drawing' strategy is identical to that utilised in experiment

one, and therefore the treatment of the questionnaire data in this chapter was similar to

that of Chapter 5. In analysing the questionnaire data of Strategy B in Experiment

two [for both 2D problems and 3D problems], the first step was to generate frequency

tables of the thinking technique types with the number of subjects and percentage of

subjects who used a particular type or combination of types of thinking techniques as

they tried to resolve the creative mental synthesis problems using Strategy B

[mentally developing the forms]. Once this was done, as was indicated in Chapter 5, a

simple and straightforward way of comparing and contrasting subjects who utilised

multiple thinking strategies, in resolving the creative mental synthesis problems, with

those subjects who utilised one particular thinking strategy exclusively, as a function

of the creative responses versus non-creative responses, as a function of the high

correspondence responses versus non-correspondence responses, and as a function of

the practical responses versus non-practical responses as they utilised drawing

Strategy B, was to generate two-dimensional contingency tables. The results from the

application of a Chi-squared test on the frequencies consistently resulted in the

following:

� The relationship between frequencies of creativity and preference for

using a single or multiple thinking strategies, indicated there was no

statistically significant difference between using either a single thinking strategy exclusively or using multiple thinking strategies when resolving the 2D problems. The obtained value of 2.45 was derived after using the frequencies and applying them in a Chi-squared test. The value of a one-tailed X^2 at the 0.05 level with one df=2.71. Since the obtained value [2.45] was less than 2.71 the results were determined not to be statistically significant.

➡ The relationship between frequencies of creativity and preference for using a single or multiple thinking strategies, indicated there was no statistically significant difference between using either a single thinking strategy exclusively or using multiple thinking strategies when resolving 3D problems. The obtained value of 0.02 was derived after using the frequencies and applying them in a Chi-squared test. The value of a one-tailed X^2 at the 0.05 level with one df=2.71. Since the obtained value [0.02] was less than 2.71 the results were determined not to be statistically significant.

➡ The relationship between frequencies of high correspondence and preference for using a single or multiple thinking strategies, indicated there was no statistically significant difference between using either a single thinking strategy exclusively or using multiple thinking strategies when resolving 2D problems. The obtained value of 0.01 was derived after using the frequencies and applying them in a Chi-squared test. The value

of a one-tailed X^2 at the 0.05 level with one df=2.71. Since the obtained

value [0.01] was less than 2.71 the results were determined not to be

statistically significant.

⬤ The relationship between frequencies of practical responses and

preference for using a single or multiple thinking strategies, indicated there

was no statistically significant difference between using either a single

thinking strategy exclusively or using multiple thinking strategies when

resolving 3D problems. The obtained value of 0.94 was derived after using

the frequencies and applying them in a Chi-squared test. The value of a

one-tailed X^2 at the 0.05 level with one df=2.71. Since the obtained value

[0.94] was less than 2.71 the results were determined not to be statistically

significant.

The questionnaires in this study, in addition to enquiring about thinking strategies,

asked questions relating to ease of use, typical use, and talking to one's self [enquiring

about sub vocalisation]. As there were a variety of drawing strategies investigated in

this study, these questions were introduced in order to gauge the level of difficulty of

the various drawing strategies. When the subjects were to use drawing Strategy B

[mentally developing ideas] in order to resolve the 2D creative mental synthesis

problems, it was found that 53.33 percent found it easy to use, and 31.67 percent

typically used this strategy. In addition it was revealed that 31.67 percent of the

subjects talked to themselves [sub vocalised] as they were developing their ideas.

Consistent with the questionnaires given to the subjects involved with the 2D creative mental synthesis problems, the questionnaires given to the subjects involved in the 3D problems, in addition to enquiring about thinking strategies, asked questions relating to ease of use, typical use, and talking to ones self [enquiring about sub vocalisation]. When the subjects were to use drawing Strategy B [mentally developing ideas] in order to resolve the 3D creative mental synthesis problems, it was found that 56.67 percent found it easy to use, and 33.33 percent typically used this strategy. In addition it was revealed that 65 percent of the subjects talked to themselves [sub vocalised] as they were developing their ideas.

9.2.3 Treatment of the questionnaire data and results [3D] Drawing Strategy D

As was discussed above and in Chapter 5, a frequency table of all subjects listing thinking technique type with the number and percent of subjects who used a particular type or combination of types of thinking techniques was generated, however, illustrated in Table 49 below are the frequencies relating to using drawing strategy D [separating ideas from the embodiment of ideas]. In his research Finke (1990) found that a majority of his subjects completing 3D creative mental synthesis task, had mostly used a trial and error thinking technique to resolve the problems. This did not occur here.

Document	one	two	three	four	one,two	one,two,three	one,two,three,four	one,three	two,three	two,four	three,four	zero
Percent	26.67	21.67	6.67	13.3	11.67	11.67	0	1.67	1.67	1.67	1.67	1.67
Totals	16	13	4	8	7	7	0	1	1	1	1	1

TABLE 49: FREQUENCY TABLE CONTRASTING THINKING TECHNIQUES AND SUBJECT FREQUENCIES WHEN THE WERE RESOLVING THE 3D CREATIVE MENTAL SYNTHESIS PROBLEMS USING THE DRAWING STRATEGY – D (SEPARATING IDEAS FROM THE EMBODIMENT OF IDEAS)

When reviewing the columns in the Table 49 above, which refer to the thinking techniques used, only 26.7 percent of the subjects exclusively used technique one [trial and error]. In addition, Table 49 above reflects the fact that over two thirds of the subjects [68.37 percent] used one thinking technique exclusively, while the remainder used multiple thinking techniques when trying to resolve the creative mental synthesis problems using Strategy D [separating ideas from the embodiment of ideas].

Again, consistent with what was discussed in previous sections, the questionnaire given to the subjects involved in the 3D problems, in addition to enquiring about thinking strategies, asked questions relating to ease of use, typical use, and talking to one's self [enquiring about sub vocalisation]. When the subjects were to use drawing Strategy D [separating ideas from the embodiment of ideas] in order to resolve the 3D creative mental synthesis problems, it was found that 43.33 percent found it easy to use, and 33.33 percent typically used this strategy. In addition it was revealed that 36.67 percent of the subjects talked to themselves [sub vocalised] as they were developing their ideas.

9.2.4 Linking Thinking techniques and Practicality [3D] Drawing Strategy D

As in the earlier frequency tables, which compared and contrasted the thinking techniques effectively used by the subjects, with effectiveness being measured by the frequency of practical inventions from a particular subject while using drawing Strategy B [mentally developing ideas], this section will compare and contrast thinking strategies and practical responses while the subjects used drawing **Strategy**

D [separating ideas from the embodiment of ideas]. For example as illustrated in

Table 50 below, when reading across the row *No. of subjects* for example, is the fact

that twelve subjects [20 percent of the subjects] were able to generate two practical

inventions from each of their respective pool of inventions. However, it should be

noted that half of the subjects [50 percent] were unable to develop any practical

inventions. This adds further support to the view that 3D problems are more difficult

to resolve than 2D problems.

Strategy D Practicality Table 3D Problems								
Number of Practical responses	0	1	2	3	4	5	6	
% of Subjects	50%	28.33%	20%	0%	1.67%	0%	0%	100%
No. Of Subjects	30	17	12	0	1	0	0	60 Subjects

TABLE 50: PERCENTAGE OF SUBJECTS WHO GENERATED A GIVEN NUMBER OF PRACTICALITY
RESPONSES [3D PROBLEMS]

Consistent with previous discussions, a simple and straightforward way of comparing

and contrasting subjects who utilised multiple thinking strategies, in resolving the

creative mental synthesis problems, with those subjects who utilised one particular

thinking strategy exclusively, as a function of the practical responses versus non-

practical responses as they utilised drawing **Strategy D**, was to generate a two-

dimensional contingency table as illustrated in Table 51 below.

	Single Thinking strategy	Multiple Thinking strategies	Totals
Practical	35	10	45
Non-practical	430	224	654
Totals	465	234	699

TABLE 51: TWO WAY CONTINGENCY TABLE – SINGLE STRATEGY AND MULTIPLE STRATEGIES VS.
PRACTICAL AND NON-PRACTICAL

In Table 51 above, the frequencies in the rows were represented by Practical and Non-practical responses respectively. The column headings are represented by Single thinking strategy and Multiple thinking strategies headings respectively. The results from the application of a Chi-squared test on the frequencies above, to determine whether there was a relationship between frequencies of practical responses, and preference for using a single or multiple thinking strategies, indicated there was a statistically significant difference between using a single thinking strategy exclusively and using multiple thinking strategies. The obtained value of 2.74 was derived after using the frequencies above and applying them in a Chi-squared test. The value of a one-tailed X^2 at the 0.05 level with one df=2.71. Since the obtained value [2.74] was greater than 2.71 the results were determined to be statistically significant.

9.2.5 Linking Thinking techniques and Creativity [3D] Drawing Strategy D

The previous section discussed the results of the questionnaire data by comparing and contrasting the thinking techniques used by the subjects with the results of the inventions judged to be practical. As in Chapter 5, the next logical step was to compare and contrast the questionnaire data regarding the thinking techniques used by the subjects with the results of the inventions judged to be creative.

As in the previous sections, a frequency table based on all subjects [60 in total] was generated. The table below [Table 52] reflects for example that six subjects [10 percent of the subjects] were able to generate five creative inventions each. Marked differences exist in the number of subjects who generated creative inventions and those who did not. This is consistent with the earlier suggestions [in previous

chapters] that 3D creative mental synthesis problems may be more difficult than 2D

creative mental synthesis problems, at least with respect to creativity.

Strategy D Creativity Table 3D Problems												
Number of Creative responses	0	1	2	3	4	5	6	7	8	9	10	
% of Subjects	30%	13.33%	11.67%	10%	8.33%	10%	6.67%	1.67%	1.67%	1.67%	5%	100%
No. of Subjects	18	8	7	6	5	6	4	1	1	1	3	60 Subjects

TABLE 52: PERCENTAGE OF SUBJECTS WHO GENERATED A GIVEN NUMBER OF CREATIVE RESPONSES [3D PROBLEMS]

Consistent with section 9.2.4 above, it was appropriate to generate a two-dimensional

contingency table [illustrated in Table 53 below] in order to compare and contrast, in

a simple and straightforward way, subjects who utilised multiple thinking strategies in

resolving the creative mental synthesis problems with those subjects who utilised one

particular thinking strategy exclusively, as a function of the creative responses versus

non-creative responses.

	Single Thinking strategy	Multiple Thinking strategies	Totals
Creative	128	46	174
Non-creative	337	188	525
Totals	465	234	699

TABLE 53: TWO WAY CONTINGENCY TABLE – SINGLE STRATEGY AND MULTIPLE STRATEGIES VS. CREATIVE AND NON-CREATIVE RESPONSES

In Table 53 above, the frequencies in the rows were represented by creative and Non-

creative responses respectively. The column headings are represented by Single

thinking strategy and Multiple thinking strategies headings respectively. The results

from the application of a Chi-squared test on the frequencies above, to determine

whether there was a relationship between frequencies of creative responses and

preference for using a single or multiple thinking strategies, indicated there was a

statistically significant difference between using a single thinking strategy exclusively

and using multiple thinking strategies. The obtained value of 5.16 was derived after

using the frequencies above and applying them in a Chi-squared test. The value of a

one-tailed X^2 at the 0.05 level with one df=2.71. Since the obtained value [5.16] was

greater that 2.71 the results were determined to be statistically significant.

9.3 Discussion Questionnaire Data [2D & 3D]

As in Chapter 5, using empirical data and accepted statistical tools [Chi-squared tests]

in order to compare and contrast creative mental synthesis responses with the

exclusive use of a single thinking technique and the use of multiple thinking

techniques, revealed there was consistently no significant difference between the

exclusive use of a single thinking technique and the use of multiple thinking

techniques when using drawing Strategy B [mentally developing ideas] to resolve

either the 2D or the 3D creative mental synthesis problems. A single exception to this

related to resolving 2D problems and correspondence. In addition, a surprising yet

statistically significant result emerged when using drawing strategy D [separating

ideas from the embodiment of ideas]. It was revealed that the exclusive use of a single

thinking technique was superior to the use of multiple thinking techniques. This

finding was both counter-intuitive and contrary to the view of the design literature as

discussed in Chapter 2 where strategy variety was thought to have advantages. A

possible explanation of these results may rest in the fact that a questionnaire was used

as the main investigative tool. This instrument may not have been the most effective

tool to use in order to investigate these issues. It is possible the use of the

questionnaire and for that matter when it was administered may have been less than

effective. For example it is possible as a result of the subjects focusing on resolving

the problems they were unable to accurately recall or analyse their thought processes.

Consequently, the questionnaire may be a less than effective instrument for

investigating thinking techniques.

In terms of the questions regarding ease of use, typical use, and talking to oneself [sub

vocalisation], it was revealed that when using strategy B in both the 2D and the 3D

problems, approximately half the subjects [53.33 percent in the case of the 2D

problems and 56.67percent in the case of the 3D problems] considered the task of

mentally developing solutions to the creative mental synthesis problems easy.

However, when the subjects were to use Strategy D [separating ideas from the

embodiment of ideas] in order to resolve the 3D problems, less than half of the

subjects [43.33 percent] considered this strategy easy to use. With respect to the issue

of typical use, irrespective of problem type [2D or 3D] and irrespective of drawing

strategy [Strategy B or Strategy D], approximately one third of the subjects [31.67

percent in the case of the 2D problems using Strategy B; 33.33 percent in the case of

the 3D problems using strategy B; and 33.33 percent in the case of the 3D problems

using strategy D] indicated they typically used those strategies. In regard to the

question of talking to themselves, one third of the subjects [31.67 percent] resolving

the 2D problems using drawing strategy B and one third of the subjects [36.67

percent] resolving the 3D problems using drawing Strategy D, talked to themselves

while using those strategies. However, two thirds of the subjects [65.00 percent]

resolving the 3D problems using drawing Strategy B talked to themselves. It would

appear that mentally developing inventions necessitates sub vocalisation within a

majority of the subjects.

Chapter 10 Discussion and Conclusions

10.1 Introduction

The objective of this thesis was to identify and adapt the more systematic research methodologies found within rather specific areas of cognitive psychology, and apply them to issues thought to be of great importance in design. A review of the design literature focusing on issues relating to design thinking revealed two core themes, which were determined as being central to the creative act of design. These were that design is essentially a process of creative mental synthesis, and that drawing plays a central role in the design process. However, the review also revealed that a great deal of the design literature is anecdotal in nature. That is to say it is largely based on designers thinking and speculating on the design process by reflecting upon their personal experiences. A review of the relevant literature in cognitive psychology revealed three basic research areas, which utilised research methodologies believed to be of potential use in this research. However, only the research methodologies relating to creative mental synthesis proved to provide an appropriate methodology. This systematic approach also allowed issues relating to the use of drawing as an aid to creative mental synthesis to be investigated. Subsequent sections, within this chapter, will recount and discuss various aspects of the procedures and findings of this study, which inturn suggest directions for future research initiatives.

10.2 Procedures [General Summary]

In earlier discussions relating to the creative mental synthesis task, it was argued that the most straightforward way of assessing the relevance of this task to the issues of mental synthesis and creativity in design was by comparing the performance of

designers and non-designers. The procedures in this study were largely based on the research methodologies of Finke & Slayton (1988), Finke (1990). However, the nature of the material in the 2D and 3D versions of the task suggested a refinement of this basic approach. One version of the task involved drawings of simple 2D forms. Such forms can be viewed as the typical forms that would be used by graphic designers. Similarly the forms in the 3D version of the task are representations of the types of objects used by industrial designers. A development of the basic hypothesis therefore was that there should be differential performance on the two versions of the task between graphic designers and industrial designers. Graphic designers should perform better on the measures of correspondence and creativity using the 2D forms than the industrial designers while the reverse should occur with the 3D version of the task. Both types of designers would however be expected to perform better than the non-designers. The first aspect of the experimental design of the first experiment therefore was the use of the two versions of the task with separate groups of industrial and graphic designers and non-designers. However, it was important not to simply use anybody who was not a designer as the basis for the non-design group. It was essential to identify a group who would contrast with the designers in terms of the types of thought processes involved in their activities. If design involves the manipulation of representations of physical objects then the most appropriate comparison group would be those whose thinking processes are based on words and abstract concepts. A number of academic disciplines could be placed in this category however the discipline of the law was chosen as the basis for the comparison group. While comparisons and contrasts between and among subjects were important, the nature of the experiment allowed comparisons and contrasts between and among judges as well.

In addition, earlier it was indicated that the design literature views drawing as an invaluable aid in creative mental synthesis. However it would appear that Anderson & Helstrup's (1993) results, combining the creative mental synthesis task and drawing, appears to conflict with the design literature. Also, as discussed earlier, there exists the possibility that Andersen and Helstrup's negative outcome could be the result of the participants having no training in using drawing in the way required to increase creative output. Given that in the first experiment the core issues investigated were differences between design disciplines and between designers and non-designers in terms of creative output, and correspondence or practicality, it is possible to test this hypothesis by repeating the first experiment and comparing performance of the three groups when they are allowed to draw during the process of developing a form with their performance when they have to perform the task using mental synthesis only. It would be predicted that drawing would increase creative output for the design groups relative to their performance when they are not allowed to draw and that non-designers would not change their level of performance. These two experimental conditions were investigated. However as discussed earlier, the structure of the creative mental synthesis task allows a more detailed examination of the role of drawing than is implied in this simple comparison.

In the design literature there are a number of more specific views about the role of drawing. It is possible, for example that the activity of drawing simply assists through the type of mechanism suggested by Anderson and Helstrup (1993) of reducing the cognitive load. However this statement is often associated with the idea that drawings that are produced trigger the emergence of new ideas or the re-interpretation of

existing ideas (see, for example Goldschmidt, 1994, on emergence and re-interpretation). The basic structure of the mental synthesis task involves the presentation of three randomly selected forms that then have to be recreated in imagery and synthesised to produce a new form. This is then externalised in written and drawn form to allow for the assessment of the results. Drawing could be introduced while this initial synthesis is taking place. However it would also be possible to introduce a second phase to the task where the normal mental synthesis procedure is carried out but participants are then allowed to got back and work on the forms they have produced either by drawing or by repeating the mental synthesis task during the second phase. In this way the issue of emergence and re-interpretation can be addressed. However, it may be that drawing is not important to either develop ideas or to reinterpret them. It could be the important creative activity occurs when forms that have been produced can be mentally manipulated and that drawing under these conditions is simply a way of externalising the results of these manipulations. This possibility was also examined by requiring the subjects use drawing to develop their forms with drawing being allowed and this was followed by a condition where participants could use mental imagery to work on the forms produced. Additionally, novice designers often use drawing to focus early on a design solution and experts tend to use drawing to generate ideas and concepts and not form in the early stages of the design process. If conditions were controlled so as to mimic the strategies of expert designers, by forcing subjects to focus on developing ideas (concepts) first and then the embodiment of those ideas, as design experts do, this should result in more creative ideas being generated and offer an opportunity to create forms which are atypical and seen as more creative. This drawing strategy was therefore also investigated.

While various issues relating to subject type, judge type, measures of creativity, in addition to measures of correspondence or practicality were investigated, an investigation of what the subjects thought they were doing in terms of thinking strategies was conducted via a questionnaire. The questionnaire was administered once the subjects completed their tasks.

In terms of the thinking strategies used by the subjects, it was argued earlier that when subjects were presented with design type problems the ones who were able to use multiple thinking strategies in lieu of using one thinking strategy exclusively should perform 'better'.

10.3 Key Research Findings and Implications

10.3.1 General Findings

As a result of using less anecdotal and more systematic methodologies in order to investigate core issues related to design involving creative mental synthesis, and the use of drawing as an aid to creative mental synthesis, the following was found.

■ This research has demonstrated that systematic empirical research methodologies, which were adopted from cognitive psychology, can be reliably applied to issues relating to design thinking.

Much of the arguments presented in the design literature were based on designers thinking and speculating about their design thinking process. However, this study has shown by adopting a more systematic and empirical approach, using accepted

statistical tools in support of the findings, more meaningful results can be obtained which in some cases appear to contradict the arguments found in the design literature. Therefore, an important implication of this research finding is that some aspects of design thinking research should move away from anecdotal evidence and toward the use of empirical methodologies.

- ■ The results of the first experiment demonstrated that the creative mental synthesis task does differentiate between non-designers and designers and between designers of different disciplines in terms of their *creative output*. Further, Graphic designers perform better on the measures of correspondence and creativity using the 2D forms in contrast to the industrial designers, while the reverse occurs with the 3D version of the task [practicality and creativity in invention].

This result indicates that design abilities may be in part tied to familiarity with a set of forms that are characteristic of the discipline concerned and this represents an area for future research as it has significant implications particularly for the teaching of design.

- ■ Consensual assessment techniques of design type tasks, irrespective of judge type, are statistically reliable.

Using accepted statistical methods comparing and contrasting the judgements of distinct and separate sets of judges making decisions about creative responses has clear implications for design research. This research adds support to the argument that

consensual assessment by appropriate observers reviewing creative output can be considered reliable.

- When resolving design type problems using only *mental imagery*, at the same time as using either multiple thinking strategies or one thinking strategy exclusively, with the exception of the result relating to 2D correspondence responses, there is no statistically significant difference in performance with respect to practicality [3D] or creativity [2D & 3D].

It is possible that the results are less a reflection of the thinking strategies and are more related to individual differences and the capabilities of individual subjects. Thus, it can be argued that the results are person dependent. Consequently, this has direct implications for design education in that it is important to find students who are predisposed to towards having and using strong mental imagery abilities when resolving design type problems irrespective of the mental imagery thinking strategies the use. Alternatively, the questionnaire techniques may not be the most appropriate investigative instrument to use in this situation. It is possible the subjects might not have access to the details relating to the thinking strategies used. Consequently, an alternative method, which investigates the details relating to the thinking strategies, should be developed in the future.

10.3.2   Findings Relating to 2D Design Type Problems & Drawing

- When using various drawing strategies to resolve 2D design type problems both 2D and 3D designers developed twice as many creative

responses as the non-designers. However, both types of designers were very similar with respect to their creative output. In addition, the strategy of *mentally developing forms* was the superior strategy for both the 2D designers and the 3D designers.

This finding has direct implications for design in that contrary to the design literature mental imagery abilities are superior to drawing strategies in the development of two-dimensional forms. A pattern seems to be emerging relating to the potency of using mental imagery. In addition, this finding also indicates that three-dimensional designers are equally capable as to their two-dimensional designer colleagues when developing creative 2D forms.

■ Contrary to the arguments presented in the design literature, when resolving 2D design type problems while using drawing to reinterpret other drawings [with the expectation of emergence], neither the 2D designers nor the 3D designers enhanced their frequency of creative responses or their correspondence responses.

A major theme throughout the design literature relates to the use of drawing as a creative tool that enables ideas to emerge from the drawings. This finding using a more systematic approach does not support this view. It can therefore be argued that design happens in the mind and drawing acts to reflect the thoughts of the designer and is not an effective tool for instigating creative ideas.

■ Overall, when using various drawing strategies to resolve 2D design type problems, the 3D designers were slightly superior to the 2D designers in measures of creativity. In addition, the 3D designers were clearly superior in measures of correspondence.

While this finding appears to contradict an earlier finding relating to the results of experiment one, it should be remembered experiment one only investigated the strategy of *mentally developing forms*. However, the results here consider the overall results using various drawing strategies. Consequently, when allowed to use various drawing strategies to resolve 2D creative mental synthesis problems, three-dimensional designers are superior to two-dimensional designers. This has implications for design education in terms of persons suited to different types of design tasks. These results reflect that both types of designers are suited to 2D tasks.

■ When resolving 2D design type problems the superior strategy, with respect to high correspondence responses, for both the 2D designers and the non-designers was that of mentally developing the forms. However, in terms of correspondence, the stronger strategies for the 3D designers were that of using the act of drawing to develop the forms, and mentally developing the forms. In addition, with respect to creativity, for the 3D designers, the superior strategy was that of mentally developing the forms.

As with the finding relating to the creative responses described earlier, this finding relating to high correspondence responses contradicts the design literature again

revealing mentally resolving design type problems is a superior strategy. As suggested in some of the findings above, the potency of using mental imagery seems to be emerging as a theme in this research. This has implications for design in that it adds further support for the argument that design happens in the mind and mental imagery is more powerful than generally given credit.

10.3.3   Findings Relating to 3D Design Type Problems & Drawing

■ When using various drawing strategies to resolve 3D design type problems, the 3D designers developed more than four times as many creative responses as the non-designers, and the 2D designers developed more than three times as many creative responses as the non-designers.

This result adds further support to the argument that design abilities may be in part tied to familiarity with a set of forms that are characteristic of the discipline concerned and this represents an area for future research as it has significant implications particularly for the teaching of design.

■ When using the expert strategy of separating ideas from the embodiment of ideas to resolve the 3D design type problems, all subjects substantially increased their creative output. In terms of creativity this was the superior strategy for all subjects.

This suggests that utilising the thinking strategy of separating the generation of ideas from the embodiment of those ideas, as expert designers tend do, substantially aids

both the designers and non-designers. This conflicts with the view that drawing assists

the creative process through exploration, since the creative output did not increase in

the second task of Strategy D, where drawing was used to reinterpret the forms

produced in the first task. Also noteworthy is that this is the only drawing strategy

[Strategy D Task 1] in which the non-designers made substantial gains in the number

of creative responses. This is significant in that they were not trained in drawing, as

when they drew was merely controlled. This has significant implications for design

education. As the role of design educators is to progress a student designer [novice]

towards becoming an expert designer, it is important that the student learn to use

expert strategies. This research has provided empirical evidence relating to the

strength of this argument.

■ When resolving 3D design type problems, contrary to both the design
literature and the cognitive psychology literature, the act of using
drawing to aid creative mental synthesis either to generate the ideas or
to reinterpret ideas was not the superior strategy for either the 2D
designers or the 3D designers in terms of either creativity or
practicality.

This was a direct result of examining the role of drawing and re-interpretation, two

issues considered to be central to design generally and creative design in particular. It

was found that drawing did not make a significant contribution to creative output

whether it was used while generating forms or in re-interpreting forms. This is a

surprising result as it directly contradicts strongly held views about the design

process. Increases in creative output, relative to the drawing conditions, however did

occur with the design groups when the task was performed using mental imagery only. This finding adds further support to the argument that design happens in the mind and drawing acts to reflect the thoughts of the designer and is not the most effective tool for instigating creative ideas.

■ When using various drawing strategies to resolve 3D design type problems the 3D designers developed approximately two times as many practical responses in contrast to both the 2D designers and the non-designers. When faced with 3D design type problems the 2D designers can be considered on par with non-designers with respect to practical responses.

Recounting an earlier finding that the three-dimensional designers were similar in capability when compared to two-dimensional designers with both types of designers being superior to non-designers, it was argued that when allowed to use various drawing strategies to resolve 2D design type problems three-dimensional designers are superior to two-dimensional designers. The finding above adds weight to this argument in that 3D designers were again superior to the 2D designers. When faced with 3D problems the 2D designers were equated to the non-designers. Again, this has implications for design education in terms of persons suited to different types of design tasks. These results reflect that 3D designers are suited to both the 2D and 3D tasks while, the 2D designer appear to be only suited to the 2D tasks.

■ When resolving 3D design type problems, contrary to both the design literature and the cognitive psychology literature, mentally developing

practical ideas was the superior strategy for the 3D designers, in contrast to using drawing to either develop practical ideas or reinterpret ideas.

This finding has implications for design education in that if students mimic the design strategies of experts who tend to think by evaluating and analysing before they use drawing, superior results may be obtained.

■ When using the expert strategy of separating ideas from the embodiment of ideas to resolve the 3D design type problems, all subjects substantially *decreased* their number of practical responses. In terms of practicality this was the weakest strategy for all subjects. However, when all the subjects were to subsequently reinterpret these initial responses by using drawing to reinterpret them, the relative number of practical responses increased for all subject types.

This finding has implications for design education in that if students mimic the design strategies of experts who tend to use detail drawing later in the design process more often than not for embodiment and analysis, increased practical designs may be developed. That is to say, if the novice designers separate ideas from the embodiment of ideas in order to generate creative ideas, and then subsequently use drawing to develop the ideas, they increase the likelihood of reforming a creative but impractical idea into one that is both creative and practical.

■ When resolving 3D design type problems using the expert strategy of separating ideas from the embodiment of ideas, while using either multiple thinking strategies or one thinking strategy exclusively, there was a statistically significant difference in performance with respect to both practicality and creativity. The bias was towards using a single thinking strategy exclusively when faced with 3D creative mental synthesis problems.

This finding has implications for design in that while it is counter-intuitive the possibility exists that when faced with 3D design type problems and using an unfamiliar strategy [separating ideas from the embodiment of ideas], the tendency is to exclusively rely on one specific thinking strategy.

10.4 Limitations and Future Research

The outcomes of this research clearly demonstrate the creative mental synthesis task appears to provide an interesting methodology for empirically examining issues thought to be important in design. As suggested earlier, the results in many respects are quite provocative outcomes given they are contrary to widely held views described in the design literature, and the views presented in cognitive psychology literature that such complex tasks place considerable loads on working memory thus requiring the use of drawing. Explanations for the absence of a positive effect of drawing may be due to the following: 1.) While the participants were all senior undergraduates, it may be that they have not developed the skills required to take advantage of drawing that an expert would possess. This is clearly open to empirical test through the use of expert groups. 2.) It may be that the creative synthesis task is

not an appropriate model for a design task. Again this is open to empirical examination, as it would be possible to develop the task to make it more like a typical design task. While both of these possibilities could explain the failure of drawing to have an impact, they cannot diminish the significance of the strong and consistent increases in creative output that were demonstrated.

The creative mental synthesis task, particularly if it were developed in appropriate ways, does therefore appear to provide a useful and interesting methodology for empirically examining cognitive processes in design. For example, the repertoire of shapes utilised in the seminal work of Finke & Slayton (1988), Finke (1990), Anderson & Helstrup (1993) were limited to basic shapes. As designers are thought to have a large repertoire of shapes from which to synthesize and develop forms, the introduction of a larger number of different types of basic shapes appropriate for the design discipline involved could be explored using mental synthesis tasks, thus examining issues of working memory and creativity.

Additionally, synthesis (essentially an additive process) is one technique for the development of form. Other techniques used by designers are subtraction and deformation. An illustration of subtraction would be a sculptor chipping away at a granite stone block, shaping the stone thus developing the shape borne in mind. An example of developing a form by deformation, a potter working on a potter's wheel deforming the rotating moist clay deftly developing a shape held in mind. These design-thinking techniques could be investigated empirically as well. Using mental synthesis tasks as one strategy then requiring subjects to use alternate strategies of

subtraction and deformation would investigate the relative comparison of the effectiveness of the different techniques used by designers.

While Anderson & Helstrup (1993) and Verstijnen (1997) found no difference between the drawing condition and mental imagery condition in their creative mental synthesis research, the results of this research show the 'mental imagery' condition not the drawing condition to be of greater benefit to designers and no aid to the non-designers. Given the clear and consistent results of this research indicating that a key core capacity of designers rests in the use of their mental imagery abilities to develop a design, further research should address issues of drawing and mental imagery.

If the act of drawing is thought to be a 'conversation' designers have with themselves, it is possible this aids a 'rehearsal loop' suggested by Reisberg & Logie (1993). However, in his research exploring drawing and the blind, Kennedy (1993) suggests that blind people have a sense of shape like that of sighted people. This has implications for design research in that it argues for the strength of mental imagery. While the work of Kennedy (1993) did not use designers, Athavankar (1995) did use designers as subjects. In a protocol study Athavankar (1995) blindfolded expert designers, and directed them to evolve their designs exclusively using mental imagery. He suggested there is some evidence to support the view that designers are able to mentally model their designs and with natural ease 'play with it' to resolve design problems. In addition some of his subjects suggested that they were in fact more fluent with ideas and enjoyed working this way [blindfolded]. It is possible to investigate the relative strengths of mental imagery and drawing comparing and contrasting subjects who complete design tasks while blindfolded.

In previous discussions it was noted a central theme in the predominantly anecdotal design literature suggested that if drawing is both important during the process of synthesising a form and then allows re-interpretation, a strategy that allows this to occur, should result in high numbers of creative responses. This did not occur in this research, as is apparent from the results. However, as expert designers are considered to be very creative then emulating their strategy [as in Strategy D Task 1- separating ideas from the embodiment of ideas] allowed both the student designers and the non-designers to generate substantially high levels of creative forms using the experts' technique. The results pointed to a large difference between this strategy and all the other strategies shown. This large difference was reflected in the results for each subject type not just the design subjects. This suggested that utilising the thinking strategy of separating the generation of ideas from the embodiment of those ideas, as expert designers do, substantially aids both the designers and non-designers. This conflicted with the view that drawing assists the creative process through exploration, since the creative output did not increase in the second task of Strategy D, where drawing was used to reinterpret the forms produced in the first task.

While high numbers of creative responses were generated when the strategy of separating ideas from the embodiment of ideas was used, this appears to be at the detriment of practical ideas. It is conceivable coupling the strategy of separating of ideas from the embodiment of ideas with the Finke (1990) task caused this drop in practical ideas. Investigating three different procedures of introducing invention topics and parts to embody the inventions, Finke (1990) found most people were most creative when they were randomly given both the topic area *and* the three forms to

work with at the same time. This does not appear to be the case as revealed in this research. It is argued that Finke (1990) did not get a high result because he did not separate ideas form embodiment of ideas when he let the subjects choose the parts.

An expert designer tends to separate ideas from the embodiment of ideas by working on the basic ideas first [a problem analysis phase]. Subsequently, they would make the idea work [become practical] as they creatively embody the idea. Designers determine the basic forms used in the synthesis activity, unlike what Finke (1990) found, when he had the subjects pick the forms when randomly given the topic area. For example if the topic were toys and games, the designer could have an idea for a pogo stick. Next they would develop the embodiment of the pogo stick by selecting forms determined to be appropriate for a creative embodiment. After they create the idea for a pogo stick, rather than being randomly given three shapes, the subjects should choose the parts to creatively embody the idea pogo stick. This is perhaps why in this study an idea may be creative but not practical. If they were allowed to choose the parts an interesting response being both creative and practical may be developed.

The Finke (1990) task was chosen because it had a validity about it allowing this research to discover its strengths and weaknesses with respect to design thinking. Perhaps, in order to investigate responses that are both creative and practical, a way forward is to again use the Finke (1990) paradigm. However, a future experiment could control the separation of ideas and the embodiment of ideas, subsequently allowing the subjects to pick the parts, which is what expert designers seem to do. Essentially the subjects would look for a concept within the randomly selected topic area, and then they could look for away to make it work in order to creatively embody

the idea by selecting the parts to synthesise. The prediction would be that designers would produce high numbers of responses that were both highly creative and highly practical.

However, a counter argument is perhaps it is the judges' views on creativity that is being demonstrated, and not the designer. The judges could view a response as being a creative embodiment and not a creative idea. After a subject used the strategy separating ideas from the embodiment of ideas, they would be forced to use a triplet of forms that would make it difficult to embody the idea they envisaged. Returning to the pogo stick example, two scenarios could illustrate the differences. Scenario one is illustrated in Example one on the left in Figure 33 below: A subject is randomly given the topic toys and games. After having the idea of a pogo stick, they are subsequently randomly given a sphere, a cylinder, and a rectangular block. This result is considered to be practical but not very creative. Scenario two is illustrated in Example two on the right in Figure 33 below: A subject is randomly given the topic toys and games. After having the idea of a pogo stick, they are subsequently randomly given a sphere, a set of wheels, and a sphere. This example would not be considered very practical, however it could be considered creative. The subject was forced into using shapes they may not have originally considered to be useful. In these two examples the idea remained the same the core difference was the shapes used. Therefore, it can be argued that the idea of the pogo stick in example two was not creative, merely a creative embodiment due to the use of unusual forms.

The judges could reflect on the drawing noting the use of the forms sphere, sphere, and wheels, and think what and interesting mind that came up with a pogo stick using

these parts. So the creativity was mainly in the mind of the judges inherent in the randomness of the idea pogo stick being separated from the selection of the parts. Conversely, after the subject develops the idea for the pogo stick, they are given the parts and think: Making a pogo stick out of a sphere, a sphere, and two wheels, will be difficult, but I'll try. The subject manipulates the parts to the best of their ability, and the judges view the result as a very good try. Consequently, in a sense the creativity was in the mind of the judge. This is a possible explanation for the high number of creative responses and low number of practical responses when using the strategy of separating ideas from the embodiment of ideas. This is certainly a key area for future research.

In order to test this it is possible to artificially control the drawings. Instead of having a subject produce a drawing, the responses could be constructed artificially. First an instance of a category is selected. Next a set of parts is determined, followed by the construction of a drawing and concept. The three parts are assembled so when someone independently looking at them, after having been told that someone generated them as if it was the Finke experiment, could determine the level of creativity and level of practicality.

The combinations of the instances and the tasks would vary. Returning again to the pogo stick example, the parts and the ideas would be controlled so a variety of responses were presented to the judges who would be blind to how the objects were generated. This would result in responses as illustrated in Example one on the left in Figure 33 below and as illustrated in Example two on the right in Figure 33 below.

Example one would be considered practical but not very creative and example two would be considered creative but not practical.

The difficulty would rest in the middle ground ideas/parts. Parts would be selected so there is increasing distance between the part and the idea. It is possible to generate appropriate artificial examples. Creativity is not being tested. What is being tested is the disparity between the parts and the ideas. The hypothesis is that when confronted with sheets of paper that have the different ideas/parts a disparity between creativity and practicality should occur, as was the case in this research.

Topic: Toys & Games

IDEA = _Pogo Stick_
Parts = cylinder-sphere-rectangular block
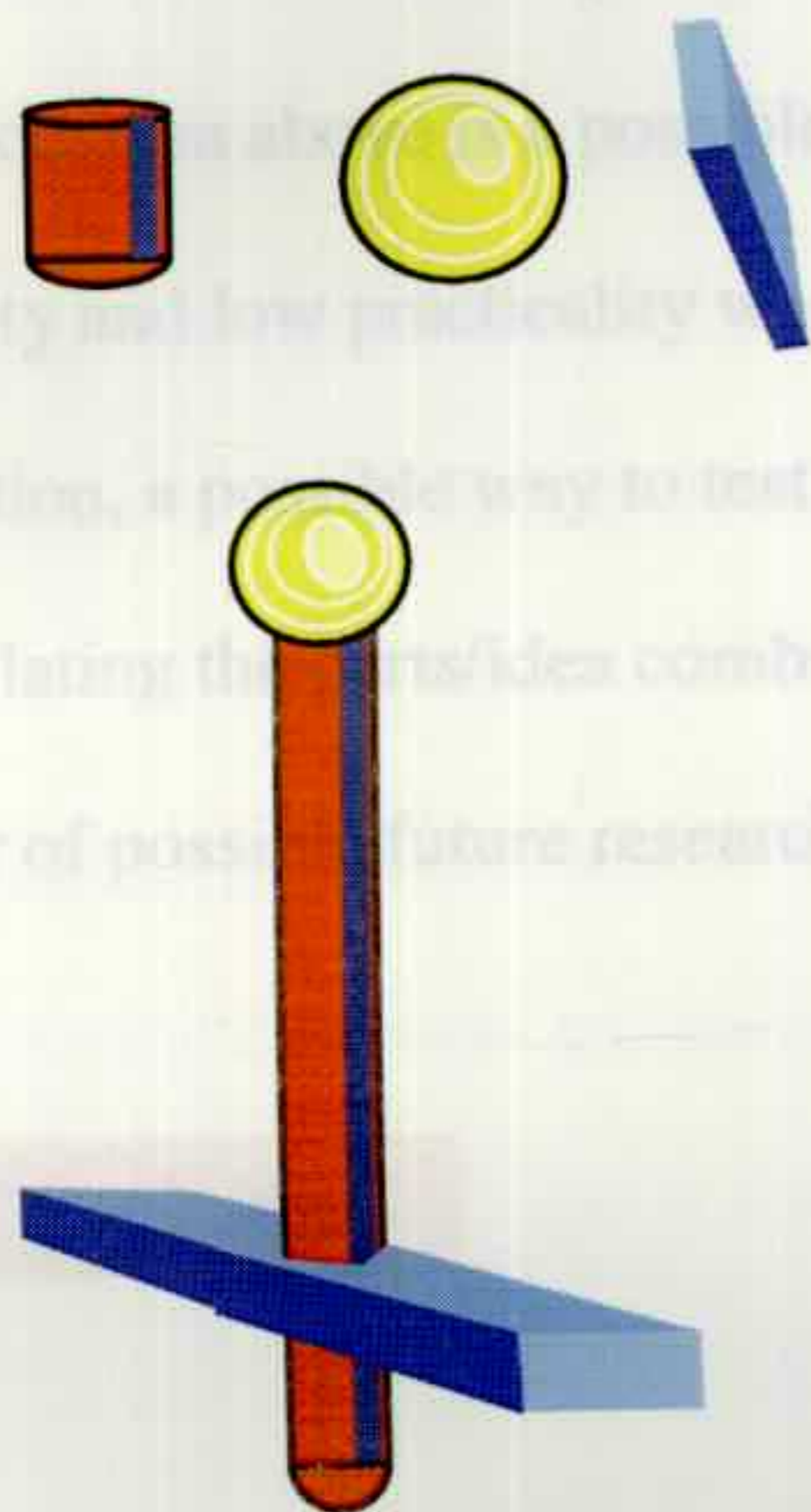
Topic: Toys & Games

IDEA = _Pogo Stick_
Parts = sphere-wheels-sphere

Hold on here

Rubber Ball

Stand on platform here
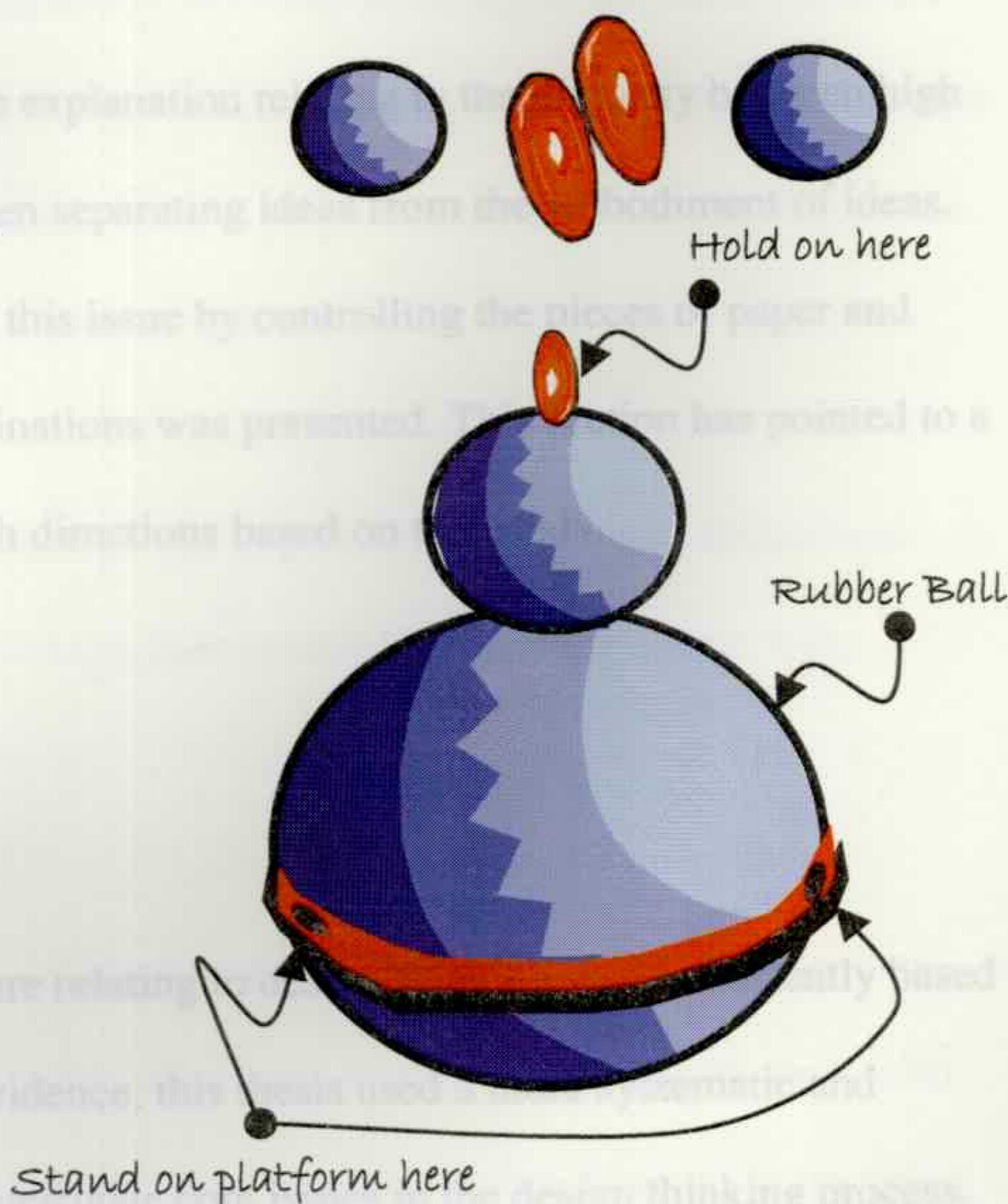
Example 1

Example 2

FIGURE 33: POGO STICK EXAMPLE OF ONE IDEA EMBODIED USING DIFFERENT PARTS

Since the middle ground is the most difficult, the responses would need to be pretested. This would be accomplished by recruiting a group of people to rank the increasing instances, which are wide apart with respect to ideas and parts. They are not judging the creativity / practicality they are judging or ranking the gap between the ideas and the parts: [i.e. 70% of the ranking judges say a given response is a middle ground response, and 60% say another response is a creative and practical one, and with another response 60% say the response is a creative but not practical etc…].

Next judges' blind to the ranking would judge creativity and practicality. A core issue of this future research relates to the disparity between high creativity and low practicality when separating ideas from the embodiment of ideas.

The discussion above is a possible explanation relating to the disparity between high creativity and low practicality when separating ideas from the embodiment of ideas. In addition, a possible way to test this issue by controlling the pieces of paper and manipulating the parts/idea combinations was presented. This section has pointed to a number of possible future research directions based on this study.

10.5 Conclusion

While much of the design literature relating to design thinking was consistently based on introspection and anecdotal evidence, this thesis used a more systematic and empirical approach in order to investigate core issues in the design thinking process. These core issues centred on creative mental synthesis and drawing. The design literature argued strongly that drawing plays a central role in creatively developing

solutions in design type problems with the expectation of emergent ideas. However, this thesis revealed findings that do not support this argument. At the same time, this thesis does not downplay the role of drawing in the design process it merely supports the argument that when and how drawing is used in the design process is very important.

By adopting and adapting accepted research methodologies from specific areas within cognitive psychology this thesis has demonstrated the importance of using these methods in order to move design-thinking research forward beyond introspection and anecdotal evidence. The objective measures used revealed findings, which in some instances contradicted and some instance supported the themes commonly found in the design literature concerned with design thinking. In doing so this thesis extends the debate regarding core issues in design thinking in a rigorous way. While a number of findings were revealed earlier in this chapter, three common themes emerged from the findings of this research. These were as follows:

Theme 1: Mimicking the strategies of expert designers greatly assists both novice designers and non-designers in creatively resolving design type problems.

Theme 2: When resolving design type problems, mentally developing forms was a superior strategy in contrast to using drawing to reinterpret ideas with the expectation of emergence. This suggests that design happens in the mind, meaning that the creative and practical development of design ideas is strongly related to mental imagery.

Theme 3: When resolving 2D design type problems, three-dimensional designers are equally capable or superior to their two-dimensional designer colleagues. Additionally, when resolving 3D design type problems three-dimensional designers are superior to their two-dimensional designer colleagues. This suggests 3D designers are capable of resolving both 2D and 3D problems, while their 2D colleagues are capable of resolving only 2D problems.

While this thesis adds to the body of knowledge on the subject of design thinking, it also points to some limitations of this study. However, this thesis suggests future areas of research and possible experiments that may overcome some of these limitations.

Extending our understanding of core issues in design thinking with respect to creative mental synthesis and drawing can assist in shaping design education. For example, this study has demonstrated that when confronted with 3D design type problems and using strategies used by expert designers, all subjects had increases in performance in measures of creativity. Consequently, educational pedagogies need to be reviewed so as to inform and guide novice designers [students] in adopting strategies effectively used by expert designers. The work completed in this thesis can be extended by application of the methodologies in future design thinking studies. This will provide a rich source of data for developing our understanding of the design process in order to more effectively educate future generations of designers.

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Appendix A

<u>Procedure</u> <u>2D</u>

   The purpose of this investigation is to explore how people combine visual parts in a mental image.
   There is a series of 8 trials or problem sets presented which explores two-dimensional mental synthesis.
   Here are 15 two-dimensional forms or parts. The experimenter indicates the name for each part that could be used.
   Each trial or problem set consists of three randomly selected forms given to you.
   These are given in any order and sometimes more than once.
   As soon as the parts are named you are to close your eyes and attempt to mentally construct a recognisable form from the parts given.
   All the parts must be used.
   If two of the same part is mentioned then both are to be used in your created form.
   You are also instructed that the figure could be anything as long as it could be recognised by another person and that it could be easily named without a long description.
   You can vary the size, position, orientation, or proportion (eg. an equilateral triangle can be shaped into an isosceles triangle) of the parts but you are not allowed to bend, trim or distort the individual parts in any way. (a circle can not be made into an ellipse)
   Here are two examples of possible mental constructions. In the first example the following is used (the letter L, a circle, and a square), the example forms are a TV set, a jack in the box, and a flag on a flagpole.
   The second set consists of the following (a horizontal line, the letter L, and the letter T). The example forms given were a pine tree, the letter E, and an antenna. These examples were used to illustrate the range of forms which could be created.
   The materials that are supplied to you are as follows:
      One pad of unlined drawing paper
      Several sharpened drawing pencils with erasers
   At the beginning of each of the trials I will call out the trial number and name the three parts to be used in that trial.
   I will repeat the names to ensure that the names were heard correctly.
   You are to close your eyes and only open them long enough to write down the name of a form, the parts it was derived from, and the trial number on one side of one sheet of paper.
   You are to turn the page over preparing for the next form.
   Then you are to close your eyes again without looking around the room.
   You can create as many forms as you like before the end of a three-minute time period.
   Each name of a form is to be put on a single side of a single sheet of paper for each trial problem set.
   You are to keep your eyes closed until you can name a form.
   This is repeated for each form created from the three parts named.
   Once three minutes is over you are to go back and draw the corresponding form they envisaged for each name. Once you start to draw the figure you cannot change anything you wrote when naming it. This is to insure that you do not discover patterns in your drawings.
   This same procedure is repeated for each of the 8 trials in this series.

At the end of this series of 8 trials you are to fill in a questionnaire concerning the strategy you used in combining the

parts to create a new form.

Appendix B

Procedure _____ 3D

The purpose of this investigation is to explore how people combine visual parts in a mental image.
The series of 8 trials or problem sets presented explores three-dimensional mental synthesis.
Here are 15 three-dimensional forms or parts.
The experimenter indicates the name for each part that could be used.
Each trial or problem set consists of three randomly selected forms given to you.
These are given in any order and sometimes more than once.
As soon as the parts are named you are to close your eyes and attempt to mentally construct a practical object from the parts given.
All the parts must be used, and the object must be of some practical value.
If two of the same parts are mentioned then both are to be used in the object.
You can vary the size, position, proportion (i.e. you could have a cone with a wide base and a shallow point or a cone with a narrow base and tall point), or orientation of the parts but you are not allowed to bend, trim or distort the individual parts in any way (i.e. a sphere cannot be an egg shape) with the exceptions of the wire and the tube. These have been defined as bendable.
The parts can be put inside one another.
They can be solid or hollow.
They can be made from any material including wood, metal, glass, rubber, or plastic, in any combination.
In addition you are given an object category randomly selected from a list of 8 categories (as shown below in Table 2).
Coupled with each new set of three randomly selected parts in each trial, of a set of 8 trials, you are given a new randomly selected object category.

Table

Allowable object categories in experiments on creative invention.

Category one		Examples
1.	Furniture	Chairs, tables, lamps, etc...
2.	Personal Items	Jewellery, glasses, etc...
3.	Transportation	Cars, boats etc...
4.	Scientific Instruments	Measuring devices, etc...
5.	Appliances	Washing machines, toasters, etc...
6.	Tools & Utensils	Screwdrivers, spoons, etc...
7.	Weapons	Guns, missiles, etc...
8.	Toys & Games	Baseball bats, dolls etc...

Note: from Finke (1990)

The materials that are supplied to you are as follows:
       One pad of unlined drawing paper
       Several sharpened drawing pencils with erasers
At the beginning of each trial I will call out the trial number and name the three parts to be used in that trial and the random category.
The names of the parts are repeated to ensure that the names were heard correctly.
You are to close your eyes and only to open them long enough to write down the name of the practical object, what it did or how it functioned, the names of the parts it was derived from, and the trial number on one side of one sheet of paper.
You are to leave room on the paper for drawing the object later.
You can create as many forms as you like before the end of a three-minute time period.
You are to turn the page over preparing for the next practical object.
Then you are to close your eyes again without looking around the room.
Each practical object is to be put on a single sheet of paper.
You are to keep your eyes closed until you can name, describe, and draw the object. But you are not to draw the object yet.
This is repeated for each object created from the three parts named.
Once three minutes is over you are given time to go back and draw the described objects.
Once you start to draw the figure you cannot change anything you wrote when naming or describing it.
This is to insure that you do not discover patterns in your drawings.
This same procedure is repeated for each of the 8 trials in this series.

Say you were given a sphere a cylinder and a rectangular block, and the category – Toys & Games. You could put the sphere on top of a long thin cylinder place the block one-third up the cylinder and call it a pogo stick. Do you have the idea?

At the end of this series of 8 trials you are to fill in a questionnaire concerning the strategy they used in combining the parts to create a new form.

Appendix C

Good Morning! Thank you all for coming today. I appreciate your help in this research. Please help yourself to some coffee and cakes before we get started. You may get up and have some more any time you wish. Notice that your name and a judging code number is on a table, and next to your name you will find a box with some papers in it. We are investigating mental synthesis. Mental synthesis is described as the ability to imagine an assembled part made of component parts. We are looking at how people combine given parts to create new parts. We are exploring two-dimensional mental synthesis and three-dimensional mental synthesis. We are using two-dimensional designers, three-dimensional designers, and non- designers. You judges are representatives from all three disciplines. The morning session will be devoted to judging the 2D responses. Then we will break for a nice lunch downstairs, and after lunch you will be judging the 3D responses. In order for you to understand what you are to do I will go over what was expected of the subjects who generated these pieces of paper. Then we will go over how you are to mark each of the pieces of paper. All of the papers are coded so you do not know which subjects generated which response. In addition each stack of papers has been randomly stacked so that the order of the papers in each of your stacks is different from each of the other judges.

The subjects were told the following:

<u>Procedure   2D</u>

The purpose of this investigation is to explore how people combine visual parts in a mental image.
The series of 8 trials or problem sets presented which explores two-dimensional mental synthesis.
Here are 15 two-dimensional forms or parts.
The experimenter indicates the name for each part that would be used.
Each trial or problem set consists of three randomly selected forms given to you.
These are given in any order and sometimes more than once.
As soon as the parts are named they were to close your eyes and attempt to mentally construct a recognisable form from the parts given.
All the parts must be used.
If two of the same part is mentioned then both are to be used in your created form.
You are also instructed that figure could be anything as long as it could be recognised by another person and that it could be easily named without a long description.
You can vary the size, position, or orientation of the parts but you are not allowed to bend, trim or distort the individual parts in any way.
The experimenter then gives two examples of possible mental constructions. In the first example the following is used (the letter L, a circle, and a square), the example forms are a TV set, a jack in the box, and a flag on a flag pole.
Once three minutes is over the subject is to go back and draw the corresponding form they envisaged for each name.
Once you start to draw the figure you cannot change anything you wrote when naming it. This is to insure that you do not discover patterns in their drawings.
This same procedure is repeated for each of the 8 trials in this series.
At the end of this series of 8 trials
Please fill in this questionnaire concerning the strategy used in combining the parts to create a new form.
The alternatives were as follows:

1) " I tried combining the parts by trial and error in my image until I happened to recognise a shape"

2) " I first thought of a possible shape, then I tried to combine the parts in my image to see whether the particular shape could be made out of the parts"

3) " I did not form an image at all, but just thought about how the parts might be combined in a more abstract way"

4) " I used some other strategy" (Please explain in the space below)

Your task is to look at each piece of paper and make a judgement as to how well what was drawn corresponds to the description or name written. You are to judge this on a scale of 1 to 5, with 1 being very poor correspondence and 5 being very high correspondence. In addition if you score the correspondence as a 4 or a 5 and you believe the response to be creative then mark in the space provided that you deem it creative by ticking the 'yes' box. Are there any questions?

Welcome back. I hope you enjoyed the lunch we provided. If you get hungry again this afternoon we will be providing afternoon tea. Feel free to have some coffee and cake when you wish. We are now going to be judging the responses of three-dimensional mental synthesis. In order for you to understand what you are to do I will go over what was expected of the subjects who generated these pieces of paper. Then we will go over how you are to mark each of the pieces of paper. All of the papers are coded so you do not know which subjects generated which response. As before each stack of papers has been randomly stacked so that the order of the papers in each of your stacks is different from each of the other judges. The following procedure is what the subjects were told.

Procedure _____ 3D

The purpose of this investigation is to explore how people combine visual parts in a mental image.

There are a series of 8 trials or problem sets presented which explores three-dimensional mental synthesis.

Here are 15 three-dimensional forms or parts.

The experimenter indicates the name for each part that would be used.

Each trial or problem set consists of three randomly selected forms given to you.

These are given in any order and sometimes more than once.

As soon as the parts are named you are to close your eyes and attempt to mentally construct a practical object from the parts given.

All the parts must be used, and the object must be of some practical value.

If two of the same parts are mentioned then both are to be used in the object.

You can vary the size, position, proportion (i.e. you could have a cone with a wide base and a shallow point or a cone with a narrow base and tall point), or orientation of the parts but you are not allowed to bend, trim or distort the individual parts in any way (i.e. a sphere cannot be an egg shape), with the exceptions of the wire and the tube. These have been defined as bendable.

The parts can be put inside one another.

They can be solid or hollow.

They can be made from any material including wood, metal, glass, rubber, or plastic, in any combination.

In addition you are given an object category randomly selected from a list of 8 categories (as shown below in Table 2).

Coupled with each new set of three randomly selected parts in each trial, of a set of 8 trials, you are given a new randomly selected object category.

Table

Allowable object categories in experiments on creative invention.

Category one		Examples
1.	Furniture	Chairs, tables, lamps, etc...
2.	Personal Items	Jewellery, glasses, etc...
3.	Transportation	Cars, boats etc...
4.	Scientific Instruments	Measuring devices, etc...
5.	Appliances	Washing machines, toasters, etc...
6.	Tools & Utensils	Screwdrivers, spoons, etc...
7.	Weapons	Guns, missiles, etc...
8.	Toys & Games	Baseball bats, dolls etc...

Note: from Finke (1990)

The materials that are supplied to you are as follows:

One pad of unlined drawing paper

Several sharpened drawing pencils with erasers

At the beginning of each trial I will call out the trial number and name the three parts to be used in that trial and the random category.

The names of the parts are repeated to ensure that the names were heard correctly.

You are to close your eyes and instructed only to open them long enough to write down the name of the practical object, what it did or how it functioned, the names of the parts it was derived from, and the trial number on one side of one sheet of paper.

You are to leave room on the paper for drawing the object later.

You can create as many forms as you like before the end of a three-minute time period.

You are to turn the page over preparing for the next practical object.

Then you are to close your eyes again without looking around the room.

Each practical object is to be put on a single sheet of paper.

You are to keep your eyes closed until you can name, describe, and draw the object. But you are not to draw the object as yet.

This is repeated for each object created from the three parts named.

Once three minutes is over you are given time to go back and draw the described objects.

Once you start to draw the figure you cannot change anything you wrote when naming or describing it.

This is to insure that you do not discover patterns in your drawings.

This same procedure is repeated for each of the 8 trials in this series.

Example

Say you were given a sphere a cylinder and a rectangular block, and the category – Toys & Games. You could put the sphere on top of a long thin cylinder place the block one-third up the cylinder and call it a pogo stick. Do you have the idea?

Judging the practical objects. You are presented with two marking scales; both are marked 1–5. One scale is for practicality and the other scale is for originality (creativity). You are to judge these issues separately. An object can be practical and not creative. It can be creative and not practical. It can be both creative and practical or neither practical nor creative or various combinations in between, based on the scales you are given.

You are to base your ratings on the concept presented, not the drawing quality. With three parts it is understood that not all details can be there so you will review the responses with this in mind. They may not have shown fastening details like screws, but this is not important.

Appendix D

Good Morning! Thank you all for coming today. I appreciate your help in this research. Please help yourself to some coffee and cakes before we get started. You may get up and have some more any time you wish. Notice that your name is on a table, and next to your name you will find a box with some papers in it. We are investigating mental synthesis. Mental synthesis is described as the ability to imagine an assembled part made of component parts. We are looking at how people combine given parts to create new parts. We are exploring two-dimensional mental synthesis. We are using two-dimensional designers (graphic artists), three-dimensional designers (industrial designers), and non-designers (law students). You judges are representatives from all three disciplines. This morning will be devoted to judging the 2D responses. When we finish will have a nice lunch downstairs. In order for you to understand what you are to do I will go over what was expected of the subjects who generated these pieces of paper. Then we will go over how you are to mark each of the pieces of paper. All of the papers are coded so you do not know which subjects generated which response. In addition each stack of papers has been randomly stacked so that the order of the papers in each of your stacks is different from each of the other judges.

The subjects were told the following:
Procedure   2D

The purpose of this investigation is to explore how people combine visual parts in a mental image.
The series of 8 trials or problem sets presented which explores two-dimensional mental synthesis.
Here are 15 two-dimensional forms or parts.
The experimenter indicates the name for each part that would be used.
Each trial or problem set consists of three randomly selected forms given to you.
These are given in any order and sometimes more than once.
As soon as the parts are named they were to close your eyes and attempt to mentally construct a recognisable form from the parts given.
All the parts must be used.
If two of the same part is mentioned then both are to be used in your created form.
You are also instructed that figure could be anything as long as it could be recognised by another person and that it could be easily named without a long description.
You can vary the size, position, or orientation of the parts but you are not allowed to bend, trim or distort the individual parts in any way.
The experimenter then gives two examples of possible mental constructions. In the first example the following is used (the letter L, a circle, and a square), the example forms are a TV set, a jack in the box, and a flag on a flag pole.
Once three minutes is over the subject is to go back and draw the corresponding form you envisaged for each name.
Once you start to draw the figure you cannot change anything you wrote when naming it. This is to insure that you do not discover patterns in your drawings.
This same procedure is repeated for each of the 8 trials in this series.
At the end of this series of 8 trials
Please fill in this questionnaire concerning the strategy used in combining the parts to create a new form.
The alternatives were as follows:

   1) " I tried combining the parts by trial and error in my image until I happened to recognise a shape"

   2) " I first thought of a possible shape, then I tried to combine the parts in my image to see whether the particular shape could be made out of the parts"

   3) " I did not form an image at all, but just thought about how the parts might be combined in a more abstract way"

   4) " I used some other strategy" (Please explain in the space below)

Your task is to look at each piece of paper and make a judgement as to how well what was drawn corresponds to the description or name written. You are to judge this on a scale of 1 to 5. With 1 being very low correspondence and 5 being very high correspondence. In addition below the correspondence scale you will find the originality scale (creativity), you are to judge the originality of the response. You are to judge this on a scale of 1 to 5. With 1 being no originality and 5 being very high originality.

Appendix E

Instructions

<u>**Instructions to Judges 2D Rejudging**</u>

Thank you for coming this morning and helping with our research. There is some coffee and cookies in the next room If you wish just help yourselves when you want some. We will work on judging the 2D Dimensional problems before lunch then 3Dimensional problems after lunch. We will break for lunch at around 12:00 then return upstairs and finish the rest of the judging from 1:00 until approximately 4:30. I say approximately because each person may judge at a different rate that others. If you should find you have finished early please do not disturb or talk to the other judges either in this room or the other judging room. Could you please retire to the coffee room and relax.

The purpose of this investigation was to explore different strategies people could use to combine visual parts to form a mental image. Basically the subjects were given three parts randomly selected from a group of 15 parts, using these three random parts they were to develop a new form. They could make as many new forms as they liked. They were to develop a **recognisable form.**

2D | **This explored two-dimensional mental synthesis.** |

Mental synthesis is described as the ability to imagine the assembly of a final part made from component parts.

As soon as the parts were named they were to attempt to construct a recognisable form, from the parts given. These are given in any order and sometimes more than once. All the parts must be used, and the object must be able to be recognised by another person. If two of the same parts are mentioned then both were to be used in the object. They could vary the size, position, proportion, or orientation of the parts but were not allowed to bend, trim or distort the individual parts in any way (circle could not be made into an ellipse). Give an example of the Flag and the TV set.

As judges your task is to assess the results of their work. Note at the top of each paper there will be two scales running from 1 thru to 5. A mark of 5 is the highest mark and a mark of 1 is the lowest mark. The first scale is for correspondence. The second scale is for originality or creativity. On each paper you are to circle a number for correspondence and a number for originality (creativity). If there is no response for that paper tick the box marked no response. We would like you to keep your papers in order so start with the top paper. Mark it by circling a number from 1-5 for correspondence then a number for originality (creativity) and turn it over and place it in the box beside you then proceed to the next paper. Do this until you have finished the stack of papers.

You are judging the ideas not the drawing quality.

Each stack of papers is arranged differently. They are randomised, so each of you are judging the papers in a different order.

Are there any questions ?

AFTERNOON JUDGING

The purpose of this investigation was to explore how people could combine visual parts to form a mental image. Basically the subjects were given three parts randomly selected from a group of 15 parts, using these three random parts they were to develop a new form. They could make as many new forms as they liked.
They were to develop a **Practical object or invention.**

3D | This explored three-dimensional mental synthesis.

Mental synthesis is described as the ability to imagine the assembly of a final part made from component parts.

As soon as the parts were named they were to attempt to construct a practical object from the parts given. These are given in any order and sometimes more than once. All the parts must be used, and the object must be of some practical value. If two of the same parts are mentioned then both were to be used in the object. They could vary the size, position, proportion, or orientation of the parts but were not allowed to bend, trim or distort the individual parts in any way with the exceptions of the wire and the tube. These have been defined as bendable. The parts could be put inside one another. They could be solid or hollow. They could be made from any material including wood, metal, glass, rubber, or plastic, in any combination. In addition they were given an object category randomly selected from a list of 8 categories (**read the examples to them**). Coupled with each new set of three randomly selected parts in each trial, they were given a new randomly selected object category.

Table 2

Allowable object categories in experiments on creative invention.

Category one	Examples
1. Furniture	Chairs, tables, lamps, etc...
2. Personal Items	Jewellery, glasses, etc...
3. Transportation	Cars, boats etc...
4. Scientific Instruments	Measuring devices, etc...
5. Appliances	Washing machines, toasters, etc...
6. Tools & Utensils	Screwdrivers, spoons, etc...
7. Weapons	Guns, missiles, etc...
8. Toys & Games	Baseball bats, dolls etc...

Here is an example: They could be given a sphere, a rectangular block, and a cylinder. Then given the category of toys and Games. They could add the sphere to the top of the cylinder then add the block one 1/3 the way up the cylinder and say it is a **pogo stick.**

As Judges your task is to assess the results of their work. Note at the top of each paper there will be two scales running from 1 thru to 5. A mark of 5 is the highest mark and a mark of 1 is the lowest mark. The first scale is for practicality. The second scale is for originality or creativity. On each paper you are to circle a number for practicality and a number for originality (creativity). If there is no response for that paper tick the box marked no response. We would like you to keep your papers in order so start with the top paper mark it by circling a number from 1-5 for practicality then a number for originality (creativity) and turn it over and place it in the box beside you then proceed to the next paper. Do this until you have finished the stack of papers.

You are judging the ideas not the drawing quality.

Each stack of papers is arranged differently. They are randomised, so the order each of you are judging the papers is different.
Are there any questions?

Appendix F

Using All judges Re-judging (2D) ID subjects

Subject	Subject Num	Sum of 1st judge Corr	Rank 1	Sum of 2nd judge Corr	Rank 2	D$_i$	D$_i^2$
ID2DG1S2	2	8	1.5	8	3	-1.5	2.25
ID2DG2S3	7	8	1.5	12	1	0.5	0.25
ID2DG2S2	6	7	3	9	2	1	1
ID2DG1S1	1	5	4	7	4.5	-0.5	0.25
ID2DG1S4	4	4	7	5	10.5	-3.5	12.25
ID2DG2S4	8	4	7	5	10.5	-3.5	12.25
ID2DG3S4	12	4	7	5	10.5	-3.5	12.25
ID2DG3S5	13	4	7	6	7	0	0
ID2DG4S2	15	4	7	7	4.5	2.5	6.25
ID2DG5S5	17	4	10	6	7	3	9
ID2DG2S1	5	3	11.5	4	7	4.5	20.25
ID2DG4S3	16	2	11.5	4	13.5	-2	4
ID2DG1S3	3	2	15.5	3	15.5	0	0
ID2DG3S1	9	1	15.5	1	18	-2.5	6.25
ID2DG3S3	11	1	15.5	1	18	-2.5	6.25
ID2DG4S1	14	1	15.5	6	10.5	5	25
ID2DG6S1	18	1	15.5	4	15.5	0	0
ID2DG7S1	19	1	15.5	2	13.5	2	4
ID2DG3S2	10	0	19	1	18	1	1
N =	19						Sum D$_i^2$ 122.5

		Tie X	Tie1 2	Tie 2 2	Tie 3 6	Tie 4 6	Tie 5	Tie 6
Sum X2c	541.5				10	17.5		
		Tie Y	Tie1 2	Tie 2 3	Tie 3 4	Tie 4 2	Tie 5 2	Tie 6 3
SumY2c	559.5		0.5	2	5	0.5	0.5	2
Rs	0.89							
Pearson-Rs	0.89							
t	8.00							

Subject	Subject Num	Sum of 1st judge Creat	Rank 1	Sum of 2nd judge Creat	Rank 2	D$_i$	D$_i^2$
ID2DG1S2	2	6	2	9	1	1	1
ID2DG2S3	7	6	2	3	8	-6	36
ID2DG4S1	14	6	2	3	8	-6	36
ID2DG1S1	1	5	6.5	2	13	-6.5	42.25
ID2DG2S4	8	5	6.5	3	8	-1.5	2.25
ID2DG3S5	13	5	6.5	3	4.5	2	4
ID2DG4S2	15	5	6.5	3	5	-1.5	2.25
ID2DG4S3	16	5	6.5	0	18.5	-12	144
ID2DG5S1	17	5	6.5	2	13	-6.5	42.25
ID2DG1S4	4	4	11.5	6	2.5	9	81
ID2DG2S1	5	4	11.5	6	2.5	9	81
ID2DG2S2	6	4	11.5	3	8	3.5	12.25
ID2DG3S4	12	4	11.5	5	4.5	7	49
ID2DG3S1	9	2	15.5	1	16.5	-1	1
ID2DG3S2	10	2	15.5	2	13	2.5	6.25
ID2DG3S3	11	2	15.5	2	13	2.5	6.25
ID2DG6S1	18	2	15.5	2	13	2.5	6.25
ID2DG7S1	19	1	18	1	16.5	1.5	2.25
ID2DG1S3	3	0	19	0	18.5	0.5	0.25
N =	19						Sum D$_i^2$ 555.5

		Tie X	Tie1 3	Tie 2 6	Tie 3 4	Tie 4 4	Tie 5	Tie 6
Sum X2c	540.5		2	17.5	5	5		
		Tie Y	Tie1 5	Tie 2 2	Tie 3 2	Tie 4 5	Tie 5 2	Tie 6 2
SumY2c	548		10	0.5	0.5	10	0.5	0.5
Rs	0.49							
Pearson-Rs	0.51							
t	2.32							

Industrial subjects (Correspondence)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{541.5 + 559.5 - 122.5}{2\sqrt{541.5 * 559.5}}$$

$$R_s = \frac{978.5}{2\sqrt{302969.25}}$$

$$R_s = 0.89$$

$$t = R_s \sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.89 \sqrt{\frac{19-2}{1-(0.89)^2}}$$

$$t = 0.89(9.0)$$

$$t = 8.0$$

$$df(17) @ 0.05 = 1.740$$

Industrial subjects (Creativity)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{540.5 + 548 - 555.5}{2\sqrt{540.5 * 548}}$$

$$R_s = \frac{533}{2\sqrt{296194.00}}$$

$$R_s = 0.49$$

$$t = R_s \sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.49 \sqrt{\frac{19-2}{1-(0.49)^2}}$$

$$t = 0.49(4.7)$$

$$t = 2.3$$

$$df(17) @ 0.05 = 1.740$$

Using All judges Re-judging (2D) Vis Com Subjects

Subject	Subject Num	Sum of 1st judge Corr	Rank 1	Sum of 2nd judge Corr	Rank 2	D_i	D_i²
VC2DG1S1	1	9	1.5	15	2	-0.5	0.25
VC2DG2S1	5	9	1.5	13	3	-1.5	2.25
VC2DG5S1	14	8	3	11	4	-1	1
VC2DG3S1	9	7	4	23	1	3	9
VC2DG1S2	2	6	5	9	5.5	-0.5	0.25
VC2DG2S4	8	5	6.5	9	5.5	1	1
VC2DG3S2	10	5	6.5	8	7	-0.5	0.25
VC2DG2S2	6	4	8	2	8.5	-1.5	2.25
VC2DG4S1	12	3	9	2	14.5	-5.5	30.25
VC2DG1S4	4	2	10.5	3	11.5	-1	1
VC2DG5S4	16	2	10.5	5	8	2.5	6.25
VC2DG1S3	3	1	14.5	3	11.5	3	9
VC2DG2S3	7	1	14.5	4	9.5	5	25
VC2DG3S3	11	1	14.5	2	14.5	0	0
VC2DG4S2	13	1	14.5	2	14.5	0	0
VC2DG5S6	18	1	14.5	1	17.5	-3	9
VC2DG5S7	19	1	14.5	2	14.5	0	0
VC2DG5S2	15	0	18.5	0	19	-0.5	0.25
VC2DG5S5	17	0	18.5	1	17.5	1	1
N	19						Sum D² 98

		Tie X		Tie 1	Tie 2	Tie 3	Tie 4	Tie 5	Tie 6
Sum X2c	550.5			2	2	2	6	2	
				0.5	0.5	0.5	17.5	0.5	
		Tie Y		Tie 1	Tie 2	Tie 3	Tie 4	Tie 5	Tie 6
SumY2c	563			2	2	2	4	2	0
				0.5	0.5	0.5	5	0.5	0
Rs	0.91								
Pearson-Rs	0.91								
t	9.17								

Subject	Subject Num	Sum of 1st judge Creat	Rank 1	Sum of 2nd judge Creat	Rank 2	D_i	D_i²
VC2DG2S2	6	14	1	3	9.5	-8.5	72.25
VC2DG2S1	5	13	2	9	1	1	1
VC2DG1S1	1	9	3	8	2	1	1
VC2DG1S2	2	8	4	5	6	-2	4
VC2DG3S1	9	7	5	6	3.5	1.5	2.25
VC2DG4S1	14	6	6	4	8	-2	4
VC2DG3S2	10	6	6	4	3.5	4.5	20.25
VC2DG4S2	13	5	8	5	6	2	4
VC2DG5S4	16	5	8	5	6	2	4
VC2DG4S1	12	3	10	3	9.5	0.5	0.25
VC2DG1S3	3	2	12.5	1	15.5	-3	9
VC2DG1S4	4	2	12.5	2	11.5	1	1
VC2DG2S3	7	2	12.5	1	15.5	-3	9
VC2DG5S6	18	2	12.5	2	19	-6.5	42.25
VC2DG2S4	8	1	17	2	11.5	5.5	30.25
VC2DG5S3	11	1	17	1	15.5	1.5	2.25
VC2DG5S2	15	1	17	1	15.5	1.5	2.25
VC2DG5S5	17	1	17	1	15.5	1.5	2.25
VC2DG5S7	19	1	17	1	15.5	1.5	2.25
N	19						Sum D² 213.5

		Tie X		Tie 1	Tie 2	Tie 3	Tie 4	Tie 5	Tie 6
Sum X2c	553			3	4	5	0		
				2	5	10	0		
		Tie Y		Tie 1	Tie 2	Tie 3	Tie 4	Tie 5	Tie 6
SumY2c	566.5			2	3	2	2	5	0
				0.5	2	0.5	0.5	10	0
Rs	0.81								
Pearson-Rs	0.81								
t	5.68								

Vis-Com subjects (Correspondence)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{550.5 + 563 - 98}{2\sqrt{550.5 * 563}}$$

$$R_s = \frac{1015.5}{2\sqrt{309931.5}}$$

$$R_s = 0.91$$

$$t = R_s \sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.91\sqrt{\frac{19-2}{1-(0.91)^2}}$$

$$t = 0.91(9.9)$$

$$t = 9.1$$

$$df(17)@\,0.05 = 1.740$$

Vis-Com subjects (Creativity)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{553 + 566.5 - 213.5}{2\sqrt{553 * 566.5}}$$

$$R_s = \frac{906}{2\sqrt{313274.5}}$$

$$R_s = 0.81$$

$$t = R_s \sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.81\sqrt{\frac{19-2}{1-(0.81)^2}}$$

$$t = 0.81(7.03)$$

$$t = 5.68$$

$$df(17)@\,0.05 = 1.740$$

Using All judges Re-judging (2D) Non-Design subjects

Subject	Subject Num	Sum of 1st judge Corr	Rank 1	Sum of 2nd judge Corr	Rank 2	Di	Di²
ND2DG1S1	1	3	3	3	4	6.5	-3.5	12.25
ND2DG1S2	2	3	3	3	4	8.5	-5.5	30.25
ND2DG1S4	4	3	3	3	4	6.5	-3.5	12.25
ND2DG1S5	5	3	3	3	10	2	1	1
ND2DG4S1	9	3	3	3	5	4.5	-1.5	2.25
ND2DG5S1	10	2	2	7	3	8.5	-1.5	2.25
ND2DG7S2	11	2	2	7	6	3	4	16
ND2DG9S2	14	2	2	7	5	4.5	2.5	6.25
ND2DG2S3	6	1	1	10.5	2	11.5	-1	1
ND2DG9S1	13	1	1	10.5	13	1	9.5	90.25
ND2DG10S1	15	0	0	13	2	11.5	1.5	2.25
ND2DG1S3	3	0	0	13	2	11.5	1.5	2.25
ND2DG2S4	7	0	0	13	2	11.5	1.5	2.25
ND2DG3S1	8	0	0	13	0	14.5	-1.5	2.25
ND2DG7S3	12	0	0	13	0	14.5	-1.5	2.25
N	15						Sum D² 185

		Tie X		Tie1 5	Tie2 8	Tie3 2	Tie4 5	Tie5	Tie6
Sum X2c	257.5			10	2	0.5	10	0
		Tie Y		Tie1 2	Tie2 2	Tie3 2	Tie4 4	Tie5 2	Tie6
SumY2c	273			2	2	2	5	2	0
				0.5	0.5	0.5	5	0.5	0
Rs	0.65
Pearson-Rs	0.67
t	3.10

Subject	Subject Num	Sum of 1st judge Creat	Rank 1	Sum of 2nd judge Creat	Rank 2	Di	Di²
ND2DG4S1	9	14	1	10	2	-1	1
ND2DG9S1	13	10	2	11	1	1	1
ND2DG1S5	5	4	4	11	11	-7	49
ND2DG7S2	11	4	4	5	4	0	0
ND2DG9S2	14	4	4	2	7	-3	9
ND2DG1S1	1	3	6.5	4	5	1.5	2.25
ND2DG1S3	3	3	6.5	3	6	0.5	0.25
ND2DG1S2	2	2	9.5	1	11	-1.5	2.25
ND2DG1S4	4	2	9.5	1	11	-1.5	2.25
ND2DG2S3	6	2	9.5	1	11	-1.5	2.25
ND2DG2S4	7	2	9.5	1	11	-1.5	2.25
ND2DG3S1	8	1	13	0	15	-2	4
ND2DG6S1	10	1	13	8	3	10	100
ND2DG7S3	12	1	13	1	11	2	4
ND2DG10S1	15	0	15	1	11	4	16
N	15						Sum D² 195.5

		Tie X		Tie1 3	Tie2 2	Tie3 4	Tie4 3	Tie5	Tie6
Sum X2c	270.5			2	0.5	5	2
		Tie Y		Tie1 7	Tie2 0	Tie3 0	Tie4 0	Tie5 0	Tie6 0
SumY2c	252			26	0	0	0	0	0
Rs	0.63
Pearson-Rs	0.65
t	2.90

Non-Design subjects (Correspondence)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{257.5 + 273 - 185}{2\sqrt{257.5 * 273}}$$

$$R_s = \frac{345.5}{2\sqrt{70297.5}}$$

$$R_s = 0.65$$

$$t = R_s \sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.65\sqrt{\frac{15-2}{1-(0.65)^2}}$$

$$t = 0.65(4.7)$$

$$t = 3.1$$

$$df(13) @ 0.05 = 1.771$$

Non-Design subjects (Creativity)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{270.5 + 252 - 195.5}{2\sqrt{270.5 * 252}}$$

$$R_s = \frac{327}{2\sqrt{68166.00}}$$

$$R_s = 0.63$$

$$t = R_s \sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.63\sqrt{\frac{15-2}{1-(0.63)^2}}$$

$$t = 0.63(4.6)$$

$$t = 2.9$$

$$df(13) @ 0.05 = 1.771$$

Using All Judges re-Judging (3D) ID subjects

Subject	Subject Num	Sum of 1st judge Prac	Rank 1	Sum of 2nd judge Prac	Rank 2	D1	D2
ID3DG2S4	5	3	10	5	7	3	9
ID3DG1S6	2	5	6	3	9.5	-3.5	12.3
ID3DG2S1	3	3	10	2	12	-2	4
ID3DG1S1	1	4	6	5	8.5	4.5	20.3
ID3DG3S1	6	7	2	5	8.5	-1.5	2.25
ID3DG5S2	15	6	3.5	6	5.5	-2	4
ID3DG2S2	4	8	1	11	1	0	0
ID3DG3S2	7	5	6	9	2	4	16
ID3DG3S3	8	5	6	8	5.5	0.5	0.25
ID3DG4S4	13	3	10	4	8	2	4
ID3DG4S1	10	1	13	3	12	1	1
ID3DG4S2	11	0	14.5	2	15	-0.5	0.25
ID3DG5S1	14	6	3.5	1	14	-11	110
ID3DG4S3	12	2	12	2	12	0	0
ID3DG3S4	9	0	14.5	3	9.5	5	25

N =15

	Sum D2 209

		Tie X		Tie1 2 0.5	Tie 2 3 2	Tie 3 3 2 0.5	Tie 4 2 0.5	Tie 5	Tie 6

Sum X2c 275

		Tie Y		Tie1 2 0.5	Tie 2 2 0.5	Tie 3 2 0.5	Tie 4 3 2	Tie 5	Tie 6

SumY2c 276.5

Rs 0.62
Pearson-Rs 0.63
t 2.86

Subject	Subject Num	Sum of 1st judge Creat	Rank 1	Sum of 2nd judge Creat	Rank 2	D1	D2
ID3DG2S4	5	4	3	2	-1	1	
ID3DG1S6	2	4	4	2	4	16	
ID3DG2S1	3	3	6	4.5	1.5	2.25	
ID3DG1S1	1	3	6	4.5	8.5	72.25	
ID3DG3S1	6	1	13	3	6.5	-3.5	12.25
ID3DG5S2	15	2	3	6.5	3	9	
ID3DG2S2	4	2	9.5	2	10	-7	49
ID3DG3S2	7	2	3	10	-0.5	0.25	
ID3DG3S3	8	2	9.5	10	-0.5	0.25	
ID3DG4S4	13	2	9.5	10	-0.5	0.25	
ID3DG4S1	10	1	9.5	10	3	9	
ID3DG4S2	11	1	13	14	-8	64	
ID3DG5S1	14	3	6	0	14	-1	1
ID3DG4S3	12	1	13	0	14	-1	1
ID3DG3S4	9	0	15	0	14	1	1

N=15

	Sum D2 238.5

		Tie X		Tie1 3 2	Tie 2 3 2	Tie 3 4 5 2	Tie 4 3 2	Tie 5	Tie 6

Sum X2c 269

		Tie Y		Tie1 3 2	Tie 2 2 0.5	Tie 3 2 0.5	Tie 4 5 10	Tie 5 3 2	Tie 6

SumY2c 265

Rs 0.55
Pearson-Rs 0.57
t 2.40

Industrial subjects (Practicality)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{275 + 276.5 - 209}{2\sqrt{275 * 276.5}}$$

$$R_s = \frac{342.5}{2\sqrt{76037.5}}$$

$$R_s = 0.62$$

$$t = R_s \sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.62 \sqrt{\frac{15-2}{1-(0.62)^2}}$$

$$t = 0.62(4.6)$$

$$t = 2.85$$

$$df(13)@\ 0.05 = 1.771$$

Industrial subjects (Creativity)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{269 + 265 - 238.5}{2\sqrt{269 * 265}}$$

$$R_s = \frac{295.5}{2\sqrt{71285.00}}$$

$$R_s = 0.55$$

$$t = R_s \sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.55 \sqrt{\frac{15-2}{1-(0.55)^2}}$$

$$t = 0.55(4.3)$$

$$t = 2.37$$

$$df(13)@\ 0.05 = 1.771$$

Using All Judges re-Judging (3D) VC subjects

Subject	Subject Num	Sum of 1st Judge Prac	Rank 1	Sum of 2nd Judge Prac	Rank 2	D1	DI2		Subject	Subject Num	Sum of 1st Judge Creat	Rank 1	Sum of 2nd Judge Creat	Rank 2	D1	DI2
VC3DG395	9	0	13.5	3	6.5	7	49		VC3DG395	8	4	8.5	6	1	2.5	6.25
VC3DG391	13	2	7	0	12.5	-5.5	30.3		VC3DG391	13	4	3.5	3	2.5	1	1
VC3DG191	1	1	10.5	2	8.5	2	4		VC3DG191	1	1	10.5	3	2.5	8	64
VC3DG392	14	3	4	6	2.5	1.5	2.25		VC3DG395	14	5	1.5	3	5.5	-4	16
VC3DG195	4	2	7	4	6	2	4		VC3DG195	4	2	7.5	3	5.5	2	4
VC3DG192	2	3	4	3	6.5	-2.5	6.25		VC3DG192	2	2	7.5	2	5.5	2	4
VC3DG364	5	0	13.5	0	12.5	1	1		VC3DG364	8	1	10.5	2	5.5	5	25
VC3DG363	7	6	2	0	12.5	-11	110		VC3DG363	7	5	1.5	1	9.5	-8	64
VC3DG461	11	1	10.5	6	2.5	8	64		VC3DG461	11	3	5	1	9.5	-4.5	20.25
VC3DG194	3	1	10.5	1	10	0.5	0.25		VC3DG194	3	2	7.5	1	9.5	-2	4
VC3DG396	10	2	7	0	12.5	-5.5	30.3		VC3DG396	10	0	13	1	9.5	3.5	12.25
VC3DG284	6	9	1	11	1	0	0		VC3DG284	6	0	13	0	13	-5.5	30.25
VC3DG462	12	1	10.5	5	4	6.5	42.3		VC3DG462	12	0	13	0	13	0	0
VC3DG261	5	3	4	2	6.5	-4.5	20.3		VC3DG261	5	0	13	0	13	0	0

							Sum DI2									Sum DI2
N = 14							364		N = 14							251
		Tie X	Tie1	Tie 2	Tie 3	Tie 4	Tie 5 Tie 6				Tie X	Tie1	Tie 2	Tie 3	Tie 4	Tie 5 Tie 6
Sum X2c	218		5	3	4	2			Sum X2c	221		2	2	4	2	
			2	2	5	0.5						0.5	0.5	5	0.5	
		Tie Y	Tie1	Tie 2	Tie 3	Tie 4 Tie 6 Tie 6					Tie Y	Tie1	Tie 2	Tie 3	Tie 4	Tie 5 Tie 6
SumY2c	221		2	2	2	4			SumY2c	215		2	4	4	3	
Rs	0.17		0.5	0.5	0.5	6			Rs	0.42		0.5	6	5	2	

Vis-Com subjects (Practicality)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{218 + 221 - 364}{2\sqrt{218 * 221}}$$

$$R_s = \frac{75}{2\sqrt{48178.0}}$$

$$R_s = 0.17$$

$$t = R_s\sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.17\sqrt{\frac{14-2}{1-(0.17)^2}}$$

$$t = 0.17(3.5)$$

$$t = .60$$

$$df(12)@\,0.05 = 1.782$$

Vis-Com subjects (Creativity)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{221 + 215 - 251}{2\sqrt{221 * 215}}$$

$$R_s = \frac{185}{2\sqrt{47515.0}}$$

$$R_s = 0.42$$

$$t = R_s\sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.42\sqrt{\frac{14-2}{1-(0.42)^2}}$$

$$t = 0.42(3.82)$$

$$t = 1.6$$

$$df(12)@\,0.05 = 1.782$$

Using All Judges re-Judging (3D) Non-Design subjects

Subject	Subject Num	Sum of 1st Judge Prac	Rank 1	Sum of 2nd Judge Prac	Rank 2	D1	DI2		Subject	Subject Num	Sum of 1st Judge Crea	Rank 1	Sum of 2nd Judge Crea	Rank 2	D1	DI2
ND3DG3S4	4	3	1	3	1	0	0		ND3DG3S4	4	2	2	1	2.5	-0.5	0.25
ND3DG3S3	3	2	2.5	2	2.5	0	0		ND3DG3S3	3	3	1	1	2.5	-1.5	2.25
ND3DG2S1	1	2	2.5	2	2.5	0	0		ND3DG2S1	1	1	5	0	6	-1	1
ND3DG3S2	2	0	5.5	1	4.5	1	1		ND3DG3S2	2	1	5	1	2.5	2.5	6.25
ND3DG6S1	5	0	5.5	1	4.5	1	1		ND3DG6S1	5	1	5	1	2.5	2.5	6.25
ND3DG9S1	6	0	5.5	0	5.5	-1	1		ND3DG9S1	6	1	5	0	6	-1	1
ND3DG10S1	7	0	5.5	0	5.5	-1	1		ND3DG10S1	7	1	5	0	6	-1	1

N = 7 Sum DI2 = 4   N = 7 Sum DI2 = 18

Left:
Sum X2c 22.5 Tie X Tie1 2 Tie2 4 / 0.5 5 Tie 3 Tie 4 Tie 5 Tie 6
SumY2c 26.5 Tie Y Tie1 2 Tie2 2 / 0.5 0.5 Tie 3 2 / 0.5 Tie 4 Tie 5 Tie 6
Rs 0.92
Pearson-Rs 0.93
t 5.30

Right:
Sum X2c 18 Tie X Tie1 5, 10 Tie2 Tie 3 Tie 4 Tie 5 Tie 6
SumY2c 21 Tie Y Tie1 4, 5 Tie2 3, 2 Tie 3 Tie 4 Tie 5 Tie 6
Rs 0.54
Pearson-Rs 0.66
t 1.43

Non-Design subjects (Practicality)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{22.5 + 26.5 - 4}{2\sqrt{22.5 * 26.5}}$$

$$R_s = \frac{45}{2\sqrt{596.25}}$$

$$R_s = 0.92$$

$$t = R_s \sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.92 \sqrt{\frac{7-2}{1-(0.92)^2}}$$

$$t = 0.92(5.7)$$

$$t = 5.25$$

$$df(5) @ 0.05 = 2.015$$

Non-Design subjects (Creativity)

$$R_s = \frac{\sum X_c^2 + \sum Y_c^2 - \sum D_i^2}{2\sqrt{\sum X_c^2 * \sum Y_c^2}}$$

$$R_s = \frac{18 + 21 - 18}{2\sqrt{18 * 21}}$$

$$R_s = \frac{21}{2\sqrt{378.00}}$$

$$R_s = 0.54$$

$$t = R_s \sqrt{\frac{N-2}{1-R_s^2}}$$

$$t = 0.54 \sqrt{\frac{7-2}{1-(0.54)^2}}$$

$$t = 0.54(2.66)$$

$$t = 1.44$$

$$df(5) @ 0.05 = 2.015$$

Appendix G

Instructions (Group A)

Instructions 2D Drawing

The purpose of this investigation is to explore 4 different strategies people could use to combine visual parts to form a mental image. Basically you will be give three parts and using these pars we would like you to develop a new form. You can make as many new forms as you like. In order to achieve this we would like you to utilise the suggested strategy at the time independent from any other strategy. There will be four different strategies explored (Refer to the hand out given). Note in the handout there are 4 Ellipse. They are labelled strategy ABCD. Also note that there are two tasks within each Strategy, you will be instructed what to do for each task in the different strategies, however, some of the tasks will be identical (point this out in the diagram they have). For each of the strategies there will be 3 trials. Therefore a total of 12 trials or problem sets will be presented to you.

2D | **These explore two dimensional mental synthesis.** |

For the sake of consistency throughout these instructions we will define the word **Form** to mean **recognisable form.**

Each strategy will have staged tasks for you to do. Listen carefully to the instructions for each staged task.

Note the materials supplied to you are as follows:
      two colour coded folders
      one pad of white pre-printed drawing paper | Hold up the sheets
      one pad of light yellow pre-printed drawing paper |
      (**In general the white paper is for task 1 and the yellow paper is for task 2**)
      several sharpened drawing pencils and erasers (**these drawing pencils are soft but you will still need to press firmly so that your work will be able to be photocopied**)

Explain the pre-printed sheets in terms of the coded areas. Strategy (represented by S followed by Letters ABCD) -Task numbers (represented by T followed by 1 & 2)- Problem numbers (they are to write in the problem number) & Response numbers (they are to write in the response number). Talk about how to use them. Tell the subjects not to write in the areas on the right hand side of the papers.

You have before you a slip cover with 15 drawings of basic parts. For the purposes of a common understanding let us go through the names of each part. (Indicate the names of the parts to them.)

In general each trial consists of three randomly selected parts which will be given to you. At the beginning of each of the trials I will let you know which colour paper you are to use and I will call out the strategy letter and the trial number. You are to circle the appropriate S letter and the appropriate T number at the top of the pre-printed paper provided. Also in the circles next to Prob. & Respon. you are to put the problem number and response number you are currently working on. When we start I will call out the names of the three parts to be used in that trial. I will repeat the names to ensure that the names were heard correctly. You are to note in the space provided and on each paper you use, the parts you were given. Do not write in the spaces on the right hand side of the paper this area is for coding purposes.

2D

As soon as the parts are named you are to attempt to construct a recognisable form from the parts given. These are given in any order and sometimes more than once. All the parts must be

used. If two of the same part is mentioned then both are to be used in your created form. The form could be anything as long as it could be recognised by another person and that it could be easily named without a long description. You can vary the size, position, orientation, or proportion (eg. an equilateral triangle can be shaped into an isosceles triangle) of the parts but you are not allowed to bend, trim or distort the individual parts in any way. (a circle can not be made into an ellipse)

Here are examples of possible mental constructions.
Say you are given (the letter L, a circle, and a square).
You would draw a square. Then add an upside-down L to the left side of the square. Shrink the circle and place it in the middle of the square. Result a flag on a flag pole.

You are to Draw a circle around your final form and write down the name or description next the your recognisable form. Then you are to the turn the page over and get a new piece of paper and proceed with creating the next form if you have finished one and the available time has not run out. Basically one solution one piece of paper.

Next example! You would draw a circle. Draw the square around the circle. Draw the L at a 45 degree angle on top of the square forming a V pattern. The result is a TV set.

Remember to ensure that you have circled the appropriate S number and the appropriate T number at the top of the pre-printed paper provided, the parts you were given are noted on the paper.

Strategy A - Task one

In this task and these trials remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to **use drawing**. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your form.

Strategy A - Task Two
In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to imagine observing the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms you have created in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. This is done so your form can be identified. Even if you only have one drawing on the page still circle it for purposes of consistency. Once you have reinterpreted the original form (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next form. Remember one form one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D

For instance: Remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy B - Task one
Even though this is a new strategy remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper. Use the white pre-printed paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In this strategy you are to close your eyes and attempt to mentally construct your solution form from the 3 parts given.
You can only open your eyes long enough to write down the name/description of the solution. Once you have done this close your eyes again and develop another form. **After the 3 minutes you will be allowed to draw your named/described forms.** When you are drawing you cannot change anything you wrote in naming/describing the forms. This is repeated for each form created from the three parts named. Once the 3 minute time period is over and after you finish drawing the forms, you will be given three new parts and asked to do the same task again.

Strategy B - Task Two
REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw to develop your forms. Draw them in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form.   You are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D
For instance remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy C - Task one

REMEMBER BEFORE WHEN YOU DREW TO DEVELOP YOUR FORMS - WE ARE GOING TO DO THIS AGAIN.

In this task remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to use drawing. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your ideas.

Strategy C - Task Two
In this task you are to reinterpret your previous solutions. Spread your previous solutions (the ones on the white paper) out in front of you and look at them. You are to pick one, then close your eyes, you are to explore your constructions by imagining the forms being rotated around or forming a mirror image of the form. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction. You are to observe the synthesised form from different orientations. **You are to do this using only mental imagery.**
You can only open your eyes long enough to write down the name/description of the solution, the parts it was derived from, and the trial number strategy number etc... then draw this new imagined form. Only open your eyes after you have new interpretation. Do not develop your ideas on paper. You are to use the **light yellow paper** to draw on. After you have drawn the reinterpreted form you are to circle the form to indicate your new interpretation. Remember one form one piece of paper. Once you have done this turn both the white paper and the yellow paper over and pick another previous form then close your eyes again and develop another new form. You may do as many as you like before the end of a 9 minute time period. It is also up to you how many re-interpretations per original you do and how many originals you re-interpret.

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D
For instance remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy D - Task one
This is a new type of strategy. In this strategy you are to mentally develop a form.
At this stage you are only to develop and name/describe your new form. A form which is a representation of a general category you are given.

Table 2

Allowable categories in experiments.

Category one	Examples
1. Road Signs	
2. Bank Logo	
3. Graphic symbols for operating equipment	
4. Sporting Graphic symbol (kind of sport)	
5. Graphic form which portrays a physical sense (sight , sound , touch , taste)	
6. A new International symbol for tourists	
7. Safety symbols for a hazard	
8. A logo for some new small business	

Before you start remember to write down the name of, strategy number, and the trial number etc.... Once you are given the category you are to close your eyes and only open them long enough to write down the name/description of a **form**. You are to turn the page over preparing for the next form (**using the white pre-printed paper**). Then you are to close your eyes again without looking around the room.

You can create as many forms as you like before the end of a 3 minute time period.

2D

Say you were given the category of a **Logo for an international company** you are to develop a new shape for a new corporation, for example a new airline logo, then another for a fast food hamburger chain logo, then a car manufacturer logo, etc...

Once the 3 minutes is over then you will be given another new category and another 3 minutes.

2D

Suppose now you are given the category of developing a **public service logo**, the shape of the form or logo could symbolise a youth camp, next a shape of another logo could reflect a child care centre, then you could develop a logo for legal aid etc..

But remember one idea, one paper. This is repeated 3 times.

PART 2

Now that you have done this 3 times you will go back and **draw to develop** your named/described forms using **three randomly selected parts given to you** for each of the three trials from task one. As soon as the parts are named you are to write them down. You are to draw on the paper you used in giving the name (the white papers). You are to circle the final form you developed.

Now Gather your papers from the first problem set. Find the ones you have marked as Problem 1. As soon as the parts are named you are to go back and draw to develop the

named/described forms from problem one - task one (which you have just completed). Once **all of you** have finished problem set one we will move on to the second problem set and responses. You will progress through all of the problem sets in order therefore, you will perform this task a total of 3 times.

Strategy D - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

This task is identical to the ones you have done before in reinterpreting your previous work so you should be familiar with it. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
Once you have developed and reorientated a form which you can reinterpret, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. **It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period**

As before remember to note the parts you were given, the strategy number, the task number etc… at the top of the paper.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc…) .

Instructions (Group B)

Instructions 2D Drawing

The purpose of this investigation is to explore 4 different strategies people could use to combine visual parts to form a mental image. Basically you will be give three parts and using these pars we would like you to develop a new form. You can make as many new forms as you like. In order to achieve this we would like you to utilise the suggested strategy at the time independent from any other strategy. There will be four different strategies explored (Refer to the hand out given). Note in the handout there are 4 Ellipse. They are labelled strategy ABCD. These may not necessarily be in that order. The sheet given to you may be different. We will proceed from the top down consequently for example strategy B may be done first because it is first on the list. Also note that there are two tasks within each Strategy, you will be instructed what to do for each task in the different strategies, however, some of the tasks will be identical (point this out in the diagram they have). For each of the strategies there will be 3 trials. Therefore a total of 12 trials or problem sets will be presented to you.

2D | These explore two dimensional mental synthesis.

For the sake of consistency throughout these instructions we will define the word **Form** to mean **recognisable form.**

Each strategy will have staged tasks for you to do. Listen carefully to the instructions for each staged task.

Note the materials supplied to you are as follows:
two colour coded folders
one pad of white pre-printed drawing paper | Hold up the sheets
one pad of light yellow pre-printed drawing paper |
(**In general the white paper is for task 1 and the yellow paper is for task 2**)
several sharpened drawing pencils and erasers (**these drawing pencils are soft but you will still need to press firmly so that your work will be able to be photocopied**)

Explain the pre-printed sheets in terms of the coded areas. Strategy (represented by S followed by Letters ABCD) -Task numbers (represented by T followed by 1 & 2)- Problem numbers (they are to write in the problem number) & Response numbers (they are to write in the response number). Talk about how to use them. Tell the subjects not to write in the areas on the right hand side of the papers.

You have before you a slip cover with 15 drawings of basic parts. For the purposes of a common understanding let us go through the names of each part. (Indicate the names of the parts to them.)

In general each trial consists of three randomly selected parts which will be given to you. At the beginning of each of the trials I will let you know which colour paper you are to use and I will call out the strategy letter and the trial number. You are to circle the appropriate S letter and the appropriate T number at the top of the pre-printed paper provided. Also in the circles next to Prob. & Respon. you are to put the problem number and response number you are currently working on. When we start I will call out the names of the three parts to be used in that trial. I will repeat the names to ensure that the names were heard correctly. You are to note in the space provided and on each paper you use, the parts you were given. Do not write in the spaces on the right hand side of the paper this area is for coding purposes.

2D

As soon as the parts are named you are to attempt to construct a recognisable form from the parts given. These are given in any order and sometimes more than once. All the parts must be

used. If two of the same part is mentioned then both are to be used in your created form. The form could be anything as long as it could be recognised by another person and that it could be easily named without a long description. You can vary the size, position, orientation, or proportion (eg. an equilateral triangle can be shaped into an isosceles triangle) of the parts but you are not allowed to bend, trim or distort the individual parts in any way. (a circle can not be made into an ellipse)

Here are examples of possible mental constructions.
Say you are given (the letter L, a circle, and a square).
You would draw a square. Then add an upside-down L to the left side of the square. Shrink the circle and place it in the middle of the square. Result a flag on a flag pole.

You are to Draw a circle around your final form and write down the name or description next the your recognisable form. Then you are to the turn the page over and get a new piece of paper and proceed with creating the next form if you have finished one and the available time has not run out. Basically one solution one piece of paper.

Next example! You would draw a circle. Draw the square around the circle. Draw the L at a 45 degree angle on top of the square forming a V pattern. The result is a TV set.

Remember to ensure that you have circled the appropriate S number and the appropriate T number at the top of the pre-printed paper provided, the parts you were given are noted on the paper.

Strategy B - Task one
Even though this is a new strategy remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper. Use the white pre-printed paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In this strategy you are to close your eyes and attempt to mentally construct your solution form from the 3 parts given.
You can only open your eyes long enough to write down the name/description of the solution. Once you have done this close your eyes again and develop another form. **After the 3 minutes you will be allowed to draw your named/described forms. When you are drawing** you cannot change anything you wrote in naming/describing the forms. This is repeated for each form created from the three parts named. Once the 3 minute time period is over and after you finish drawing the forms, you will be given three new parts and asked to do the same task again.

Strategy B - Task Two
In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw to develop your forms. Draw them in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form. You are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D
For instance remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy C - Task one
In this task remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to use drawing. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your ideas.

Strategy C - Task Two
In this task you are to reinterpret your previous solutions. Spread your previous solutions (the ones on the white paper) out in front of you and look at them. You are to pick one, then close your eyes, you are to explore your constructions by imagining the forms being rotated around or forming a mirror image of the form. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction. You are to observe the synthesised form from different orientations. **You are to do this using only mental imagery.**
You can only open your eyes long enough to write down the name/description of the solution, the parts it was derived from, and the trial number strategy number etc... then draw this new imagined form. Only open your eyes after you have new interpretation. Do not develop your ideas on paper. You are to use the **light yellow paper** to draw on. After you have drawn the reinterpreted form you are to circle the form to indicate your new interpretation. Remember one form one piece of paper. Once you have done this turn both the white paper and the yellow paper over and pick another previous form then close your eyes again and develop another new form. You may do as many as you like before the end of a 9 minute time period. It is also up to you how many re-interpretations per original you do and how many originals you re-interpret.

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

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For instance remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy A - Task one

REMEMBER BEFORE WHEN YOU DREW TO DEVELOP YOUR FORMS - WE ARE GOING TO DO THIS AGAIN.

In this task and these trials remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to **use drawing**. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your form.

Strategy A - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to imagine observing the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms you have created in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. This is done so your form can be identified. Even if you only have one drawing on the page still circle it fotr purposes of consistency. Once you have reinterpreted the original form (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next form. Remember one form one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D
For instance: Remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

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Strategy D - Task one

This is a new type of strategy. In this strategy you are to mentally develop a form.
At this stage you are only to develop and name/describe your new form. A form which is a representation of a general category you are given.

> **2D only**
> In this particular task you will also be given a randomly selected category from 8 different categories. You are to use this random category to develop your form. For example you may be given a category from one of the following. **Read them to the subjects**

Table 2

Allowable categories in experiments.

	Category one	Examples
1.	Road Signs	
2.	Bank Logo	
3.	Graphic symbols for operating equipment	
4.	Sporting Graphic symbol (kind of sport)	
5.	Graphic form which portrays a physical sense (sight , sound , touch , taste)	
6.	A new International symbol for tourists	
7.	Safety symbols for a hazard	
8.	A logo for some new small business	

Before you start remember to write down the name of, strategy number, and the trial number etc.... Once you are given the category you are to close your eyes and only open them long enough to write down the name/description of a **form**. You are to turn the page over preparing for the next form (**using the white pre-printed paper**). Then you are to close your eyes again without looking around the room.
You can create as many forms as you like before the end of a 3 minute time period.

> **2D**
> Say you were given the category of a **Logo for an international company** you are to develop a new shape for a new corporation, for example a new airline logo, then another for a fast food hamburger chain logo, then a car manufacturer logo, etc...

Once the 3 minutes is over then you will be given another new category and another 3 minutes.

> **2D**
> Suppose now you are given the category of developing a **public service logo**, the shape of the form or logo could symbolise a youth camp, next a shape of another logo could reflect a child care centre, then you could develop a logo for legal aid etc..

But remember one idea, one paper. This is repeated 3 times.

PART 2

Now that you have done this 3 times you will go back and **draw to develop** your named/described forms using **three randomly selected parts given to you** for each of the three trials from task one. As soon as the parts are named you are to write them down. You are to draw on the paper you used in giving the name (the white papers). You are to circle the final form you developed.

Now Gather your papers from the first problem set. Find the ones you have marked as Problem 1. As soon as the parts are named you are to go back and draw to develop the

named/described forms from problem one - task one (which you have just completed). Once **all of you** have finished problem set one we will move on to the second problem set and responses. You will progress through all of the problem sets in order therefore, you will perform this task a total of 3 times.

Strategy D - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

This task is identical to the ones you have done before in reinterpreting your previous work so you should be familiar with it. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
Once you have developed and reorientated a form which you can reinterpret, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. **It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period**

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Instructions (Group C)

<u>Instructions   2D Drawing</u>

The purpose of this investigation is to explore 4 different strategies people could use to combine visual parts to form a mental image. Basically you will be give three parts and using these pars we would like you to develop a new form. You can make as many new forms as you like. In order to achieve this we would like you to utilise the suggested strategy at the time independent from any other strategy. There will be four different strategies explored (Refer to the hand out given). Note in the handout there are 4 Ellipse. They are labelled strategy ABCD. These may not necessarily be in that order. The sheet given to you may be different. We will proceed from the top down consequently for example strategy C may be done first because it is first on the list. Also note that there are two tasks within each Strategy, you will be instructed what to do for each task in the different strategies, however, some of the tasks will be identical (point this out in the diagram they have). For each of the strategies there will be 3 trials. Therefore a total of 12 trials or problem sets will be presented to you.

2D | **These explore two dimensional mental synthesis.**

For the sake of consistency throughout these instructions we will define the word **Form** to mean **recognisable form.**

Each strategy will have staged tasks for you to do. Listen carefully to the instructions for each staged task.

Note the materials supplied to you are as follows:
      two colour coded folders
      one pad of white pre-printed drawing paper | Hold up the sheets
      one pad of light yellow pre-printed drawing paper |
      (**In general the white paper is for task 1 and the yellow paper is for task 2**)
      several sharpened drawing pencils and erasers (**these drawing pencils are soft but you will still need to press firmly so that your work will be able to be photocopied**)

Explain the pre-printed sheets in terms of the coded areas. Strategy (represented by S followed by Letters ABCD) -Task numbers (represented by T followed by 1 & 2)- Problem numbers (they are to write in the problem number) & Response numbers (they are to write in the response number). Talk about how to use them. Tell the subjects not to write in the areas on the right hand side of the papers.

You have before you a slip cover with 15 drawings of basic parts. For the purposes of a common understanding let us go through the names of each part. (Indicate the names of the parts to them.)

In general each trial consists of three randomly selected parts which will be given to you. At the beginning of each of the trials I will let you know which colour paper you are to use and I will call out the strategy letter and the trial number. You are to circle the appropriate S letter and the appropriate T number at the top of the pre-printed paper provided. Also in the circles next to Prob. & Respon. you are to put the problem number and response number you are currently working on. When we start I will call out the names of the three parts to be used in that trial. I will repeat the names to ensure that the names were heard correctly. You are to note in the space provided and on each paper you use, the parts you were given. Do not write in the spaces on the right hand side of the paper this area is for coding purposes.

2D

As soon as the parts are named you are to attempt to construct a recognisable form from the parts given. These are given in any order and sometimes more than once. All the parts must be

used. If two of the same part is mentioned then both are to be used in your created form. The form could be anything as long as it could be recognised by another person and that it could be easily named without a long description. You can vary the size, position, orientation, or proportion (eg. an equilateral triangle can be shaped into an isosceles triangle) of the parts but you are not allowed to bend, trim or distort the individual parts in any way. (a circle can not be made into an ellipse)

Here are examples of possible mental constructions.
Say you are given (the letter L, a circle, and a square).
You would draw a square. Then add an upside-down L to the left side of the square. Shrink the circle and place it in the middle of the square. Result a flag on a flag pole.

You are to Draw a circle around your final form and write down the name or description next the your recognisable form. Then you are to the turn the page over and get a new piece of paper and proceed with creating the next form if you have finished one and the available time has not run out. Basically one solution one piece of paper.

Next example! You would draw a circle. Draw the square around the circle. Draw the L at a 45 degree angle on top of the square forming a V pattern. The result is a TV set.

Remember to ensure that you have circled the appropriate S number and the appropriate T number at the top of the pre-printed paper provided, the parts you were given are noted on the paper.

Strategy C - Task one
In this task remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to use drawing. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your ideas.

Strategy C - Task Two
In this task you are to reinterpret your previous solutions. Spread your previous solutions (the ones on the white paper) out in front of you and look at them. You are to pick one, then close your eyes, you are to explore your constructions by imagining the forms being rotated around or forming a mirror image of the form. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction. You are to observe the synthesised form from different orientations. **You are to do this using only mental imagery.**
You can only open your eyes long enough to write down the name/description of the solution, the parts it was derived from, and the trial number strategy number etc... then draw this new imagined form. Only open your eyes after you have new interpretation. Do not develop your ideas on paper. You are to use the **light yellow paper** to draw on. After you have drawn the reinterpreted form you are to circle the form to indicate your new interpretation. Remember one form one piece of paper. Once you have done this turn both the white paper and the yellow paper over and pick another previous form then close your eyes again and develop another new form. You may do as many as you like before the end of a 9 minute time period. It is also up to you how many re-interpretations per original you do and how many originals you re-interpret.

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D

For instance remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy B - Task one
Even though this is a new strategy remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper. Use the white pre-printed paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In this strategy you are to close your eyes and attempt to mentally construct your solution form from the 3 parts given.
You can only open your eyes long enough to write down the name/description of the solution. Once you have done this close your eyes again and develop another form. **After the 3 minutes you will be allowed to draw your named/described forms.** When you are drawing you cannot change anything you wrote in naming/describing the forms. This is repeated for each form created from the three parts named. Once the 3 minute time period is over and after you finish drawing the forms, you will be given three new parts and asked to do the same task again.

Strategy B - Task Two
In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw to develop your forms. Draw them in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form. You are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D
For instance remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy A - Task one

REMEMBER BEFORE WHEN YOU DREW TO DEVELOP YOUR FORMS - WE ARE GOING TO DO THIS AGAIN.

In this task and these trials remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to **use drawing**. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your form.

Strategy A - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to imagine observing the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms you have created in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. This is done so your form can be identified. Even if you only have one drawing on the page still circle it fotr purposes of consistency. Once you have reinterpreted the original form (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next form. Remember one form one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D
For instance: Remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy D - Task one
This is a new type of strategy. In this strategy you are to mentally develop a form.

At this stage you are only to develop and name/describe your new form. A form which is a representation of a general category you are given.

> **2D only**
> In this particular task you will also be given a randomly selected category from 8 different categories. You are to use this random category to develop your form. For example you may be given a category from one of the following. **Read them to the subjects**

Table 2

Allowable categories in experiments.

Category one	Examples
1. Road Signs	
2. Bank Logo	
3. Graphic symbols for operating equipment	
4. Sporting Graphic symbol (kind of sport)	
5. Graphic form which portrays a physical sense (sight , sound , touch , taste)	
6. A new International symbol for tourists	
7. Safety symbols for a hazard	
8. A logo for some new small business	

Before you start remember to write down the name of, strategy number, and the trial number etc.... Once you are given the category you are to close your eyes and only open them long enough to write down the name/description of a **form**. You are to turn the page over preparing for the next form **(using the white pre-printed paper)**. Then you are to close your eyes again without looking around the room.
You can create as many forms as you like before the end of a 3 minute time period.

> **2D**
> Say you were given the category of **a Logo for an international company** you are to develop a new shape for a new corporation, for example a new airline logo, then another for a fast food hamburger chain logo, then a car manufacturer logo, etc...

Once the 3 minutes is over then you will be given another new category and another 3 minutes.

> **2D**
> Suppose now you are given the category of developing a **public service logo**, the shape of the form or logo could symbolise a youth camp, next a shape of another logo could reflect a child care centre, then you could develop a logo for legal aid etc..

But remember one idea, one paper. This is repeated 3 times.

PART 2

Now that you have done this 3 times you will go back and **draw to develop** your named/described forms using **three randomly selected parts given to you** for each of the three trials from task one. As soon as the parts are named you are to write them down. You are to draw on the paper you used in giving the name (the white papers). You are to circle the final form you developed.

Now Gather your papers from the first problem set. Find the ones you have marked as Problem 1. As soon as the parts are named you are to go back and draw to develop the named/described forms from problem one - task one (which you have just completed). Once

all of you have finished problem set one we will move on to the second problem set and responses. You will progress through all of the problem sets in order therefore, you will perform this task a total of 3 times.

Strategy D - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

This task is identical to the ones you have done before in reinterpreting your previous work so you should be familiar with it. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.

Once you have developed and reorientated a form which you can reinterpret, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. **It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period**

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Instructions (Group D)

Instructions 2D Drawing

The purpose of this investigation is to explore 4 different strategies people could use to combine visual parts to form a mental image. Basically you will be give three parts and using these pars we would like you to develop a new form. You can make as many new forms as you like. In order to achieve this we would like you to utilise the suggested strategy at the time independent from any other strategy. There will be four different strategies explored (Refer to the hand out given). Note in the handout there are 4 Ellipse. They are labelled strategy ABCD. These may not necessarily be in that order. The sheet given to you may be different. We will proceed from the top down consequently for example strategy C may be done first because it is first on the list. Also note that there are two tasks within each Strategy, you will be instructed what to do for each task in the different strategies, however, some of the tasks will be identical (point this out in the diagram they have). For each of the strategies there will be 3 trials. Therefore a total of 12 trials or problem sets will be presented to you.

2D | **These explore two dimensional mental synthesis.**

For the sake of consistency throughout these instructions we will define the word **Form** to mean **recognisable form.**

Each strategy will have staged tasks for you to do. Listen carefully to the instructions for each staged task.

Note the materials supplied to you are as follows:
> two colour coded folders
> one pad of white pre-printed drawing paper | Hold up the sheets
> one pad of light yellow pre-printed drawing paper |
> (**In general the white paper is for task 1 and the yellow paper is for task 2**)
> several sharpened drawing pencils and erasers (**these drawing pencils are soft but you will still need to press firmly so that your work will be able to be photocopied**)

Explain the pre-printed sheets in terms of the coded areas. Strategy (represented by S followed by Letters ABCD) -Task numbers (represented by T followed by 1 & 2)- Problem numbers (they are to write in the problem number) & Response numbers (they are to write in the response number). Talk about how to use them. Tell the subjects not to write in the areas on the right hand side of the papers.

You have before you a slip cover with 15 drawings of basic parts. For the purposes of a common understanding let us go through the names of each part. (Indicate the names of the parts to them.)

In general each trial consists of three randomly selected parts which will be given to you. At the beginning of each of the trials I will let you know which colour paper you are to use and I will call out the strategy letter and the trial number. You are to circle the appropriate S letter and the appropriate T number at the top of the pre-printed paper provided. Also in the circles next to Prob. & Respon. you are to put the problem number and response number you are currently working on. When we start I will call out the names of the three parts to be used in that trial. I will repeat the names to ensure that the names were heard correctly. You are to note in the space provided and on each paper you use, the parts you were given. Do not write in the spaces on the right hand side of the paper this area is for coding purposes.

2D

As soon as the parts are named you are to attempt to construct a recognisable form from the parts given. These are given in any order and sometimes more than once. All the parts must be

used. If two of the same part is mentioned then both are to be used in your created form. The form could be anything as long as it could be recognised by another person and that it could be easily named without a long description. You can vary the size, position, orientation, or proportion (eg. an equilateral triangle can be shaped into an isosceles triangle) of the parts but you are not allowed to bend, trim or distort the individual parts in any way. (a circle can not be made into an ellipse)

Here are examples of possible mental constructions.
Say you are given (the letter L, a circle, and a square).
You would draw a square. Then add an upside-down L to the left side of the square. Shrink the circle and place it in the middle of the square. Result a flag on a flag pole.

You are to Draw a circle around your final form and write down the name or description next the your recognisable form. Then you are to the turn the page over and get a new piece of paper and proceed with creating the next form if you have finished one and the available time has not run out. Basically one solution one piece of paper.

Next example! You would draw a circle. Draw the square around the circle. Draw the L at a 45 degree angle on top of the square forming a V pattern. The result is a TV set.

Remember to ensure that you have circled the appropriate S number and the appropriate T number at the top of the pre-printed paper provided, the parts you were given are noted on the paper.

Strategy C - Task one
In this task remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to use drawing. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your ideas.

Strategy C - Task Two
In this task you are to reinterpret your previous solutions. Spread your previous solutions (the ones on the white paper) out in front of you and look at them. You are to pick one, then close your eyes, you are to explore your constructions by imagining the forms being rotated around or forming a mirror image of the form. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction. You are to observe the synthesised form from different orientations. **You are to do this using only mental imagery.**
You can only open your eyes long enough to write down the name/description of the solution, the parts it was derived from, and the trial number strategy number etc... then draw this new imagined form. Only open your eyes after you have new interpretation. Do not develop your ideas on paper. You are to use the **light yellow paper** to draw on. After you have drawn the reinterpreted form you are to circle the form to indicate your new interpretation. Remember one form one piece of paper. Once you have done this turn both the white paper and the yellow paper over and pick another previous form then close your eyes again and develop another new form. You may do as many as you like before the end of a 9 minute time period. It is also up to you how many re-interpretations per original you do and how many originals you re-interpret.

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D

For instance remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy A - Task one

REMEMBER BEFORE WHEN YOU DREW TO DEVELOP YOUR FORMS - WE ARE GOING TO DO THIS AGAIN.

In this task and these trials remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to **use drawing**. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your form.

Strategy A - Task Two
In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to imagine observing the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms you have created in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. This is done so your form can be identified. Even if you only have one drawing on the page still circle it fotr purposes of consistency. Once you have reinterpreted the original form (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next form. Remember one form one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D
For instance: Remember   **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy B - Task one

Even though this is a new strategy remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper. Use the white pre-printed paper.

Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In this strategy you are to close your eyes and attempt to mentally construct your solution form from the 3 parts given.

You can only open your eyes long enough to write down the name/description of the solution. Once you have done this close your eyes again and develop another form. **After the 3 minutes you will be allowed to draw your named/described forms.** When you are drawing you cannot change anything you wrote in naming/describing the forms. This is repeated for each form created from the three parts named. Once the 3 minute time period is over and after you finish drawing the forms, you will be given three new parts and asked to do the same task again.

Strategy B - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw to develop your the forms. Draw different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.

If you can develop a reinterpretation of your form. You are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. **It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period**

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 2D
For instance remember the flag pole example given earlier is turned upside down and the vertical leg lengthened. **The renaming now is a golf club hitting a golf ball.**

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .
Strategy D - Task one
This is a new type of strategy. In this strategy you are to mentally develop a form.
At this stage you are only to develop and name/describe your new form. A form which is a representation of a general category you are given.

2D only
In this particular task you will also be given a randomly selected category from 8 different categories. You are to use this random category to develop your form. For example you may be given a category from one of the following. **Read them to the subjects**

Table 2

Allowable categories in experiments.

Category one	Examples
1. Road Signs	
2. Bank Logo	
3. Graphic symbols for operating equipment	
4. Sporting Graphic symbol (kind of sport)	
5. Graphic form which portrays a physical sense (sight , sound , touch , taste)	
6. A new International symbol for tourists	
7. Safety symbols for a hazard	
8. A logo for some new small business	

Before you start remember to write down the name of, strategy number, and the trial number etc.... Once you are given the category you are to close your eyes and only open them long enough to write down the name/description of a **form**. You are to turn the page over preparing for the next form (**using the white pre-printed paper**). Then you are to close your eyes again without looking around the room.

You can create as many forms as you like before the end of a 3 minute time period.

2D
Say you were given the category of **a Logo for an international company** you are to develop a new shape for a new corporation, for example a new airline logo, then another for a fast food hamburger chain logo, then a car manufacturer logo, etc...

Once the 3 minutes is over then you will be given another new category and another 3 minutes.

2D
Suppose now you are given the category of developing a **public service logo**, the shape of the form or logo could symbolise a youth camp, next a shape of another logo could reflect a child care centre, then you could develop a logo for legal aid etc..

But remember one idea, one paper. This is repeated 3 times.

PART 2

Now that you have done this 3 times you will go back and **draw to develop** your named/described forms using **three randomly selected parts given to you** for each of the three trials from task one. As soon as the parts are named you are to write them down. You are to draw on the paper you used in giving the name (the white papers). You are to circle the final form you developed.

Now Gather your papers from the first problem set. Find the ones you have marked as Problem 1. As soon as the parts are named you are to go back and draw to develop the named/described forms from problem one - task one (which you have just completed). Once **all of you** have finished problem set one we will move on to the second problem set and responses. You will progress through all of the problem sets in order therefore, you will perform this task a total of 3 times.

Strategy D - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

This task is identical to the ones you have done before in reinterpreting your previous work so you should be familiar with it. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.

Once you have developed and reorientated a form which you can reinterpret, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. **It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period**

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Appendix H

Instructions (Group A)

Instructions 3D Drawing

The purpose of this investigation is to explore 4 different strategies people could use to combine visual parts to form a mental image. Basically you will be give three parts and using these pars we would like you to develop a new form. You can make as many new forms as you like. In order to achieve this we would like you to utilise the suggested strategy at the time independent from any other strategy. There will be four different strategies explored (Refer to the hand out given). Note in the handout there are 4 Ellipse. They are labelled strategy ABCD. Also note that there are two tasks within each Strategy, you will be instructed what to do for each task in the different strategies, however, some of the tasks will be identical (point this out in the diagram they have). For each of the strategies there will be 3 trials. Therefore a total of 12 trials or problem sets will be presented to you.

3D | **These explore three dimensional mental synthesis.** |

For the sake of consistency throughout these instructions we will define the word **Form** to mean **Practical object or invention.**

Each strategy will have staged tasks for you to do. Listen carefully to the instructions for each staged task.

Note the materials supplied to you are as follows:
        two colour coded folders
        one pad of white pre-printed drawing paper | Hold up the sheets
        one pad of light yellow pre-printed drawing paper |
        (**In general the white paper is for task 1 and the yellow paper is for task 2**)
        several sharpened drawing pencils and erasers (**these drawing pencils are soft but you will still need to press firmly so that your work will be able to be photocopied**)

Explain the pre-printed sheets in terms of the coded areas. Strategy (represented by S followed by Letters ABCD) -Task numbers (represented by T followed by 1 & 2)- Problem numbers (they are to write in the problem number) & Response numbers (they are to write in the response number). Talk about how to use them. Tell the subjects not to write in the areas on the right hand side of the papers.

You have before you a slip cover with 15 drawings of basic parts. For the purposes of a common understanding let us go through the names of each part. (Indicate the names of the parts to them.)

In general each trial consists of three randomly selected parts which will be given to you. At the beginning of each of the trials I will let you know which colour paper you are to use and I will call out the strategy letter and the trial number. You are to circle the appropriate S letter and the appropriate T number at the top of the pre-printed paper provided. Also in the circles next to Prob. & Respon. you are to put the problem number and response number you are currently working on. When we start I will call out the names of the three parts to be used in that trial. I will repeat the names to ensure that the names were heard correctly. You are to note in the space provided and on each paper you use, the parts you were given. Do not write in the spaces on the right hand side of the paper this area is for coding purposes.

3D

As soon as the parts are named you are to attempt to construct a practical object from the parts given. These are given in any order and sometimes more than once. All the parts must be used, and the object must be of some practical value. If two of the same parts are mentioned then both are to be used in the object. You can vary the size, position, proportion, or orientation of the parts but you are not allowed to bend, trim or distort the individual parts in any way with the exceptions of the wire and the tube. These have been defined as bendable. The parts can be put inside one another. They can be solid or hollow. They can be made from any material including wood, metal, glass, rubber, or plastic, in any combination. In addition you are given an object category randomly selected from a list of 8 categories (**read the examples to them**). Coupled with each new set of three randomly selected parts in each trial, you are given a new randomly selected object category.

Table 2

Allowable object categories in experiments on creative invention.

Category one		Examples
1.	Furniture	Chairs, Tables, Lamps, etc...
2.	Personal Items	Jewellery, glasses, etc...
3.	Transportation	Cars, boats etc...
4.	Scientific Instruments	Measuring devices, etc...
5.	Appliances	Washing machines, toasters, etc...
6.	Tools & Utensils	Screwdrivers, spoons, etc...
7.	Weapons	Guns, missiles, etc...
8.	Toys & Games	Baseball bats, dolls etc...

Here is an example : If you are given a sphere, a rectangular block, and a cylinder. Then you are given the category of toys. You could draw a long cylinder then add the block one 1/3 the way up the cylinder and add the sphere to the top of the cylinder and say it is a **pogo stick**.

Remember to ensure that you have circled the appropriate S number and the appropriate T number at the top of the pre-printed paper provided, the parts you were given are noted on the paper and the category you were given is on the paper.

Strategy A - Task one
In this task and these trials remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to **use drawing**. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your form.

Strategy A - Task Two

In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to imagine observing the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms you have created in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. This is done so your form can be identified. Even if you only have one drawing on the page still circle it for

purposes of consistency. Once you have reinterpreted the original form (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next form. Remember one form one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 3D
For instance remember the **pogo stick** example the rectangular block slides to the bottom of the cylinder, the whole objects is scaled down and it becomes a **potato masher**.
Or
The Sphere is scaled up in size and it becomes a big **helium balloon ride**. The cylinder becomes a grab post and the rectangular block becomes a seat.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy B - Task one
Even though this is a new strategy remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper. Use the white pre-printed paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In this strategy you are to close your eyes and attempt to mentally construct your solution form from the 3 parts given.
You can only open your eyes long enough to write down the name/description of the solution. Once you have done this close your eyes again and develop another form. **After the 3 minutes you will be allowed to draw your named/described forms.** When you are drawing you cannot change anything you wrote in naming/describing the forms. This is repeated for each form created from the three parts named. Once the 3 minute time period is over and after you finish drawing the forms, you will be given three new parts and asked to do the same task again.

Strategy B - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form. You are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. It is up to you how many re-interpretations per original you do and how many

originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 3D
For instance remember the **pogo stick** example the rectangular block slides to the bottom of the cylinder, the whole objects is scaled down and it becomes a **potato masher**.
Or
The Sphere is scaled up in size and it becomes a big **helium balloon ride**. The cylinder becomes a grab post and the rectangular block becomes a seat.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy C - Task one

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In this task remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to use drawing. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your ideas.

Strategy C - Task Two
In this task you are to reinterpret your previous solutions. Spread your previous solutions (the ones on the white paper) out in front of you and look at them. You are to pick one, then close your eyes, you are to explore your constructions by imagining the forms being rotated around or forming a mirror image of the form. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction. You are to observe the synthesised form from different orientations. **You are to do this using only mental imagery.**
You can only open your eyes long enough to write down the name/description of the solution, the parts it was derived from, and the trial number strategy number etc... then draw this new imagined form. Only open your eyes after you have new interpretation. Do not develop your ideas on paper. You are to use the **light yellow paper** to draw on. After you have drawn the reinterpreted form you are to circle the form to indicate your new interpretation. Remember one form one piece of paper. Once you have done this turn both the white paper and the yellow paper over and pick another previous form then close your eyes again and develop another new form. You may do as many as you like before the end of a 9 minute time period. It is also up to you how many re-interpretations per original you do and how many originals you re-interpret.

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At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy D - Task one
This is a new type of strategy. In this strategy you are to mentally develop a form.
At this stage you are only to develop and name/describe your new form. A form which is a representation of a general category you are given.

3D only Remember we defined the word **Form** to mean **Practical object or invention.**

Before you start remember to write down the name of, strategy number, and the trial number etc.... Once you are given the category you are to close your eyes and only open them long enough to write down the name/description of a **form**. You are to turn the page over preparing for the next form (**using the white pre-printed paper**). Then you are to close your eyes again without looking around the room.
You can create as many forms as you like before the end of a 3 minute time period.

3D Say you were given the category of **Farming & Gardening** you could develop a way to plant seeds, then a novel way to get rid of weeds, next a way to protect you from the sun, and then an animal shelter etc...

Once the 3 minutes is over then you will be given another new category and another 3 minutes.

3D Suppose now you are given the category of **Sporting equipment** you could develop a new piece of equipment for children with a handicap, then a sporting device helping lost backpackers, then something to teach people to swim, etc...

But remember one idea, one paper. This is repeated 3 times.

Now that you have done this 3 times you will go back and **draw to develop** your named/described forms using **three randomly selected parts given to you** for each of the three trials from task one. As soon as the parts are named you are to write them down. You are to draw on the paper you used in giving the name (the white papers). You are to circle the final form you developed.

Now Gather your papers from the first problem set. Find the ones you have marked as Problem 1. As soon as the parts are named you are to go back and draw to develop the named/described forms from problem one - task one (which you have just completed). Once **all of you** have finished problem set one we will move on to the second problem set and responses. You will progress through all of the problem sets in order therefore, you will perform this task a total of 3 times.

Strategy D - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

This task is identical to the ones you have done before in reinterpreting your previous work so you should be familiar with it. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
Once you have developed and reorientated a form which you can reinterpret, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. **It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period**

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Instructions (Group B)

Instructions 3D Drawing

The purpose of this investigation is to explore 4 different strategies people could use to combine visual parts to form a mental image. Basically you will be give three parts and using these pars we would like you to develop a new form. You can make as many new forms as you like. In order to achieve this we would like you to utilise the suggested strategy at the time independent from any other strategy. There will be four different strategies explored (Refer to the hand out given). Note in the handout there are 4 Ellipse. They are labelled strategy ABCD. These may not necessarily be in that order. The sheet given to you may be different. We will proceed from the top down consequently for example strategy B may be done first because it is first on the list. Also note that there are two tasks within each Strategy, you will be instructed what to do for each task in the different strategies, however, some of the tasks will be identical (point this out in the diagram they have). For each of the strategies there will be 3 trials. Therefore a total of 12 trials or problem sets will be presented to you.

3D | These explore three dimensional mental synthesis.

For the sake of consistency throughout these instructions we will define the word **Form** to mean **Practical object or invention.**

Each strategy will have staged tasks for you to do. Listen carefully to the instructions for each staged task.

Note the materials supplied to you are as follows:
  two colour coded folders
  one pad of white pre-printed drawing paper | Hold up the sheets
  one pad of light yellow pre-printed drawing paper |
  (In general the white paper is for task 1 and the yellow paper is for task 2)
  several sharpened drawing pencils and erasers (these drawing pencils are soft but you will still need to press firmly so that your work will be able to be photocopied)

Explain the pre-printed sheets in terms of the coded areas. Strategy (represented by S followed by Letters ABCD) -Task numbers (represented by T followed by 1 & 2)- Problem numbers (they are to write in the problem number) & Response numbers (they are to write in the response number). Talk about how to use them. Tell the subjects not to write in the areas on the right hand side of the papers.

You have before you a slip cover with 15 drawings of basic parts. For the purposes of a common understanding let us go through the names of each part. (Indicate the names of the parts to them.)

In general each trial consists of three randomly selected parts which will be given to you. At the beginning of each of the trials I will let you know which colour paper you are to use and I will call out the strategy letter and the trial number. You are to circle the appropriate S letter and the appropriate T number at the top of the pre-printed paper provided. Also in the circles next to Prob. & Respon. you are to put the problem number and response number you are currently working on. When we start I will call out the names of the three parts to be used in that trial. I will repeat the names to ensure that the names were heard correctly. You are to note in the space provided and on each paper you use, the parts you were given. Do not write in the spaces on the right hand side of the paper this area is for coding purposes.

3D
As soon as the parts are named you are to attempt to construct a practical object from the parts given. These are given in any order and sometimes more than once. All the parts must be

used, and the object must be of some practical value. If two of the same parts are mentioned then both are to be used in the object. You can vary the size, position, proportion, or orientation of the parts but you are not allowed to bend, trim or distort the individual parts in any way with the exceptions of the wire and the tube. These have been defined as bendable. The parts can be put inside one another. They can be solid or hollow. They can be made from any material including wood, metal, glass, rubber, or plastic, in any combination. In addition you are given an object category randomly selected from a list of 8 categories (**read the examples to them**). Coupled with each new set of three randomly selected parts in each trial, you are given a new randomly selected object category.

Table 2

Allowable object categories in experiments on creative invention.

	Category one	Examples
1.	Furniture	Chairs, Tables, Lamps, etc...
2.	Personal Items	Jewellery, glasses, etc...
3.	Transportation	Cars, boats etc...
4.	Scientific Instruments	Measuring devices, etc...
5.	Appliances	Washing machines, toasters, etc...
6.	Tools & Utensils	Screwdrivers, spoons, etc...
7.	Weapons	Guns, missiles, etc...
8.	Toys & Games	Baseball bats, dolls etc...

Here is an example : If you are given a sphere, a rectangular block, and a cylinder. Then you are given the category of toys. You could draw a long cylinder then add the block one 1/3 the way up the cylinder and add the sphere to the top of the cylinder and say it is a **pogo stick**.

Remember to ensure that you have circled the appropriate S number and the appropriate T number at the top of the pre-printed paper provided, the parts you were given are noted on the paper and the category you were given is on the paper.

Strategy B - Task one
Even though this is a new strategy remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper. Use the white pre-printed paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In this strategy you are to close your eyes and attempt to mentally construct your solution form from the 3 parts given.
You can only open your eyes long enough to write down the name/description of the solution. Once you have done this close your eyes again and develop another form. **After the 3 minutes you will be allowed to draw your named/described forms.** When you are drawing you cannot change anything you wrote in naming/describing the forms. This is repeated for each form created from the three parts named. Once the 3 minute time period is over and after you finish drawing the forms, you will be given three new parts and asked to do the same task again.

Strategy B - Task Two
In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
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have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 3D

For instance remember the **pogo stick** example the rectangular block slides to the bottom of the cylinder, the whole objects is scaled down and it becomes a **potato masher**.
Or
The Sphere is scaled up in size and it becomes a big **helium balloon ride**. The cylinder becomes a grab post and the rectangular block becomes a seat.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy C - Task one

In this task remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to use drawing. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your ideas.

Strategy C - Task Two

In this task you are to reinterpret your previous solutions. Spread your previous solutions (the ones on the white paper) out in front of you and look at them. You are to pick one, then close your eyes, you are to explore your constructions by imagining the forms being rotated around or forming a mirror image of the form. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction. You are to observe the synthesised form from different orientations. **You are to do this using only mental imagery.**
You can only open your eyes long enough to write down the name/description of the solution, the parts it was derived from, and the trial number strategy number etc... then draw this new imagined form. Only open your eyes after you have new interpretation. Do not develop your ideas on paper. You are to use the **light yellow paper** to draw on. After you have drawn the reinterpreted form you are to circle the form to indicate your new interpretation. Remember one form one piece of paper. Once you have done this turn both the white paper and the yellow paper over and pick another previous form then close your eyes again and develop another new form. You may do as many as you like before the end of a 9 minute time period. It is also up to you how many re-interpretations per original you do and how many originals you re-interpret.

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Strategy A - Task one

REMEMBER BEFORE WHEN YOU DREW TO DEVELOP YOUR FORMS - WE ARE GOING TO DO THIS AGAIN.

In this task and these trials remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to **use drawing**. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your form.

Strategy A - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to imagine observing the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms you have created in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
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Strategy D - Task one

This is a new type of strategy. In this strategy you are to mentally develop a form.
At this stage you are only to develop and name/describe your new form. A form which is a representation of a general category you are given.

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You can create as many forms as you like before the end of a 3 minute time period.

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Once the 3 minutes is over then you will be given another new category and another 3 minutes.

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Suppose now you are given the category of **Sporting equipment** you could develop a new piece of equipment for children with a handicap, then a sporting device helping lost backpackers, then something to teach people to swim, etc...

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Instructions (Group C)

Instructions 3D Drawing

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Strategy C - Task Two
In this task you are to reinterpret your previous solutions. Spread your previous solutions (the ones on the white paper) out in front of you and look at them. You are to pick one, then close your eyes, you are to explore your constructions by imagining the forms being rotated around or forming a mirror image of the form. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction. You are to observe the synthesised form from different orientations. You are to do this using only mental imagery.
You can only open your eyes long enough to write down the name/description of the solution, the parts it was derived from, and the trial number strategy number etc... then draw this new imagined form. Only open your eyes after you have new interpretation. Do not develop your ideas on paper. You are to use the **light yellow paper** to draw on. After you have drawn the reinterpreted form you are to circle the form to indicate your new interpretation. Remember one form one piece of paper. Once you have done this turn both the white paper and the yellow paper over and pick another previous form then close your eyes again and develop

another new form. You may do as many as you like before the end of a 9 minute time period. It is also up to you how many re-interpretations per original you do and how many originals you re-interpret.

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 3D
For instance remember with the **pogo stick** example the rectangular block slides to the bottom of the cylinder, the whole objects is scaled down and it becomes a **potato masher**.
Or
The Sphere is scaled up in size and it becomes a big **helium balloon ride**. The cylinder becomes a grab post and the rectangular block becomes a seat.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy B - Task one
Even though this is a new strategy remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper. Use the white pre-printed paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In this strategy you are to close your eyes and attempt to mentally construct your solution form from the 3 parts given.
You can only open your eyes long enough to write down the name/description of the solution. Once you have done this close your eyes again and develop another form. **After the 3 minutes you will be allowed to draw your named/described forms.** When you are drawing you cannot change anything you wrote in naming/describing the forms. This is repeated for each form created from the three parts named. Once the 3 minute time period is over and after you finish drawing the forms, you will be given three new parts and asked to do the same task again.

Strategy B - Task Two
In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form. You are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 3D
For instance remember the **pogo stick** example the rectangular block slides to the bottom of the cylinder, the whole objects is scaled down and it becomes a **potato masher**.
Or
The Sphere is scaled up in size and it becomes a big **helium balloon ride**. The cylinder becomes a grab post and the rectangular block becomes a seat.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy A - Task one

REMEMBER BEFORE WHEN YOU DREW TO DEVELOP YOUR FORMS - WE ARE GOING TO DO THIS AGAIN.

In this task and these trials remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to use **drawing**. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your form.

Strategy A - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to imagine observing the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms you have created in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. This is done so your form can be identified. Even if you only have one drawing on the page still circle it fotr purposes of consistency. Once you have reinterpreted the original form (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next form. Remember one form one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 3D
For instance remember the **pogo stick** example the rectangular block slides to the bottom of the cylinder, the whole objects is scaled down and it becomes a **potato masher**.
Or

The Sphere is scaled up in size and it becomes a big **helium balloon ride**. The cylinder becomes a grab post and the rectangular block becomes a seat.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy D - Task one
This is a new type of strategy. In this strategy you are to mentally develop a form.
At this stage you are only to develop and name/describe your new form. A form which is a representation of a general category you are given.

> **3D only**
> Remember we defined the word **Form** to mean **Practical object or invention.**

Before you start remember to write down the name of, strategy number, and the trial number etc.... Once you are given the category you are to close your eyes and only open them long enough to write down the name/description of a **form**. You are to turn the page over preparing for the next form (**using the white pre-printed paper**). Then you are to close your eyes again without looking around the room.
You can create as many forms as you like before the end of a 3 minute time period.

> **3D**
> Say you were given the category of **Farming & Gardening** you could develop a way to plant seeds, then a novel way to get rid of weeds, next a way to protect you from the sun, and then an animal shelter etc...

Once the 3 minutes is over then you will be given another new category and another 3 minutes.

> **3D**
> Suppose now you are given the category of **Sporting equipment** you could develop a new piece of equipment for children with a handicap, then a sporting device helping lost backpackers, then something to teach people to swim, etc...

But remember one idea, one paper. This is repeated 3 times.

Now that you have done this 3 times you will go back and **draw to develop** your named/described forms using **three randomly selected parts given to you** for each of the three trials from task one. As soon as the parts are named you are to write them down. You are to draw on the paper you used in giving the name (the white papers). You are to circle the final form you developed.

Now Gather your papers from the first problem set. Find the ones you have marked as Problem 1. As soon as the parts are named you are to go back and draw to develop the named/described forms from problem one - task one (which you have just completed). Once **all of you** have finished problem set one we will move on to the second problem set and responses. You will progress through all of the problem sets in order therefore, you will perform this task a total of 3 times.

Strategy D - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

This task is identical to the ones you have done before in reinterpreting your previous work so you should be familiar with it. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.

Once you have developed and reorientated a form which you can reinterpret, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. **It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period**

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Instructions (Group D)

Instructions 3D Drawing

The purpose of this investigation is to explore 4 different strategies people could use to combine visual parts to form a mental image. Basically you will be give three parts and using these pars we would like you to develop a new form. You can make as many new forms as you like. In order to achieve this we would like you to utilise the suggested strategy at the time independent from any other strategy. There will be four different strategies explored (Refer to the hand out given). Note in the handout there are 4 Ellipse. They are labelled strategy ABCD. These may not necessarily be in that order. The sheet given to you may be different. We will proceed from the top down consequently for example strategy C may be done first because it is first on the list. Also note that there are two tasks within each Strategy, you will be instructed what to do for each task in the different strategies, however, some of the tasks will be identical (point this out in the diagram they have). For each of the strategies there will be 3 trials. Therefore a total of 12 trials or problem sets will be presented to you.

3D | **These explore three dimensional mental synthesis.** |

For the sake of consistency throughout these instructions we will define the word **Form** to mean **Practical object or invention.**

Each strategy will have staged tasks for you to do. Listen carefully to the instructions for each staged task.

Note the materials supplied to you are as follows:
  two colour coded folders
  one pad of white pre-printed drawing paper | Hold up the sheets
  one pad of light yellow pre-printed drawing paper |
  (**In general the white paper is for task 1 and the yellow paper is for task 2**)
  several sharpened drawing pencils and erasers (**these drawing pencils are soft but you will still need to press firmly so that your work will be able to be photocopied**)

Explain the pre-printed sheets in terms of the coded areas. Strategy (represented by S followed by Letters ABCD) -Task numbers (represented by T followed by 1 & 2)- Problem numbers (they are to write in the problem number) & Response numbers (they are to write in the response number). Talk about how to use them. Tell the subjects not to write in the areas on the right hand side of the papers.

You have before you a slip cover with 15 drawings of basic parts. For the purposes of a common understanding let us go through the names of each part. (Indicate the names of the parts to them.)

In general each trial consists of three randomly selected parts which will be given to you. At the beginning of each of the trials I will let you know which colour paper you are to use and I will call out the strategy letter and the trial number. You are to circle the appropriate S letter and the appropriate T number at the top of the pre-printed paper provided. Also in the circles next to Prob. & Respon. you are to put the problem number and response number you are currently working on. When we start I will call out the names of the three parts to be used in that trial. I will repeat the names to ensure that the names were heard correctly. You are to note in the space provided and on each paper you use, the parts you were given. Do not write in the spaces on the right hand side of the paper this area is for coding purposes.

3D

As soon as the parts are named you are to attempt to construct a practical object from the parts given. These are given in any order and sometimes more than once. All the parts must be

used, and the object must be of some practical value. If two of the same parts are mentioned then both are to be used in the object. You can vary the size, position, proportion, or orientation of the parts but you are not allowed to bend, trim or distort the individual parts in any way with the exceptions of the wire and the tube. These have been defined as bendable. The parts can be put inside one another. They can be solid or hollow. They can be made from any material including wood, metal, glass, rubber, or plastic, in any combination. In addition you are given an object category randomly selected from a list of 8 categories (**read the examples to them**). Coupled with each new set of three randomly selected parts in each trial, you are given a new randomly selected object category.

Table 2
Allowable object categories in experiments on creative invention.

Category one		Examples
1.	Furniture	Chairs, Tables, Lamps, etc...
2.	Personal Items	Jewellery, glasses, etc...
3.	Transportation	Cars, boats etc...
4.	Scientific Instruments	Measuring devices, etc...
5.	Appliances	Washing machines, toasters, etc...
6.	Tools & Utensils	Screwdrivers, spoons, etc...
7.	Weapons	Guns, missiles, etc...
8.	Toys & Games	Baseball bats, dolls etc...

Here is an example : If you are given a sphere, a rectangular block, and a cylinder. Then you are given the category of toys. You could draw a long cylinder then add the block one 1/3 the way up the cylinder and add the sphere to the top of the cylinder and say it is a **pogo stick.**

Remember to ensure that you have circled the appropriate S number and the appropriate T number at the top of the pre-printed paper provided, the parts you were given are noted on the paper and the category you were given is on the paper.

Strategy C - Task one
In this task remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to use drawing. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your ideas.

Strategy C - Task Two
In this task you are to reinterpret your previous solutions. Spread your previous solutions (the ones on the white paper) out in front of you and look at them. You are to pick one, then close your eyes, you are to explore your constructions by imagining the forms being rotated around or forming a mirror image of the form. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction. You are to observe the synthesised form from different orientations. You are to do this using only mental imagery.
You can only open your eyes long enough to write down the name/description of the solution, the parts it was derived from, and the trial number strategy number etc... then draw this new imagined form. Only open your eyes after you have new interpretation. Do not develop your ideas on paper. You are to use the **light yellow paper** to draw on. After you have drawn the reinterpreted form you are to circle the form to indicate your new interpretation. Remember one form one piece of paper. Once you have done this turn both the white paper and the yellow paper over and pick another previous form then close your eyes again and develop

another new form. You may do as many as you like before the end of a 9 minute time period. It is also up to you how many re-interpretations per original you do and how many originals you re-interpret.

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 3D
For instance remember with the **pogo stick** example the rectangular block slides to the bottom of the cylinder, the whole objects is scaled down and it becomes a **potato masher**.
Or
The Sphere is scaled up in size and it becomes a big **helium balloon ride**. The cylinder becomes a grab post and the rectangular block becomes a seat.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy A - Task one

REMEMBER BEFORE WHEN YOU DREW TO DEVELOP YOUR FORMS - WE ARE GOING TO DO THIS AGAIN.

In this task and these trials remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper. Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In order to aid in the synthesis process it may help to **use drawing**. The suggested strategy is to draw one of the parts given then add the other parts and attempt to construct a solution from the parts given.
As soon as the parts are named you may draw on the **white paper** provided in order to develop your form.

Strategy A - Task Two
In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to imagine observing the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms you have created in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. This is done so your form can be identified. Even if you only have one drawing on the page still circle it for purposes of consistency. Once you have reinterpreted the original form (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next form. Remember one form one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 3D
For instance remember the **pogo stick** example the rectangular block slides to the bottom of the cylinder, the whole objects is scaled down and it becomes a **potato masher.**
Or
The Sphere is scaled up in size and it becomes a big **helium balloon ride**. The cylinder becomes a grab post and the rectangular block becomes a seat.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy B - Task one
Even though this is a new strategy remember you can create as many solutions as you like before the end of a 3 minute time period. However, remember one solution one piece of paper. Use the white pre-printed paper.
Once the 3 minute time period is over you will be given three new parts and asked to do the same task again. You will perform this task a total of 3 times.

In this strategy you are to close your eyes and attempt to mentally construct your solution form from the 3 parts given.
You can only open your eyes long enough to write down the name/description of the solution. Once you have done this close your eyes again and develop another form. **After the 3 minutes you will be allowed to draw your named/described forms.** When you are drawing you cannot change anything you wrote in naming/describing the forms. This is repeated for each form created from the three parts named. Once the 3 minute time period is over and after you finish drawing the forms, you will be given three new parts and asked to do the same task again.

Strategy B - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

In this task you are to reinterpret your previous forms. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
If you can develop a reinterpretation of your form. You are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

Example 3D

For instance remember the **pogo stick** example the rectangular block slides to the bottom of the cylinder, the whole objects is scaled down and it becomes a **potato masher**.
Or
The Sphere is scaled up in size and it becomes a big **helium balloon ride**. The cylinder becomes a grab post and the rectangular block becomes a seat.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Strategy D - Task one
This is a new type of strategy. In this strategy you are to mentally develop a form.
At this stage you are only to develop and name/describe your new form. A form which is a representation of a general category you are given.

> **3D only**
> Remember we defined the word **Form** to mean **Practical object or invention.**

Before you start remember to write down the name of, strategy number, and the trial number etc.... Once you are given the category you are to close your eyes and only open them long enough to write down the name/description of a **form**. You are to turn the page over preparing for the next form **(using the white pre-printed paper)**. Then you are to close your eyes again without looking around the room.
You can create as many forms as you like before the end of a 3 minute time period.

> **3D**
> Say you were given the category of **Farming & Gardening** you could develop a way to plan seeds, then a novel way to get rid of weeds, next a way to protect you from the sun, and then an animal shelter etc...

Once the 3 minutes is over then you will be given another new category and another 3 minutes.

> **3D**
> Suppose now you are given the category of **Sporting equipment** you could develop a new piece of equipment for children with a handicap, then a sporting device helping lost backpackers, then something to teach people to swim, etc...

But remember one idea, one paper. This is repeated 3 times.

Now that you have done this 3 times you will go back and **draw to develop** your named/described forms using **three randomly selected parts given to you** for each of the three trials from task one. As soon as the parts are named you are to write them down. You are to draw on the paper you used in giving the name (the white papers). You are to circle the final form you developed.

Now Gather your papers from the first problem set. Find the ones you have marked as Problem 1. As soon as the parts are named you are to go back and draw to develop the named/described forms from problem one - task one (which you have just completed). Once **all of you** have finished problem set one we will move on to the second problem set and responses. You will progress through all of the problem sets in order therefore, you will perform this task a total of 3 times.

Strategy D - Task Two

REMEMBER BEFORE WHEN YOU REINTEERPRETED YOUR FORMS - WE ARE GOING TO DO THIS AGAIN. So spread all of your sheets in font of you and look at them.

This task is identical to the ones you have done before in reinterpreting your previous work so you should be familiar with it. Spread your previous solutions out in front of you and look at them. You are to explore your constructions by imagining the form being rotated around or forming a mirror image of the form. You are to observe the synthesised form from different orientations. In order to aid in performing this task you are encouraged to draw the forms in different orientations. You are to use the **light yellow paper** to draw on. You are only allowed to change the proportions of the form, scale, stretch it, slide parts, and change it's orientation, not how it is constructed. You cannot rearrange the construction.
Once you have developed and reorientated a form which you can reinterpret, you are to rename and/or describe the new form and circle the form to indicate which drawing is your new interpretation. Once you have reinterpreted the original ideas (found on the white paper), turn both the white paper and the yellow paper over and move on to reinterpreting the next idea. Remember one idea one piece of paper. **It is up to you how many re-interpretations per original you do and how many originals you re-interpret. You may do as many as you like before the end of a 9 minute time period**

As before remember to note the parts you were given, the strategy number, the task number etc... at the top of the paper.

At the end of this series of trials and this suggested strategy, fill in a questionnaire concerning the strategy you used in combining the parts to create a new form and make any comments you think relevant about this strategy (ease of use, problems encountered, do you typically use this technique in solving problems? Etc...) .

Appendix I

Instructions
Instructions to Judges 2D Drawing

Thank you for coming this morning and helping with our research. Here is some coffee and cookies. If you wish just help yourselves when you want some. We will work on judging the first half of responses before lunch, then we will break for lunch at around 12:00 then return upstairs and finish the rest of the judging from 1:00 until approximately 4:30. I say approximately because each person may judge at a different rate than others.

The purpose of this investigation was to explore different strategies people could use to combine visual parts to form a mental image. Basically the subjects were given three parts randomly selected from a group of 15 parts, using these three random parts they were to develop a new form. They could make as many new forms as they liked.

They were to develop a recognisable form.

2D   This explored two-dimensional mental synthesis.

Mental synthesis is described as the ability to imagine the assembly of a final part made from component parts.

As soon as the parts were named they were to attempt to construct a recognisable form, from the parts given. These are given in any order and sometimes more than once. All the parts must be used, and the object must be able to be recognised by another person. If two of the same parts are mentioned then both were to be used in the object. They could vary the size, position, proportion, or orientation of the parts but were not allowed to bend, trim or distort the individual parts in any way (circle could not be made into an ellipse). Give an example of the Flag and the TV set.

As judges your task is to assess the results of their work. Note at the top of each paper there will be two scales running from 1 thru to 5. A mark of 5 is the highest mark and a mark of 1 is the lowest mark. The first scale is for correspondence. The second scale is for originality or creativity. On each paper you are to circle a number for correspondence and a number for originality (creativity). If there is no response for that paper tick the box marked no response. We would like you to keep your papers in order so start with the top paper, mark it by circling a number from 1-5 for correspondence then a number for originality (creativity) and turn it over and place it in the box beside you then proceed to the next paper. Do this until you have finished the stack of papers.

You are judging the ideas not the drawing quality.

Each stack of papers is arranged differently. They are randomised, so the order each of you is judging the papers in a different order. Again! Thank you for your help. Any questions???

Appendix J

Instructions
Instructions to Judges 3D Drawing

Thank you for coming this morning and helping with our research. Here is some coffee and cookies. If you wish just help yourselves when you want some. We will work on judging the first half of responses before lunch, then we will break for lunch at around 12:00 then return upstairs and finish the rest of the judging from 1:00 until approximately 4:00.

The purpose of this investigation was to explore different strategies people could use to combine visual parts to form a mental image. Basically the subjects were given three parts randomly selected from a group of 15 parts, using these three random parts they were to develop a new form. They could make as many new forms as they liked.
They were to develop a Practical object or invention.

> 3D   This explored three-dimensional mental synthesis.

Mental synthesis is described as the ability to imagine the assembly of a final part made from component parts.

As soon as the parts were named they were to attempt to construct a practical object from the parts given. These are given in any order and sometimes more than once. All the parts must be used, and the object must be of some practical value. If two of the same parts are mentioned then both were to be used in the object. They could vary the size, position, proportion, or orientation of the parts but were not allowed to bend, trim or distort the individual parts in any way with the exceptions of the wire and the tube. These have been defined as bendable. The parts could be put inside one another. They could be solid or hollow. They could be made from any material including wood, metal, glass, rubber, or plastic, in any combination. In addition they were given an object category randomly selected from a list of 8 categories (read the examples to them). Coupled with each new set of three randomly selected parts in each trial, they were given a new randomly selected object category.

Table 2

Allowable object categories in experiments on creative invention.

	Category one	Examples
1.	Furniture	Chairs, tables, lamps, etc...
2.	Personal Items	Jewellery, glasses, etc...
3.	Transportation	Cars, boats etc...
4.	Scientific Instruments	Measuring devices, etc...
5.	Appliances	Washing machines, toasters, etc...
6.	Tools & Utensils	Screwdrivers, spoons, etc...
7.	Weapons	Guns, missiles, etc...
8.	Toys & Games	Baseball bats, dolls etc...

Here is an example: They could be given a sphere, a rectangular block, and a cylinder. Then given the category of toys and Games. They could add the sphere to the top of the cylinder then add the block one 1/3 the way up the cylinder and say it is a pogo stick.

As judges your task is to assess the results of their work. Note at the top of each paper there will be two scales running from 1 thru to 5. A mark of 5 is the highest mark and a mark of 1 is the lowest mark. The first scale is for practicality. The second scale is for originality or creativity. On each paper you are to circle a number for practicality and a number for originality (creativity). If there is no response for that paper tick the box marked no response. We would like you to keep your papers in order so start with the top paper mark it by circling a number from 1-5 for practicality then a number for originality (creativity) and turn it over and place it in the box beside you then proceed to the next paper. Do this until you have finished the stack of papers.

You are judging the ideas not the drawing quality.

Each stack of papers is arranged differently. They are randomised, so the order each of you is judging the papers in a different order. Thank you for your help. Any questions?

Appendix K

2D Creative results [Different Cohorts of Judges]

	Drawing Strategies & Creative Mental Synthesis (Creativity 2D) [ID judges]								
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Creative
Industrial Designers	45	21	43	20	38	23	28	20	238
Vis - Com (Students)	40	25	38	26	38	18	25	30	240
Non-designers (Law students)	34	20	40	24	34	21	35	27	235
Total Creative	119	66	121	70	110	62	88	77	713

Number of creative responses attributed to subject type, strategy type and task

	Drawing Strategies & Creative Mental Synthesis (Creativity 2D) [VC judges]								
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total
Industrial Designers	5	3	5	4	8	2	7	3	37
Vis - Com (Students)	4	3	3	4	7	6	9	1	37
Non-designers (Law students)	5	3	3	3	9	2	2	7	34
Total Creative	14	9	11	11	24	10	18	11	108

Number of creative responses attributed to subject type, strategy type and task

	Drawing Strategies & Creative Mental Synthesis (Creativity 2D) [Non-design judges]								
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total
Industrial Designers	20	6	22	13	11	7	28	13	120
Vis - Com (Students)	13	13	19	11	14	14	18	7	109
Non-designers (Law students)	8	4	10	8	11	7	15	8	71
Total Creative	41	23	51	32	36	28	61	28	300

Number of creative responses attributed to subject type, strategy type and task

2D Correspondence results [Different Cohorts of Judges]

Drawing Strategies & Creative Mental Synthesis (Correspondence 2D) [ID judges]								
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Correspondence
Industrial Designers	91	45	91	46	64	30	51	31	449
Vis - Com (Students)	78	29	65	38	59	26	32	40	367
Non-designers (Law students)	65	21	80	35	74	27	43	39	384
Total Creative	234	95	236	119	197	83	126	110	1200

Number of creative responses attributed to subject type, strategy type and task

Drawing Strategies & Creative Mental Synthesis (Correspondence 2D) [VC judges]								
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Correspondence
Industrial Designers	7	1	5	1	1	1	2	2	20
Vis - Com (Students)	0	1	4	1	0	1	4	1	12
Non-designers (Law students)	4	1	6	0	1	0	1	1	14
Total Creative	11	3	15	2	2	2	7	4	46

Number of creative responses attributed to subject type, strategy type and task

Drawing Strategies & Creative Mental Synthesis (Correspondence 2D) [ND judges]								
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Correspondence
Industrial Designers	29	14	29	10	17	6	17	12	134
Vis - Com (Students)	23	18	30	10	16	10	16	13	136
Non-designers (Law students)	15	5	22	4	21	2	12	8	89
Total Creative	67	37	81	24	54	18	45	33	359

Number of creative responses attributed to subject type, strategy type and task

Appendix L

3D Creative results [Different Cohorts of Judges]

Drawing Strategies & Creative Mental Synthesis (Creativity 3D) [ID judges]									
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Creative
Industrial Designers	15	12	51	18	30	15	81	13	235
Vis - Com (Students)	21	10	23	4	14	4	70	14	160
Non-designers (Law students)	3	4	14	4	5	5	42	2	79
Total Creative	39	26	88	26	49	24	193	29	474

Number of creative responses attributed to subject type, strategy type and task

Drawing Strategies & Creative Mental Synthesis (Creativity 3D) [VC judges]									
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Creative
Industrial Designers	13	15	41	17	19	13	65	16	199
Vis - Com (Students)	10	9	23	7	14	12	56	13	144
Non-designers (Law students)	2	7	6	5	5	4	28	4	61
Total Creative	25	31	70	29	38	29	149	33	404

Number of creative responses attributed to subject type, strategy type and task

Drawing Strategies & Creative Mental Synthesis (Creativity 3D) [ND judges]									
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Creative
Industrial Designers	16	13	34	10	16	9	69	10	177
Vis - Com (Students)	9	7	19	5	10	5	56	7	118
Non-designers (Law students)	3	3	13	7	2	1	27	4	60
Total Creative	28	23	66	22	28	15	152	21	355

Number of creative responses attributed to subject type, strategy type and task

3D Practicality results [Different Cohorts of Judges]

| Drawing Strategies & Creative Mental Synthesis (Practicality 3D) [ID judges] | | | | | | | | | |
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Practicality
Industrial Designers	28	20	66	32	24	24	12	23	229
Vis - Com (Students)	24	15	24	11	20	18	4	19	135
Non-designers (Law students)	9	13	25	20	29	31	5	14	146
Total Creative	61	48	115	63	73	73	21	56	510

Number of creative responses attributed to subject type, strategy type and task

| Drawing Strategies & Creative Mental Synthesis (Practicality 3D) [VC judges] | | | | | | | | | |
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Practicality
Industrial Designers	8	7	27	10	9	5	12	15	93
Vis - Com (Students)	8	9	4	6	1	4	4	3	39
Non-designers (Law students)	1	2	9	3	12	3	0	5	35
Total Creative	17	18	40	19	22	12	16	23	167

Number of creative responses attributed to subject type, strategy type and task

| Drawing Strategies & Creative Mental Synthesis (Practicality 3D) [ND judges] | | | | | | | | | |
	Strategy A Task 1	Strategy A Task 2	Strategy B Task 1	Strategy B Task 2	Strategy C Task 1	Strategy C Task 2	Strategy D Task 1	Strategy D Task 2	Total Practicality
Industrial Designers	17	23	53	22	24	20	17	27	203
Vis - Com (Students)	18	11	21	15	8	14	13	15	115
Non-designers (Law students)	12	13	22	11	22	22	20	15	137
Total Creative	47	47	96	48	54	56	50	57	455

Number of creative responses attributed to subject type, strategy type and task