CreativeTeams: Exploring the creative performance of co-located and virtual teams

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Submitted 31st March 2017

A thesis submitted to Lancaster University for the degree of

Doctor of Philosophy in the Faculty of Science and Technology

Abstract

This thesis compares the creative performance of traditional co-located and virtual teams. Motivation for this research is twofold. Firstly there is the reluctance shown by many organisations to adopt virtual working practises. Second, there is the gap in existing research exploring how virtual teams collaborate synchronously when addressing complex tasks. In particular there is a lack of empirical research comparing co-located and virtual team performance. The CreativeTeams tool has been created to address this by providing an objective method of measuring team creative performance regardless of location. Creativity is assessed because it is an important socio-cognitive process, and is often key in addressing complex tasks requiring extensive team collaboration such as designing, problem solving and emergency planning. Such complex tasks have traditionally been the sole domain of co-located teams. This thesis therefore provides a point of comparison. The tool itself incorporates a number of activities, the core of which are adapted from the Torrance Tests of Creative Thinking.

A study has been run with 150 student participants, working in 50 teams. Each team completes the CreativeTeams activities in either a co-located or virtual environment. Outputs from these activities are assessed by multiple markers and analysed along with meta data from the tool. A comparison of these metrics indicates no significant difference in co-located and virtual team performance across the majority of metrics. This demonstrates that virtual teams can be as effective as co-located teams in addressing complex tasks and is a key research contribution, as is the formation of the CreativeTeams tool itself.

Acknowledgements

I would like to thank a number of people for helping me with this thesis. I need to thank Professor Pete Sawyer for being a bit of a hero and stepping into the supervision void, taking over supervision mid-way through my PhD and sticking it out to the very end. I also need to thank Dr Paul Ralph for being ambitious enough to suggest I pursue this area in the first place.

I need to thank the various developers who have worked with me on this project including David Gullick and Adam Smith at Lancaster University and Habib Naderi at the University of Auckland.

I need to thank family and friends for putting up with this nonsense and in particular my fiancée Dr Kylie O'Shea for all her support throughout the PhD.

This work has been funded by the Digital Economy programme (RCUK Grant EP/G037582/1), which supports the HighWire Centre for Doctoral Training at Lancaster University

Declaration

This thesis is my own work and no portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification at this or any other institute of learning.

Contents

Chapter 1

Introduction

1.1 Creativity in teams

This thesis describes a study to compare the creative performance of traditional co-located and virtual teams. Creativity is "the ability to produce work that is both novel (i.e. original, unexpected), and appropriate (i.e. useful, adaptive to task constraints)." [1]. It is a key component in the way that teams address complex and often ambiguous tasks like designing, or problem solving.

Co-located teams are the traditional office-based teams with which we are all familiar. Virtual teams by contrast are "groups of geographically, organizationally and/or time dispersed workers brought together by information and telecommunication technologies to accomplish one or more organizational tasks" [2]. The nature of virtual teams means that employees can (in theory) benefit from improved control over their work-life balance. Likewise, employers can benefit from reduced overheads and access to the best workers from the global workforce. However, virtual working does introduce completely different team dynamics and therein lies the problem. There is only a limited amount of research into virtual teams in contrast with co-located teams. And, given the relative immaturity of virtual working there aren't established best practises yet. This makes adopting virtual working inherently risky for many organisations because they are unable

to predict whether these teams will be better or worse than their co-located counterparts.

The CreativeTeams tool has therefore been developed to provide an objective means of gauging the creative performance of both types of team. This tool is used in a study with 150 participants working in 50 teams in both co-located and virtual environments (see the method in chapter 4 for more detail). The data from the two team environments is compared providing an initial indication that virtual teams are as creative as their traditional co-located counterparts (see findings in chapter 6).

1.2 Practice-based motivation

Virtual work in practice remains contentious despite offering an apparent panacea for modern life. Interest in virtual working has been steadily growing over the last twenty years, spurred on by improvements in communication infrastructure and tools that make virtual work a practical alternative to co-located work. However, many organisations remain unconvinced, with some banning it outright and others limiting it to only very specific (usually simple) tasks for individuals. The mainstream press is littered with articles like "Why aren't we all working from home today?" [3], "Teleworking: The myth of working from home" [4] and "Yahoo chief bans working from home" [5] that suggest that subscribing to this new means of working is by no means simple. And whilst there are some organisations like Virgin and Canonical that actively embrace virtual working, many remain unconvinced.

This hesitation to adopt virtual working is easy to appreciate, after all people have been working in traditional co-located teams since time immemorial. Virtual working by comparison is in its infancy and the level of research reflects this. Virtual working ultimately represents a shift in how organisations structure themselves. Collaborators no longer have to meet face to face. They can instead video conference and work together from opposite sides of the planet. Many tasks can be (and indeed are) readily adapted to this way of working. However, other tasks require more complex interactions between team members to succeed. These are typically tasks involving the negotiation of ambiguous problems and are often associated with high stake consequences. Creativity is key to the way that teams develop understanding and go about resolving these situations.

The practice-based motivation for this thesis is to provide organisations and the wider practitioner community with a comparison of co-located and virtual team performance as they address such complex tasks.

1.3 Knowledge-based motivation

There is extensive research into virtual team working within Computer Supported Cooperative Work (CSCW), Information Systems (IS) and wider schools of Management research. Recent work by Vlaar et al. [6] has applied sensemaking theory to understand the way that physically distributed organisations share information and develop understanding together. Meanwhile work by Kanawattanachi et al. [7] has demonstrated that virtual teams can demonstrate comparable Transactive Memory Systems (a type of complex socio-cognitive process) to co-located teams. However, these represent the closest research to that within this thesis.

The focus of this thesis is on an organisational framing of creativity. That is, creativity which helps teams to resolve problems or develop innovations and opportunities. Organisations often use the terms creativity, sensemaking, problem identification and problem solving interchangeably to describe this action-orientated form of creativity. In this thesis I therefore utilise Torrance's [8] definition which states that creativity is:

> "A process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifiying the difficulty; searching for solutions, making guesses, or formulating hypotheses about the deficiencies: testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results" [8].

The knowledge-based motivation for this thesis is therefore to contribute to the fledgling discussion on virtual team creativity by providing empirical evidence of the differences in co-located and virtual team performance.

1.4 Research approach

The measurement of creativity is paramount to this thesis. Unfortunately there is little consensus around what constitutes creativity, instead most researchers adopt a "we know it when we see it" approach. Despite this ambiguity, the majority of disciplines readily acknowledge the importance that creativity plays in the identification and resolution of problems and opportunities. There is a school of research within Psychology in particular concerned with the measurement of creativity. E.P.Torrance is considered one of the founders of this school and is responsible for developing The Torrance Tests of Creative Thinking (TTCT) [8].

The TTCT were originally developed in the 1960s as an alternative to the IQ test that was being used within the U.S.A. to identify gifted children. The TTCT include both figural (involving drawing) and verbal activities that are then scored against established criteria to provide an indication of an individual's creativity. The TTCT are still considered valid despite their relative age [9]. I have adapted them first to work with teams and then further extended them to measure virtual (and co-located) team creativity.

A number of challenges needed to be addressed in order to use the TTCT to study co-located and virtual teams performance. The original TTCT is paper based and intended for individuals. Initial research therefore explored whether teams could complete the figural form of these tests using a series of paper prototypes tested with a series of teams. The outcome of this early testing indicated that co-located teams were capable of completing the TTCT figural component as Torrance intended. However, virtual teams would not be able to complete the adaptation in this form because it relied on teams working on the same single white board (see section 4.1.2 for more details).

The CreativeTeams platform was developed as part of this thesis to overcome this problem. The platform provides teams with an iPad based adaptation of the TTCT that is identical for both co-located and virtual teams. A shared synchronous drawing canvas is included in the CreativeTeams platform and participants are provided with digital pencils to draw with. This mimics the experience that a team would have if they were drawing together on the same piece of paper,

participants can see and edit what each other are drawing in real time. The risk of bias from the use of technology is reduced by designing the interface to be as simple as possible and the collaboration synchronous.

Ideally, practising co-located and virtual teams would be recruited to complete the CreativeTeams activities. However, this proved problematic on several fronts. Firstly it was impossible to negotiate access to a sufficient number of practising teams for meaningful statistical comparison. Secondly, the communication tools used by any practicing virtual teams would have varied, introducing additional complications to the analysis. I therefore decided to recruit teams from the student population, this enabled me to control team formation and the communication tools used by the virtual teams (they used Google Hangouts for video conferencing). The final data set is drawn from 90 participants completing the activity in 30 teams, each session lasting just over one hour. This provides a rich data set comprising of not only hundreds of drawings from teams that are assessed according to Torrance's criteria [8], but also highly reliable meta data from the CreativeTeams tool that describe how teams used the tool, along with video footage of both the teams and drawing process. Multiple markers are used and the level of inter-rater agreement assessed to ensure that there was no risk of bias introduced during scoring, resulting in reliable data.

1.5 Outline of thesis

In summary, the goals of this research are first to adapt the Torrance Tests of Creative Thinking into not only a team format, but a synchronous digital format; and second, to then run an experiment in which both co-located and virtual teams complete the Adapted TTCT. The overall motivation of this approach is to provide empirical data that highlights the differences in the performance of co-located and virtual teams completing complex creative activities.

Chapter 2 reviews the literature related to creativity including research in both co-located and virtual team contexts and uses this to identify the research questions to be addressed in this thesis. The methodological considerations and use of an interpretive stance are discussed in chapter 3. Chapter 4 introduces the method employed in this research, with a dedicated section describing the development of the CreativeTeams tool and a sectioned describing the final tool itself in detail. Chapter 5 describes how the study outputs are scored by multiple markers and inter-rater agreement is assessed. Chapter 6 outlines the key findings from the study. There follows the discussion of this study (chapter 7) which highlights the key contributions of this thesis along with threats to validity and reflections on the process. Finally, chapter 8 concludes this thesis with a dedicated section on future research.

Chapter 2

Related work: The role of creativity in virtual teams

This chapter outlines the existing literature related to creativity in co-located and virtual teams. This thesis is motivated by the challenge that many organisations currently face in moving toward virtual forms of working. That is, trying to gauge the impact that a move to virtual working may have on performance. In particular this work explores the potential impact that these differing methods of working have on the creativity of teams. Organisations continue to place a high value on 'creativity', that is the capacity to identify, make sense of problems and ultimately to innovate.

Figure 2.1 outlines the conceptual path used to structure this chapter and illustrates how these complex interwoven research areas have been navigated to arrive at the final research questions (section 2.5). I begin by introducing a summary of virtual work research that provides the overarching context for this research (section 2.2). Section 2.3.1 then provides an introduction to the work on creativity, paying particular attention to the research into divergent thinking (section 2.3.1.1). This is followed by a review of work in the emerging field of creativity science (section 2.3.2). This field of research synthesises work from design and CSCW to consider the impact that new tools and techniques can have on creativity. Section 2.3.3 then takes a look at the underlying sensemaking

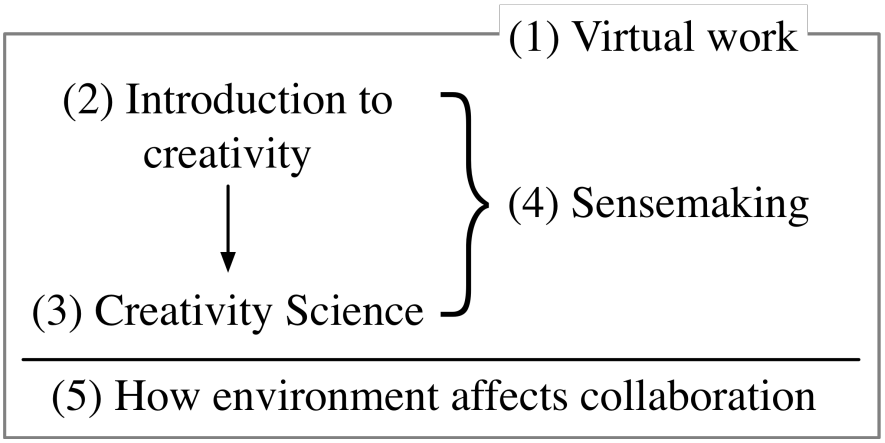


Figure 2.1: Conceptual path through related research

work that underpins much of the creativity that is valued by organisations. This is because organisations often treat the term creativity as an analog for problem solving and innovation. Section 2.3.4 then ties all four areas of research together to highlight how collaboration differs between individuals and co-located or virtual teams. Finally, section 2.4 summarises the chapter before introducing the research questions in section 2.5 that underpin this thesis.

2.1 Literature Review Method

The method used in this literature review has been developed taking into account the valuable suggestions made by Webster and Watson [10] relating to ideal approaches for identifying and analysing literature.

1. Range of disciplines explored
   I have reviewed literature from a range of disciplines with an emphasis on the following related disciplines: Computer Supported Cooperative Work (CSCW), Creativity Science, Management, Information Systems (IS), Requirements Engineering (RE) and Global Software Engineering/Design (GSE/D).

2. Provide definitions of key topic areas
   Sections 2.2 and 2.3 explore the key characteristics and definitions that exist in the existing literature and outlines the accepted definition used throughout the rest of this thesis.

3. Themes in existing topic area research are identified
   Where possible I have used well cited meta-analyses or existing literature reviews to provide a broad overview of research themes within a topic, I have then supplemented these with any important missing themes and research. Where a pre-existing review does not exist I have identified topic themes myself.

4. Themes are discussed to highlight key areas
   Themes are discussed to identify those areas key to my thesis, these are then explored in detail reviewing key trends and major contributions.

5. Calls for research and gaps in the literature are highlighted
   Gaps in existing work are described and calls for future research explained. From these the core research questions are developed at the end of the chapter.

2.2 Virtual Working and Virtual Teams

Powell et al. define virtual teams as "groups of geographically, organizationally and/or time dispersed workers brought together by information and telecommunication technologies to accomplish one or more organizational tasks" [2]. They [2] suggest that *Teams* and *Groups* are in fact very different things citing Cohen & Bailey [11] who state "A team is a collection of individuals who are interdependent in their tasks, who share responsibility for outcomes, who see themselves and who are seen by others as an intact social entity embedded in one or more larger social systems, and who manage their relationship across organizational boundaries." [11]. By contrast, a group is a collection of individuals who happen to be co-located but do not rely upon each other to complete tasks e.g., Chambers, where a group of Barristers work but where each addresses their cases in isolation.

The importance of teams in organisations has long been established. Teams are often formed where tasks are ambiguous and complex; requiring the knowledge and skills of multiple individuals. Teams are utilised for a wide range of organisational tasks: from permanent organisational teams (e.g., Computer Support Teams) to temporary teams (e.g., Project Teams). This thesis focuses on teams, maintaining the distinction set out by Cohen & Bailey [11].

Whilst there is a wealth of research on virtual working, my focus in particular is upon virtual teams. The term *virtual teams* is commonly associated with Information Systems (IS) research. However, it describes such a ubiquitous phenomenon that it is also referred to as distributed working, remote working and telecommuting amongst other terms. I therefore take a multi-disciplinary approach in order to develop as broad an understanding of the state of research as possible. Research is included from Management, Information Systems (IS), Requirements Engineering (RE), Computer Supported Cooperative Work (CSCW) and Global Software Engineering/Design (GSE/D).

This section is structured using the major themes identified by Powell et al. [2] in their literature review (see Fig 2.2). I briefly discuss which of these contribute to my understanding of virtual team creativity, focusing on the Task

Processes (§ 2.2.1) and Socio-Emotional Processes (§ 2.2.2). Finally, I conclude with a summary (§ 2.2.3) outlining the importance of a greater understanding of socio-cognitive processes (such as collective creativity) in virtual teams.

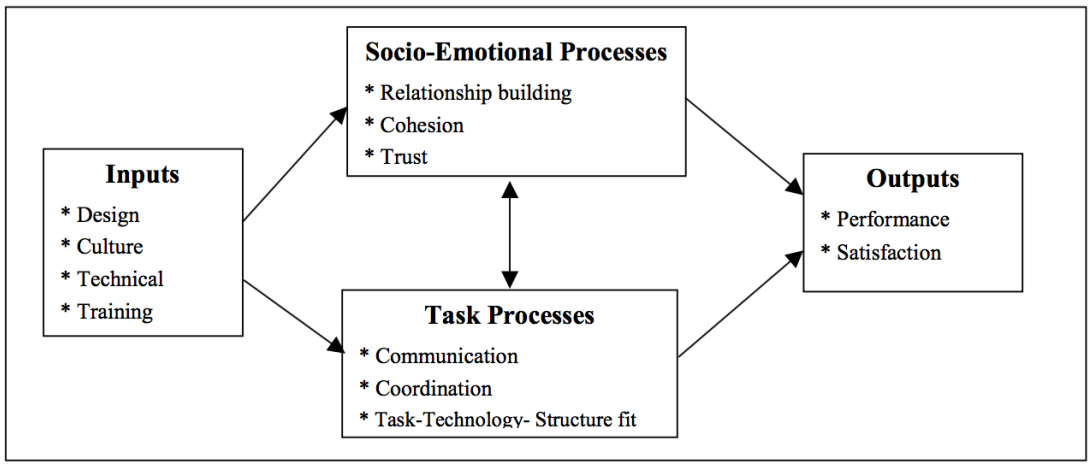


Figure 2.2: Model of virtual Team literature [2]

Powell et al. [2] adapt Saunders [12] highly cited *Life Cycle Model* utilising the four variables (Inputs, Socio-Emotional Processes, Task Processes and Outputs) as categories that contain related research themes. I use Powell et al.'s [2] model to show the position of my research within virtual team literature. Whilst Raghuram et al.'s [13] co-citation analysis offers a more recent review it utilises auto-generated groupings of the literature. These auto-generated groupings do not describe the literature as concisely as Powell et al.'s [2] model. I therefore structure my analysis using Powell et al.'s [2] model but incorporate the more recent work identified by Raghuram et al. [13].

Saunders *Life Cycle Model* [12] introduces four broad categories of virtual team research (see Fig 2.2): *Inputs, Socio-Emotional Processes, Task Processes and Outputs*. Research relating to *Inputs* tends to explore the design and characteristics of a virtual team, including studies of resources available like the skills and abilities of team members. The category of *Socio-Emotional Processes* includes research into the social aspects of teams; how team relationships develop and the associated synergistic aspects of cohesion and trust. Much of this research originates from IS, Management, Sociology and Organisational Psychology. *Task*

Processes research explores the communication processes and associated practises that enable and inhibit virtual team working. Research in this area is commonly from CSCW, IS, Management or GSD disciplines. Finally, research categorised in *Outputs* tends to focus on establishing the effectiveness of virtual teams to support discussions surrounding the efficiency of such teams. Research in this final categories is predominantly from Management and IS.

This thesis sets out to explore the creativity of teams. I am interested in team creativity within an organisational context. For organisations, creativity tends to either be proactive or reactive. That is, creativity that involves opportunity identification and exploitation in the form of innovation and ultimately competitive advantage (proactive). Reactive creativity by contrast, is associated with problem identification and resolution. Creativity as far as organisations are concerned is therefore closely aligned with sensemaking, that is the capacity to notice changes in the environment and develop a response.

I am therefore interested in exploring the way that collective understanding is developed. This work closely relates to research on the *Task Processes* of teams and their *Socio-emotional Processes*. In particular I am interested in the cohesion aspect of socio-emotional processes.

In the next two subsections I move on to describe key virtual work research pertaining to *Task Processes* and *Socio-emotional Processes*, and highlight gaps and calls for research.

2.2.1 Task Processes

The category of *Task Processes* introduces three sub-themes in Powell et al.'s [2] review: *Communication, Coordination* and *Task-Technology-Structure fit*.

Communication is vital for virtual teams to collaborate successfully. Research in this area (e.g., [14, 15]) discuss a range of topics including: tool evaluation, tool proposal and sufficiency of media richness.

Research relating to *Coordination* perhaps offers the closest overlap with organisational creativity; it refers to the way that team members from different backgrounds are able to align their thoughts, activity and understanding. There

are a wide range of contributions to this theme [16, 17, 18, 19, 20]. I supplement this with an additional theme on temporal-separation and its impact on coordination (e.g., [21, 22, 23, 24]).

Finally, Task-technology-structure research explores the relationship between both communication (i.e., the tool, its design and function) and coordination (i.e., the impact the tool has on the way a team thinks) [25, 26, 27, 28].

Research in these three themes covers a range of topics related to virtual team creativity. Research pertaining to *communication* is generally concerned with the tools used by teams to communicate and collaborate and as such is a well established field of research. However, much of the work on tool development assumes that the best way to work is to emulate co-located methods of working. There is very little communication research that is related to the way meaning is developed, I have therefore not explored the associated research further.

Work related to *task-technology-structure-fit* generally evaluates how organisational processes and communication tools adjust in order to support virtual working better. Little of this research explores creativity or work related to it. As such, research in this area is not particularly relevant to this thesis, even if the findings in this thesis contribute to the design of tools and organisational processes.

Coordination research by contrast is much more closely related to my area of interest with a number of papers introducing work about how teams coordinate meaning and understanding. Work by Rogers [16] discusses distributed cognition (collective sensemaking), summarising a number of previous studies of teams in situ. Rogers [16] argues that "a general assumption of the distributed cognition approach is that cognitive systems consisting of more than one individual have cognitive properties that differ from those individuals that participate in those systems" [16]. Rogers [16] describes a small collection of related work that seeks to understand how two or more teams operate when all the team members are co-located, but where each team is in a different location. Such studies include analysis of how London underground control rooms operate [17] when the control team is physically distributed from multiple other teams working on the network. Other notable studies have explored how flight deck [29] teams and emergency room teams work [30]. Whilst these studies are all about how distributed teams

develop understanding (in the strict definition of distribution outlined earlier in this section), my thesis focus is on teams that are fully geographically distributed. That is, teams where each team member works from a separate location (e.g., employees who work from home). It is important to note that whilst much of the aforementioned research does touch on creativity in distributed teams, most fail to explore the creativity of fully geographically distributed teams that form the focus of this thesis.

2.2.2 Socio-Emotional Processes

This category incorporates a wide range of literature, particularly from management, relating to the themes of *Relationship Building, Cohesion* and *Trust* [2].

Research into *relationship building* explores the way that team relationships develop over time. In the virtual work environment it isn't always necessary (or possible) to work synchronously (e.g., via video conferencing) and consequently it can be harder for teams to develop beyond task-oriented relationships. However, it has been found that virtual teams can develop task-related, and social relationships over time [31, 32]. Other work in this area has explored how teams resolve conflicts [33, 34].

The second theme, *team cohesion* is closely related to *relationship building* but emphasises understanding of how teams develop not only emotionally, but how they come to understand and perform together. Since Powell et al.'s [2] paper was published new research has found that virtual teams can develop Transactive Memory Systems (TMS) [7, 35]; "TMS refer to the specialised division of labour that develops within a team with respect to the encoding, storage, and retrieval of knowledge (Wegner, 1987)" [7]. That is, Transactive Memory Systems are the awareness of other team member's strengths, weaknesses and preferences allowing teams to divide tasks more efficiently. This is important because Kanawattanachai and Yoo's [7] paper is the first to demonstrate that virtual teams can demonstrate complex socio-cognitive processes in the same way as co-located teams.

The third theme in this category *Trust* is another major area of importance affecting virtual teams, with a wide range of research contributing to this area

recently (e.g., [36, 37, 38, 39, 40, 41]). Trust is vital for virtual teams to operate, especially when team members may never meet. Combine this with the slow pace of virtual team relationship building and a tendency toward task-only communication and it becomes apparent that virtual teams need careful coaching to establish trust, especially in short-term projects. My research involves working with newly formed teams which should mean all teams will have similar levels of trust. The teams may vary in the speed with which they develop trust. However, because they will only be working together for a very short time I have not focused in more detail on work relating to trust.

Research into these three areas helps to explain the relationship between social interactions and shared socio-cognitive development. Of these themes, research relating to cohesion contributes the most to my understanding of virtual team creativity. In particular the work by Kanawattanachai et al. [7] contributes to the motivation for this research by highlighting the capacity for virtual teams to demonstrate complex socio-cognitive processes. This thesis builds on the work of Kanawattanachai et al. [7] by demonstrating how virtual teams utilise other complex socio-cognitive processes in the form of creativity.

2.2.3 Summary

Virtual working provides the key context for this thesis. Virtual work affects the way that teams are able to operate and it is these differences that I am particularly interested in, especially in relation to creativity. While the aforementioned themes in this section introduce related research (e.g., Cohesion and Coordination) there are few that address creativity (in one guise or another). We can infer certain speculations about virtual team creativity from a number of these contributions. For example, the research into TMS in virtual teams [7, 35] demonstrates that virtual teams are capable of complex socio-cognitive processes. Such contributions are important to support what we know from experience, i.e., that virtual teams can be creative. The virtual working literature introduces a range of research that contributes to our understanding of virtual team creativity.

2.3 Creativity

This section provides a review of the wide range of creativity research (see figure 2.3). Each of the four levels in figure 2.3 illustrate a stage of refinement. The top level lists the 10 broad areas of creativity research as suggested by Kozbelt et al. [42]. The arrows highlight those areas that are particularly pertinent to my work. These are explored in further detail in the second level with a particular focus on those area related to team creativity. The third layer refines this further by emphasising creativity research in virtual environments. Finally, divergent thinking (level 4) represents the most pertinent area of research to this thesis.

This section is structured as follows. Section 2.3.1 provides an overview of the broad field of creativity research, with section 2.3.1.1 focussing on divergent thinking. This is followed by section 2.3.2 which summarises the research within the emergent field of creativity science. Section 2.3.3 then introduces a review of sensemaking; this research helps to explain the way that understanding is developed and is particularly key to understanding the way that organisations frame and use creativity. Section 2.3.4 discusses how the creative process changes between individuals and co-located/virtual teams. Finally, section 2.3.5 provides a closing summary.

2.3.1 What is creativity?

Torrance defines creativity as:

> "A process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifiying the difficulty; searching for solutions, making guesses, or formulating hypothesis about the deficiencies: testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results" [8].

Torrance suggests that creativity is not just the act of thinking, but of identifying the need to think in the first place, and the exploratory and reasoning process that leads to a conclusion.

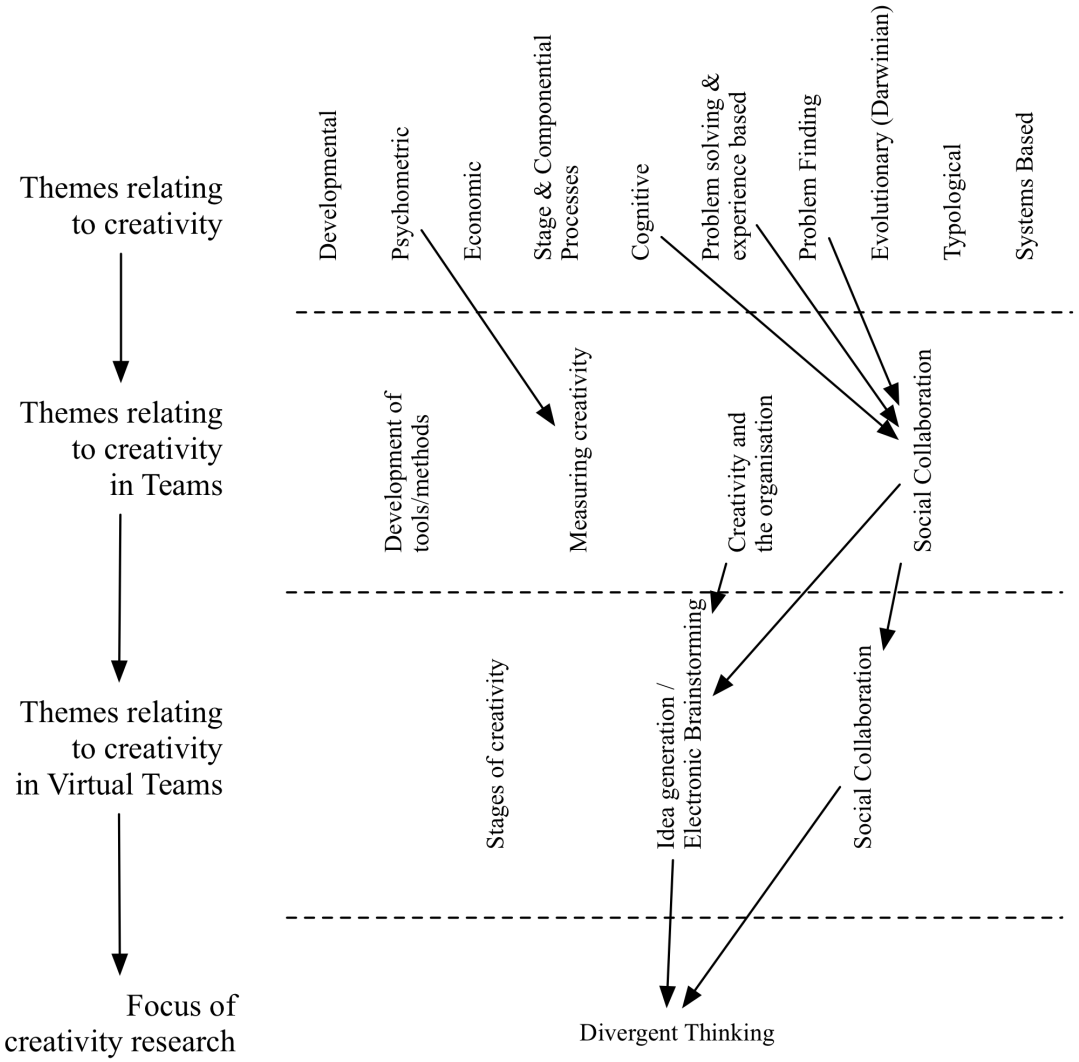


Figure 2.3: Process of refining creativity literature

Creativity is highly subjective, making it difficult to identify and quantify consistently; after all, what you and I consider creative may differ. To address this some researchers choose to describe creativity in terms of magnitude; at one extreme is *Big-C* Creativity - this describes the extreme creativity of individuals like Leonardo da Vinci and Wolfgang Mozart [43]. Unfortunately we aren't all Mozart and yet we are still creative, often on a smaller scale, this is described as *little-c* creativity. More recently Kaufman and Beghetto [44] have proposed that there are in fact further forms of creativity. They suggest that individuals experience creativity when they learn for themselves; during the act of learning an individual may not be making something truly new, but it is new to the individual. Kaufman and Beghetto [44] classify this as *mini-c* creativity. Finally, they propose that there is often a difference between creative professionals who do not achieve Big-C status, yet who are creative professionally in a way that is more substantial than little-c creativity. This they refer to as *Pro-C* creativity.

The ambiguous nature of creativity results in highly varied research. Most research tends to focus on one of the four Ps of creativity: *Process, Product, Person* and *Place* [45, 46]. More recent research has argued for the addition of 2 more dimensions: *Persausion* [47] and *Potential* [48].

Research that explores the *processes* of creativity tends to focus on the cognitive processes that occur during creativity. Research exploring *product* is more interested in the end result of the creativity. Research that emphasises the *person* (or personality) seeks to investigate the relationship between creativity and the creator's personality and background. This ties into the idea of *place*, that is research that explores how the context or environment affects creativity. *Persuasion* research explores how people go about altering the way others think during creativity. Finally, *potential* based research seeks to understand if (and how) we can identify underlying creative potential. In this thesis I am most interested in the *process* of creativity, how creativity emerges in a team, noting that *persuasion* also plays an important role. It is important to clarify that the *place* research does not relate to the focus of this research. Research categorised as *place* tends to explore how the immediate physical environment can be augmented to better support creativity (e.g., new interactive tools for design studios). As opposed to

my my research which seeks to explore the impact that working in co-located and virtual environments have on creative performance.

A recent review of existing creativity research by Kozbelt et al. [42] suggests that existing research can be split into ten broad categories: *Developmental, Psychometric, Economic, Stage & Componential Process, Cognitive, Problem Solving & Expertise Based, Problem Finding, Evolutionary (Darwinian), Typological* or *Systems based*; each emphasising slightly different aspects of the six Ps. *Developmental research* explores how an individuals' background and experiences inform their creativity. This research often includes working with significantly creative individuals (Big-C) to understand how their childhood and life experiences have helped them to develop. This form of research emphasises the role of the Person aspect of creativity. *Psychometric research* is concerned with measuring creativity. Most of this research explores the creative product and how best to analyse it. Key concerns pertain to reliability and validity of measuring methods. This form of research emphasises the creative Product. *Economic* approaches attempt to synthesise the repeatable methods of economic modelling with creativity. *Stage & Componential Process* seeks to explore creativity as a series of stages, a process that can be modelled. *Cognitive research* seeks to understand if there is a difference in the way that highly creative people think. There are many studies that explore creative cognition. *Problem Solving & Expertise related research* treats creativity as a rational phenomenon that occurs during problem solving. A sub-set of this research addresses the role of expert knowledge in creativity. *Problem Finding* is distinct from Problem solving, the research explores the aspect of creativity concerned with developing problem and requirement understanding. *Evolutionary theories* draw from a Darwinian perspective and explore creativity as a complex organic process. *Typological research* attempts to identify types of creator. This research is often closely related to the developmental research as it attempts to categorise creators. Finally, *Systems research* tends not to focus on any aspect of creativity, instead considering creativity as emerging from a complex series of sub-components.

Of these ten suggested areas, this thesis is mostly closely aligned with the work pertaining to psychometric research and problem solving & expertise related research. The latter subset of research further highlights the framing of

creativity as more than just a source of fine artwork but as a mechanism for problem solving and innovation that can be utilised by organisations. The field of psychometric research is typically concerned with the ability to assess creative performance and provides methods for comparing the creativity of co-located and virtual environments that are used in this thesis.

Other research into creativity within Management and Computer Science research is concerned with the development of tools, methods and guides for supporting creativity (e.g.,[49, 50, 51, 52, 53, 54]). Other research explores the efficiency and effectiveness of creativity (e.g., [55, 56, 57]). However, my research does not propose methods of improving creativity in terms of efficiency nor effectiveness. My research is partially motivated by some of the discussions within this research area, particularly in response to the work of Nemiro [55]. In this work Nemiro [55] introduces five building blocks for enhancing and supporting creative work in virtual teams: *Design, Climate, Resources, Norms and Protocols*, and *Continual Assessment*. As part of the process of identifying these five functions Nemiro [55] has completed a review of research relating to virtual team effectiveness (including [58, 59, 60, 61]). Despite this wide ranging literature review Nemiro [55] doesn't identify any research related to the way teams use creativity or collaborate to solve problems. This is indicative of much of the research on creative efficiency; there is little to no consideration of the role of team cognition.

Many researchers take a holistic view of creativity; that it is too complex a phenomenon to develop generalisable representations. Other researchers meanwhile attempt break creativity into stages (e.g., [62, 63, 64]). It seems unlikely that such an ambiguous phenomenon as creativity can ever be definitively modelled. This is reflected in the lack of consensus about what constitutes creativity, despite the extensive body of research. In this thesis I therefore take a holistic view of creativity, seeking only to explore aspects of creativity specific to the context of my research.

One subset of research that tends to extend from Management research explores the role of creativity in organisations (e.g., [65, 66, 67, 68]). This research often emphasises the development of a culture of creativity in organisations. Authors discussing creativity in organisations have a tendency to emphasise the relationship between creativity and innovation, Bourguignon [66] describes how

organisations often view creativity "as a basic skill for those whose job it is to invent and design new products, materials or services." [66]. Whilst creativity is important for organisations, most are wary of creativity for it's own sake. For many organisations creativity is often associated with vague project specifications, time wasted over-exploring requirements, and projects that run over-schedule and over-budget. It is for these reasons that organisations often prefer structuring creative processes using methods like brainstorming [69] and convergent/divergent processes [70].

Related to this organisational framing of creativity is research into social collaboration. This represents one of the key motivations for forming teams; to share knowledge, ideas and opinions to arrive at informed decisions. There is an established field of research that explores the role of social interactions in the creative process (e.g., [1, 71, 72, 73]). Of particular note is the research by Ford [71]. In his paper Ford [71] discusses not only the close relationship between creativity and innovation, but also the relationship between creativity and sensemaking. He outlines the existing discussion around what makes creativity and innovation different; proposing that both are similar, but that innovation tends to emphasise the production of something tangible. Ford [71] relates sensemaking and creativity by proposing that creativity is key for resolving ambiguity during sensemaking. Ford [71] suggests that interpretive processes are vital for making sense of highly ambiguous stimuli, stating that "relatively few empirical or conceptual efforts have been focused on these interpretative processes". Fischer [74] discusses the importance of social collaboration for creativity specifically within virtual environments. Fischer [74] argues that creativity is inherently social (even when an individual process), "The complexity of design problems transcends the individual human mind" [74]. Fischer [74] argues that creativity requires social collaboration to explore a wider range of perspectives and knowledge. He argues that the virtualisation of creativity through communication tools and online communities serves only to enhance creativity.

An important strand of research that is closely related with my research is work on idea generation and electronic brainstorming [75, 76, 77]. This area of research is particularly popular because it provides a means of structuring and bounding creativity. Methods such as Brainstroming proposed by Osborn [69]

have since been adapted for use with virtual teams. Such structured forms of creativity are often referred to as *Divergent Thinking (DT)*, and are a considered a specific form of creativity. I explore divergent thinking in more detail in the next section 2.3.1.1.

2.3.1.1 Divergent Thinking

Divergent thinking describes the process of generating ideas. It is typified by Osborn's [69] extremely popular brainstorming model where groups are encouraged to list as many possible responses (e.g., questions, solutions, ideas, information, criticisms) to a given task. The aim is to allow the generation of responses in a non-judgemental environment. Once gathered, responses can then be reviewed. Using such an approach means that a wider range of responses can be gathered and evaluated. This Divergent-Convergent approach to exploring ideas and problems represents the dominant form of creativity used by many organisations. This research uses divergent thinking as a heuristic for measuring general creativity because "divergent thinking is related to real life creative behaviour" [78]. The popularity of divergent thinking stems from its bounded nature and the fact that it follows a specific, repeatable (and readily understood) process, unlike many other aspects of creativity.

A small collection of research explores divergent thinking specifically within a virtual context (e.g. [76, 79, 80, 81]). The paper by DeRosa [76] provides a meta analysis of Electronic Brainstorming research, exploring various factors including the evaluation of EBS Groups Vs Traditional face-to-face Groups; the paper concludes that EBS groups outperform face-to-face groups the majority of the time in terms of number and quality of ideas generated. Other papers in this area [79, 80, 81] are based on the development and exploration of EBS with a view to providing practical improvements. Liikkanen et al. [80] seek to explore why face-to-face brainstorming is still most commonly used when EBS has been proven more effective. In doing so they develop a new EBS tool by augmenting traditional brainstorming approaches. Whilst these papers explore the process of idea generation in a virtual context their emphasis on the development of tools often means they are driven by the need for a practical outcome, rather than by an

interest in understanding the underlying socio-cognitive processes. Furthermore, these tools are extensions of Osborn's [69] brainstorming technique. This means they aim to improve practice, rather than generate new information about the actual phenomenon.

Recent Requirement Engineering research has used Divergent Thinking to help stakeholders think beyond their existing working practices, or to help identify features that will give software producers an innovative edge (e.g. [1, 73, 82, 83]). A reductive form of DT has even been used as the basis for algorithmic methods for combining linguistic elements of existing (human-authored) requirements to synthesise new requirements [84].

A large proportion of divergent thinking research explores the relationship between creativity and divergent thinking (e.g. [78, 85, 86]). This conversation has its roots in the works of Guilford [87], Torrance [8] and their peers. This group of psychologists disagreed with the use of IQ tests as an absolute measure of intelligence, proposing instead that creativity should be included in any measure of intelligence, motivating the development of a range of creativity tests. Modern reviewers criticise the claim that these tests measure creativity [9, 86]. Instead, they assert that such tests capture an aspect of creativity that we now identify as divergent thinking. More recent work accepts this distinction and acknowledges the validity of DT as a means of exploring creativity. Runco [86] notes "One attractive feature of research on DT is that it offers information about both creative product and the creative process". It is for this reason that I will be incorporating divergent thinking methods in this thesis.

Two of the most widely used and well established methods of measuring divergent thinking are the Torrance Tests of Creative Thinking (TTCT) [8] and Guilford's Alternative Uses test [87].

The Torrance Tests of Creative Thinking (TTCT) [8] challenges individuals to complete a series of abstract drawing and reasoning challenges. These are scored against a set lexicon of common responses to provide a score indicative of both the originality along with an indication of the level of complexity of responses. Despite it's relative age the TTCT is still in use through the U.S.A. as a means of identifying gifted children. Recent critiques by Runco [86] and Kim [9] acknowledge the continuing validity of the TTCT, although they suggest

utilising it as part of a triangulation strategy for gathering a broad understanding of creative performance. It is important to note that in it's original form the TTCT is a paper-based test for individuals. Whilst Torrance suggests that it should be applicable to teams there is no such adaptation currently available.

Guilford's [87] Alternative Uses Test is less complex than the TTCT but still equally valid (so much so that Torrance incorporates it into his test). The test challenges participants to list as many different uses for a particular given object (e.g., a brick) as possible. The list of suggested uses is then scored against a lexicon of common responses to gauge creative thinking. Unlike the TTCT, Guilford's Alternative Uses Test is widely used with teams (e.g., as the core method of analysis in Kanawattanachai and Yoo's [7] study of TMS in virtual teams) with no further adaptation required.

My research utilises both TTCT and Guilford's Alternative Uses Test to gauge the creativity of teams (measuring creativity is discussed in more detail in section 3.2.3). I focus on the divergent thinking aspect of creativity for two reasons: First, Divergent Thinking represents a bounded form of creativity often uses by organisations. Secondly, I am able to draw on the proven tests developed by Torrance [8] and Guilford [87].

2.3.2 Creativity Science

Creativity science is an emerging field that synthesises aspects of computer science and design research (amongst others) to explore how creativity is affected by and affects distributed working. The field originates from early Computer Supported Cooperative Work (CSCW) research into basic approaches for distributed collaboration. Over time the infrastructure and tools and techniques have improved drastically enabling people to design and create collaboratively across both geographic and temporal barriers.

There are two core creativity science research areas that inform this thesis: firstly, research that explores how people and teams collaborate; and secondly research that introduces new tools and methods for supporting (and evaluating) creativity. Figure 2.4 outlines these two core areas and the sub-areas of Trust and Awareness, Team Dynamics, Supporting Creativity and Evaluating tools that sit within these. The size of the circles provides a rough indication of the relative quantity of research in these areas, with research into supporting creativity (via tools and methods) the dominant research focus within creativity science.

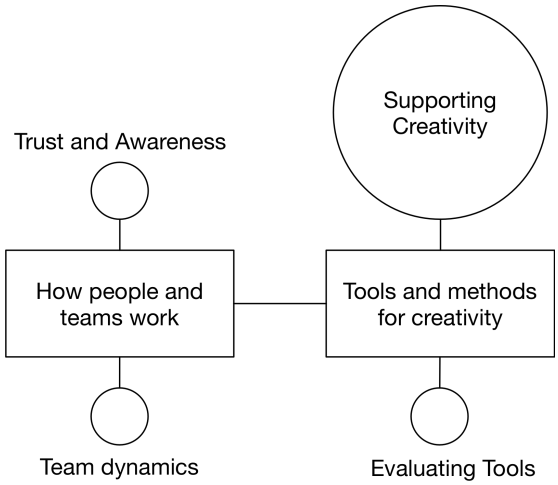


Figure 2.4: Core creativity science themes
(Size of circle relative to quantity of research in area)

Research into how teams collaborate is often concerned with how teams establish trust and awareness. Research explores this from both co-located [88, 89]

and virtual perspectives [90, 91]. Awareness is particularly important to the sensemaking aspect of collaborative creativity (see section 2.3.4) because it helps collaborators to recognise when contributors are stating fact or hypothesising. Of particular note in this area is the work by Lopez and Guerrero [92] who provide a systematic review of the awareness-supporting technologies used in a wide array of collaborative systems that have been proposed during the last ten years, reviewing some 400 papers in total. They define awareness as "the knowledge that a person has of the activities they are supposed to execute and the activities their collaborators are performing" [92]. They make a point that despite reviewing over 400 papers they have found no tools (or studies) for exploring synchronous collaboration of both co-located and distributed teams. Whilst this review specifically relates to the use of awareness technologies in particular, it serves to highlight an overarching trend within the literature, namely that very little research has provided a comparison between co-located and virtual team interactions.

Other research in this area has explored collaborative decision-making. Studies have looked at the way that user roles emerge during decision-making tasks [93]. Luther et al. [94] introduce a new tool, Pipeline, to aid the management of online creative collaborations. They [94] suggest that many fully-distributed creative collaborations fail because the new work domain introduces challenges for the management and leadership of teams. They utilise distributed leadership theory to inform the design of Pipeline. Pipeline serves to help leaders of these teams to decentralise tasks and delegate them amongst the online workforce. It is interesting in that it suggests that delegation of tasks is much harder in virtual teams. It is possible that this is a trend that emerges during the study used in this thesis.

Other work on decision making investigates how relief volunteers were coordinated online following the Haiti earthquake [95]. This research follows on from that of Weick [29] and others who have used analysis of similar extreme situations to highlight how creative sensemaking occurs. Tausczik et al. [64] provide a further study of collaborative problem solving within the MathOverflow online community. It is interesting to observe how little problem solving research there is given the importance of creativity and decision-making. This helps to illustrate

the relative lack of dialogue around creativity/sensemaking particularly within a virtual context.

The core of the research in creativity science relates to the development of new tools and techniques for supporting creativity. This research tends to be split between co-located and virtual contexts. The co-located tools proposed often set out to support the awareness of collaborators by helping them to communicate choices (e.g.,[96]) better. Other work helps collaborators to reflect in order to aid the sensemaking process (e.g.,[97]). Some tools aid the decision making process by digitally augmenting the environment.

In the case of Verma et al. [98] this is done by providing a means for teams to share the information stored on the multiple devices each team member typically owns in order to help collaborators encounter a wider range of contextual information. Shi et al. [99] introduce another contextualisation tool - a digital wall that listens to conversations and then uses speech recognition to source and display further contextual information automatically.

Biskjaer et al. [100] describe approaches for helping interaction designers during the early stages of design. They suggest a number of methods for "scaffolding creativity and innovation". These include a range of workshop suggestions and approaches to help promote creative thinking. Whilst these are interesting they are almost exclusively practice-based and meant to be used with co-located teams.

Geyer et al. [101] propose a tool to help augment affinity diagramming during the very early stages of design in a co-located team. They emphasise the fact that design teams still prefer to use physical materials during the early stages of design instead of using digital mediums, because of perceived barriers to creativity. However, they suggest that ubiquitous computing has improved to such an extent that new tools can be developed with design affordances such that these barriers to use and creativity are greatly reduced. They introduce a new tool to support these co-located teams and report on initial feedback indicating that their digital tool can indeed supplement the design process. This finding serves to support the notion that technology has improved to the point that it can be used for complex creative tasks.

Closely related to this is a piece by O'Neill [102] who presents a short reflection on how to design a digital sketchbook. His review of existing tools is especially

interesting, he notes in particular that over-design (e.g., a large and often confusing range of brushes etc) of such tools is often a key inhibitor of creativity. He suggests that a more basic and easily understood range of options is all that is really necessary in order to effectively mimic the creativity that emerges from most artists' interactions with traditional sketchbooks. He does concede that the ability to undo/redo does provide a particular bonus of digital sketchbooks. Similarly, Obrenovic and Martens [103] reflect on their study to investigate how sketching can be used to support innovation. They ultimately conclude that people innovate the most when sketching in response to abstract prompts and when sketching without a prompt.

Tools that support virtual collaboration relate to advances in video communication and new collaboration tools/methods. Some of this research (e.g.,[104, 105]) explores how video communication itself can be augmented to improve interactions. Research by Li et al. [106] is perhaps the most relevant to this thesis. In their research they introduce SketchComm [106], a tool for supporting the early idea generation of teams that work asynchronously. They explain that face to face meetings are often key during the early stages of design activities but that this isn't always possible. SketchComm is introduced as a tool to help in these situations by enabling designers to include an array of additional contextual information along with the design ideas to help alleviate the constraints enforced by asynchronous collaboration. A small number of papers propose new working methods to support distributed collaborative creativity, for example Malone et al. [107] who introduce a new method for breaking complex tasks into smaller subordinate tasks that can then be reassembled once addressed.

There are a number of similar papers that explore techniques for evaluating these tools and interactions (e.g.,[108, 109, 110, 111, 112]). Dong and Fu [109] introduce a review of video communication and demonstrate that it is a more effective communication medium for negotiation and conflict resolution. Rae et al. [110] introduce a new framework that aims to help designers of telepresence interfaces. Carroll and Latulipe [112] introduce a simple survey tool based on the NASA Task Level Index to help interaction designers consider how to support creativity. Finally, Yamauchi et al. [111] provide a paper that reports on the psychology of the user during a collaborative video conference.

Finally, there is a small subset of this research related to the measurement of creativity (e.g.,[113, 114, 115, 116]). Han Koh et al. [113] look at how to measure creative divergence. Davis et al. [114] explore how to quantify interaction dynamics. Tripathi et al. [115] propose new ways to predict creativity in situ. Finally, Mattingly et al. [116] examine the creative activities of participants as they go about designing a chair. I am wary of using such new methods for measuring aspects of creativity in this thesis because such approaches are relatively immature and often focus on very specific aspects of creative interactions. I am interested in gathering as broad an understanding of creativity as possible, for which the TTCT and Guilford's Alternative Uses Test provide a better (and more established) fit. However, I will seek to borrow from these newer approaches in the development of my third supplementary approach to measuring creativity.

In summary, the existing creativity science literature helps to provide important contextual information for this thesis. It highlights the opportunity to provide a meaningful comparison between the creativity of co-located and virtual teams. Despite the wide array of existing research no one appears to have established a direct point of comparison between co-located and virtual environments. Furthermore, there is relatively little research within this field that actually explores creative performance with the bulk of the related research focusing on how to evaluate ideation alone rather than establishing a broader exploration of creativity. It is clear that the core research is into the development of new tools, some tend to focus on the collaboration aspect that forms the mainstay of CSCW whilst relatively little actually discusses supporting creativity directly. Of this research the most relevant for this thesis are the very short observations made by O'Neill [102].

It seems that there is a gap within this area of research first and foremost to provide a comparison of co-located and virtual team creativity. Such a comparison would be invaluable to those developing tools within creativity science by providing a method for evaluating performance as well as providing an initial demonstration of how early stage collaborative creativity occurs in both environments.

2.3.3 Sensemaking

Sensemaking and creativity are inherently linked. Where creativity is *"The ability to produce work that is both novel (i.e. original, unexpected), and appropriate (i.e. useful, adaptive to task constraints)."* [1], sensemaking is described as "a developing set of ideas with explanatory possibilities, rather than as a body of knowledge. This means that the topic exists in the form of an ongoing conversation" [117]. The close relationship between creativity and sensemaking is especially apparent within an organisational context where 'creativity' is often used interchangeably to refer to both the identification and exploitation of opportunities in order to develop innovations; and the identification and resolution of complex problems. In both cases teams demonstrate sensemaking in order to recognise these scenarios and then to develop an understanding or to plan a response. For example, a team of engineers designing a car will have to work through many complex design problems and decisions utilising both sensemaking and creativity concurrently. Brown et al. [118] describe the interplay between sensemaking and creativity as:

> "A kind of creative authoring on the part of individuals and groups who construct meaning from initially puzzling and sometimes troubling data (Shotter, 1993; Weick, 1995)" [118].

Sensemaking is therefore about developing an understanding of some newly encountered phenomenon. The emphasis is on developing possible explanations. Note that sensemaking does not have to be about developing absolute knowledge; it is often about developing increasingly accurate hypotheses about phenomenon. As such, sensemaking is often explained as the process by which we "structure the unknown" [119] by synthesising past experiences, researched information and experimentation that help the sensemaker to "comprehend, understand, explain, attribute, extrapolate, and predict" [120] the phenomenon. A great deal of the existing sensemaking literature describes sensemaking in these terms: *as the placement of phenomenon into some kind of framework.*

We can consider sensemaking in terms of scale of magnitude from everyday simple individual sensemaking through to complex sensemaking requiring knowledge and input from multiple sensemakers. Simple forms of sensemaking often

occur mindlessly, that is the sensemaker may develop their framework of understanding drawing on past experiences and information without conscious effort. Organisations, however often encounter complex situations that require sensemaking by teams; this is because no single individual has sufficient knowledge that can address the problem, or political authority to do so alone. As we will see later (see section 2.3) the insights provided by others' creativity play an important role in sensemaking. In these situations sensemaking becomes a collective process, often fraught with complications, where team members go about collective sensemaking. The sort of situations that call for team sensemaking (e.g., designing, problem solving) are often high impact, and complex, so any improvement in sensemaking is of vital importance. The team that can make sense of an opportunity before their competitors may be key to organisational success. This thesis explores the latter form of sensemaking which often occurs during creativity, requiring contribution, collaboration and negotiation by multiple sensemakers' as a team addressing a sensemaking task of higher magnitude (complexity).

Weick [117] suggests that sensemaking is often treated as a retrospective process, particularly at an organisational level to try and make sense of past actions. This is reflected in the range of sensemaking research that is based upon secondary sources of information e.g., research that uses sensemaking to analyse responses to and the causes of complex disaster situations (e.g., [121, 122, 123, 124]). Whilst these retrospective analyses provide valuable insight, the use of secondary sources and retrospective analysis are criticised for the risk that post-event accounts provide a 'rose-tinted' version of the event [120]. There is therefore a need to try and observe sensemaking first-hand, analysing primary data to gain an alternative (and hopefully more realistic) insight to how sensemaking occurs (e.g., [6, 120, 125, 126, 127, 128]). My work follows this second school by studying the interactions of teams within a repeated experiment.

Sensemaking occurs at *Individual* and *Group/Team* levels, as well as at *organisational* and *inter-organisational* levels. Research at the *individual* level seeks to understand the way that individuals make sense of the world. The *group/team* level research explores how collections of individuals collaborate together to make sense. This level introduces socio-cognitive, knowledge, political and power complexities. Sensemaking at an *organisational* level explores the

macro-level strategic decision making that steers an organisation. Above this lies the *inter-organisational* level that explores the sensemaking that occurs amongst organisations. Much of the research at this level explores how major disasters have been addressed by collaboration between multiple parties. Finally, spanning all of these levels is research into methods and tools for supporting sensemaking (e.g., [129, 130, 131, 132, 133]).

Existing theories of sensemaking tend to describe sensemaking in terms of very broad characteristics [117, 118, 120, 125, 134, 135]. Weick [117] is perhaps the best know researcher in this area. His book *Sensemaking in Organizations* [117] suggests that sensemaking be described in terms of the following seven characteristics:

1. Grounded in identity construction
   Whilst there may only be an individual who is sensemaking, their own identity is part of the wider set of interactions they have with their environment. So, as they interact with others, perhaps gathering knowledge to aid their sensemaking they are going about a process of choosing what to share and how to behave with others. The representation the sensemaker chooses to portray varies depending on their environment and who they are interacting with.

2. Retrospective
   This relates to a point raised by Starbuck and Milliken [120] that much of our sensemaking occurs when we try to reason, to understand past events. It is important to recognise this because so much sensemaking and decision making is based upon previous experiences.

3. Enactive of sensible environments
   When sensemaking, people often affect their sensemaking environment, introducing boundaries and constraints. This point is related to the description of sensemaking being about the development of frameworks that explain a phenomenon's characteristics [120, 125].

4. Social

   Weick argues that all sensemaking has a *social* element. Even if not discussing problems with others, our understanding can still be affected by interactions.

5. Ongoing

   The *social* nature of sensemaking is best explained alongside the idea that sensemaking is *ongoing*. This is a key characteristic of sensemaking; that the framework of understanding is constantly evolving. It is only ever accurate in the particular time-place that it is described. Russell et al. [125] describe the same concept as a series of iterative *learning loops*. It is important to note that sensemaking often has enforced conclusions e.g., action, time or power constraints that may effectively conclude the sensemaking at that particular time-place.

6. Focused on and by extracted cues

   Sensemaking is inherently *focused on and by extracted cues*. This explains the phenomenon by which we are seemingly able to make sense of anything. Weick explains that throughout our lives we are learning and subconsciously storing information on everything we encounter. Cueing is the process by which we recall and use these encounters. It explains how we can encounter something new and draw on previous memories to understand some of its characteristics. However, we can't always draw a comparison until something else cues that memory. This is a very important part of sensemaking - how we recall and use past experiences. This characteristic is what makes sensemaking so complex. The sources that cue re-development (or iterations) of the framework of understanding are almost endless, from social interactions, to prototyping, to searching online.

7. Driven by plausibility rather than accuracy

   Finally Weick suggests that sensemaking is ultimately *driven by plausibility rather than accuracy*. That is, we are making sense of something, to the best of our abilities. At first our framework of understanding may only

roughly describe the phenomenon, but over time new information improves this and the ability for the framework to explain the phenomenon improves.

These seven characteristics broadly describe sensemaking as Weick [117] recognised it in 1995. He has arrived at this work by synthesising a wide range of sensemaking case studies. Whilst his work is based on secondary accounts his characteristics are key to our current understanding of the sensemaking process.

Related to Weick [117, 134] are a number of shorter but notable contributions [120, 125] that explore the sensemaking process that occur within organisations. Starbuck and Milliken [120] investigate how successful executives perceive their environments. They propose that successful executives are better at perceiving threats and opportunities in their environments. They build on the suggestion initially made by Goleman [136] suggesting that executives make sense by placing phenomenon into frameworks (or schemata) that enable them to make sense of the phenomenon. Many of these frameworks are based on best guesses and assumptions and they are constantly changing. Similarly, Russell et al. [125] study the learning process of Xerox trainees. They propose a highly structured model that attempts to identify the cost of sensemaking. Alongside this they make a more important contribution by suggesting that sensemaking is in fact a learning loop. This is a series of iterative loops triggered by new information.

More recently work by Brown et al. [118] has analysed the sensemaking of a project team by using a narratological approach to explore the agreed and discrepant sensemaking of the team. Their work attributes these differences to the way that team members present themselves and their understandings to each another. This work emphasises the *grounded in identity construction* characteristic observed by Weick [117] and finds evidence for it in analysis of team interviews. The use of a narrative-based analysis is interesting and seems logical since collective sensemaking can be considered story-telling. The paper makes an important contribution by emphasising the role that identities and their associated narratives play in sensemaking, and the breakdown in sensemaking that can occur within a team.

Weick [117] introduces a thread of research on exploring the collective mind, i.e., how team thinking develops. One key paper on this area by Weick and

Roberts [29] explores how the control team of an aircraft carrier maintained error free, high responsibility team coordination and sensemaking. More recent work by Kanawattanachi et al. [7] describes a very similar phenomenon in the form of Transactive Memory Systems (TMS). The work of Kanawattanachi et al. [7] and Weick [117] are closely related. However, comparison of case studies is highly problematic because case studies are usually of unique (and therefore incomparable) situations. Unfortunately this is a key criticism that is applicable to the majority of sensemaking research. Whilst case studies can provide valuable insight to either co-located or virtual sensemaking they are rarely suitable for comparison of the two environments.

One of the key problems highlighted by much of the aforementioned research is related to the data source used. The majority of the research into sensemaking is developed from secondary data. It is important where possible to develop case studies from primary data and observations to derive more concrete understanding of virtual team sensemaking characteristics. Whilst there have been a number of important contributions derived from secondary source case studies, they are regularly criticised. The nature of sensemaking tends to inhibit simultaneous observation and analysis. Sensemaking studies have therefore often been retrospective analyses (e.g. [121, 122, 123]). These studies attempt to identify causality, assuming that retrospective data used for analysis is objective. This approach is problematic, with participants often trying to explain (and justify) their past actions, and researchers trying to second-guess what really happened. Weick [134] discusses this problem, commenting that:

> "To deal with ambiguity, interdependent people search for meaning, settle for plausibility, and move on. These are moments of sensemaking, and scholars stretch these moments, scrutinize them, and name them in the belief that they affect how action gets routinized, flux gets tamed, objects get enacted, and precedents get set." [134]

Suchman's [137] discussion of plans and situated actions helps to further explain this disconnect. She suggests that plans which are created either before or after an event, never truly explain what has happened. She uses the analogy of kayaking down a river to illustrate this. When kayaking, you may come to

a difficult passage, you stop, get out and plan what you should do to get down the river safely. However, what actually happens when you go to carry out the plan can vary. The context of the action means that it is nearly always different from the plan - she refers to this as the situated action. The same is true when analysing sensemaking retrospectively, whilst we can identify details about the sensemaking, the lack of primary access to the situation means there is a risk that the account will over-rationalise the process into a plan.

Similarly, Starbuck and Milliken [120] also criticise the use of retrospective analyse of sensemaking in management literature:

> "Prevalent though they are, retrospective explanations of past events encourage academics to overstate the contributions of executives and the benefits of accurate perceptions or careful analyses. Because retrospective analyses oversimplify the connections between behaviours and outcomes, prescriptions derived from retrospective understanding may not help executives who are living amid current events." [120]

From this it is clear that retrospective analyses are problematic, yet despite this, I cannot avoid using them in my research. My methodology will therefore attempt to limit retrospective analysis.

There are relatively few studies of virtual teams based on primary data. Vlaar et al. [6] provide one such study that is perhaps the most closely aligned to this research. In their paper they have researched the sensemaking process that occurs between a company and its offshore developers. Vlaar et al. [6] reiterate a gap that is becoming apparent in the existing virtual team, creativity and sensemaking literature:

> "Achieving shared, common, or mutual understandings among geographically dispersed workers is a central concern in the distributed work literature. Nonetheless, little is known yet about the sociocognitive acts and communication processes involved with synchronizing and cocreating understandings in such settings." [6]

Vlaar et al. [6] suggest that differences in knowledge and experience (amongst others) prompt teams to go about sensemaking. This is particularly apparent during the early stages of collaboration where personality, culture, language and time differences further complicate socio-cognitive processes. However, it is during these opening stages of a project that much of the key work occurs. Vlaar et al. [6] observe what they describe as three different forms of sensemaking: *sensegiving, sensedemanding* and *sensebreaking*. They [6] have derived these three sub-forms of sensemaking following a number of interviews with members of both onsite (based in New Jersey, USA) and offshore (based in Bangalore, India) teams. Their analysis explores the communication practises used by these teams from which they derive a "conceptual framework that depicts the development of understanding as an iterative sequence of socio-cognitive acts and processes." and is shown in figure 2.5.

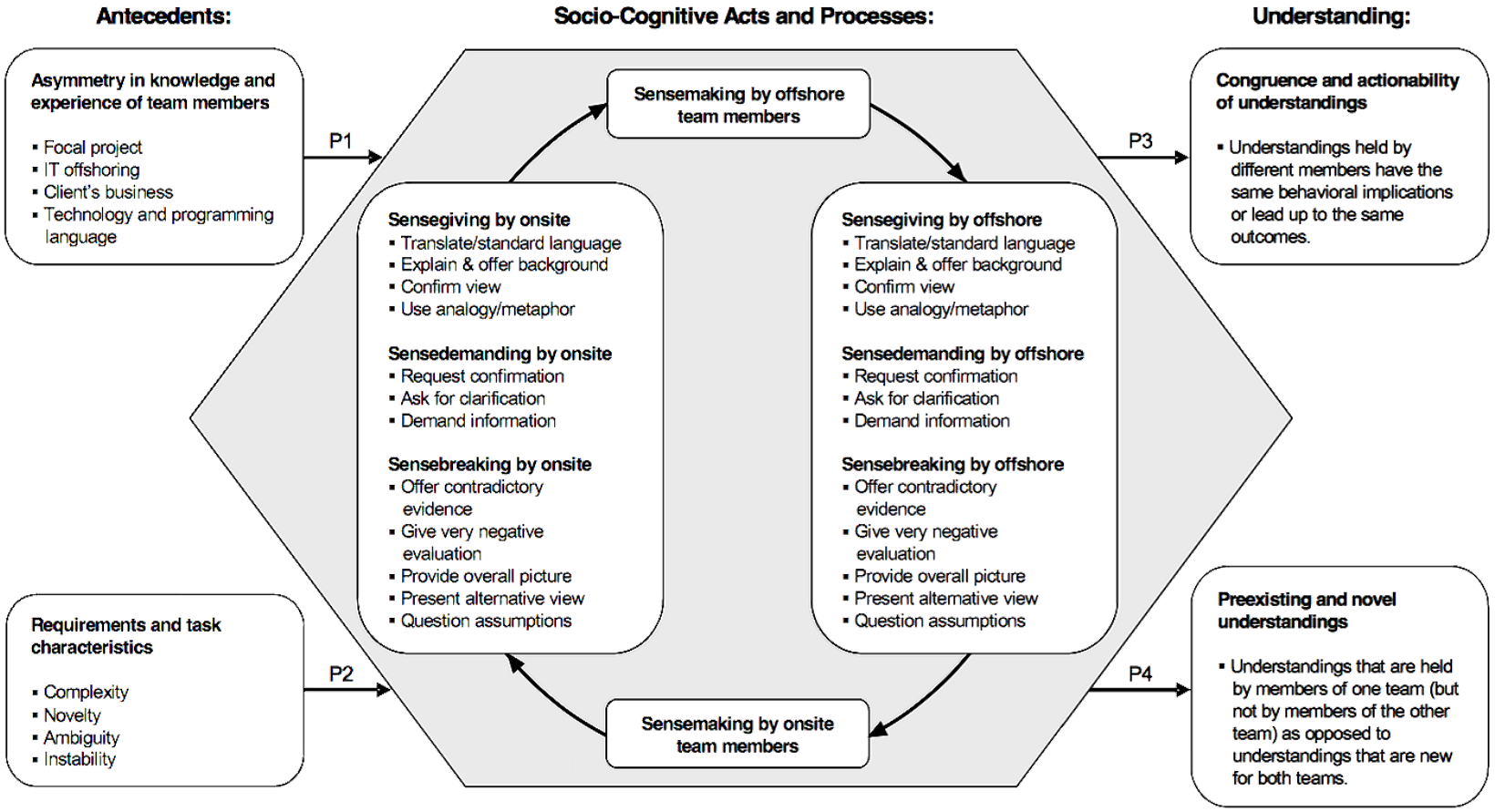


Figure 2.5: Developing Congruent and Actionable Understandings in Distributed Work Settings. Reproduced verbatim [6].

Vlaar et al.'s [6] model (see figure 2.5) provides insight into the distributed sensemaking that occurs specifically within the context of the teams studied. The concepts of *sensegiving, sensedemanding* and *sensebreaking* developed provide an interesting development of Weick's [117] sensemaking characteristics. Unfortunately, their analysis is only of partially-distributed teams.

That is, the two teams are organisationally and geographically distributed (one team is based in the USA and the other in India). However, the teams themselves are both co-located. So the team in the USA all work in the same office together and the same is true of the team in India. As such, this study doesn't provide insight into the fully geographically distributed teams that are the focus of this thesis.

2.3.4 The impact of environment on the creative process

Virtual working affects the way that teams are able to collaborate with a potential impact on socio-cognitive processes. Virtual team collaboration generally occurs either synchronously or asynchronously depending on a number of factors such as time difference (larger time differences tend to be resolved by increased reliance on asynchronous communication tools) and type of work being addressed (more complex or urgent work tends to demand more immediate feedback from synchronous communication tools).

In this thesis I am interested in how virtual teams collaborate together on complex creative projects e.g., design or problem-solving teams. Such teams are unlikely to have worked together before, being formed either on the spur of the moment based on availability of team members (in the case of a problem solving team), or often from multiple departments in an organisation (for design teams). I am assuming that such a team communicates synchronously using video conferencing, at least during the early stages of a project. During this time the team will be constantly adjusting, seeking to understand both the problem and each-other.

Figure 2.6 provides an illustration of the individual creativity process. In this figure the individual encounters a situation that requires understanding and they begin to develop a *Schema*; this is their current model of understanding.

This schema is constantly in flux, it is constantly being revised as the individual encounters new information, perhaps by testing their current schema, or by researching information, or through interactions with others. Almost anything can prompt a revision of the schema. Some things will prompt it consciously e.g., searching for information, whilst others prompt a revision unconsciously e.g., recalling a previously forgotten experience. The individual is shown within their own work system [138], with new sources of information and triggers from the external environment affecting the creative process. The concept of a work system [138] helps to describe the interactions that occur between individuals and (often) computing systems. It provides a useful way of illustrating how creativity can occur in isolation of the external environment (if left to do so), but also helps demonstrate how any interaction with the external environment may affect the creative process.

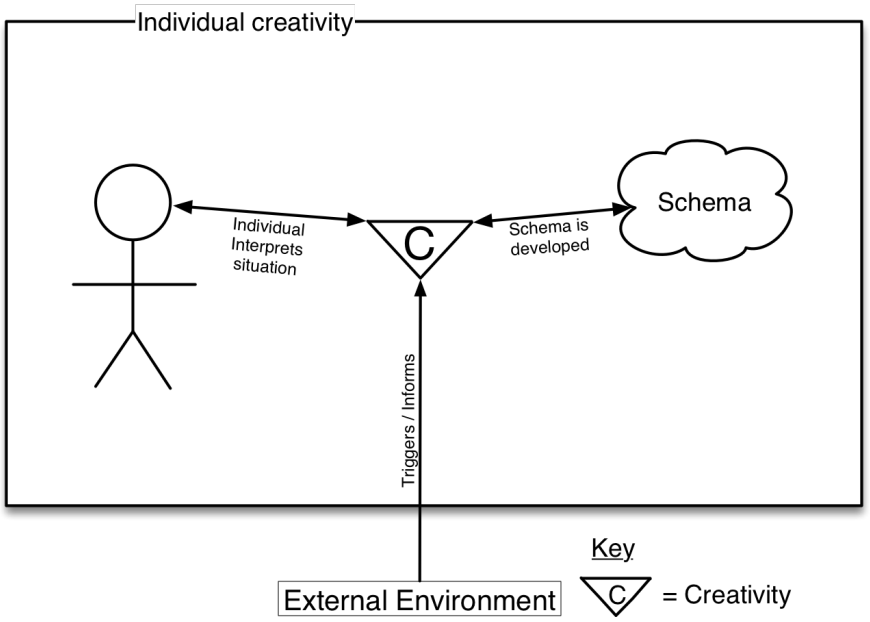


Figure 2.6: Individual creativity

This is a very simplistic representation of how an individual identifies, interprets and responds to a trigger. As soon as the individual is placed within a team then this process becomes far more complex (see figure 2.7).

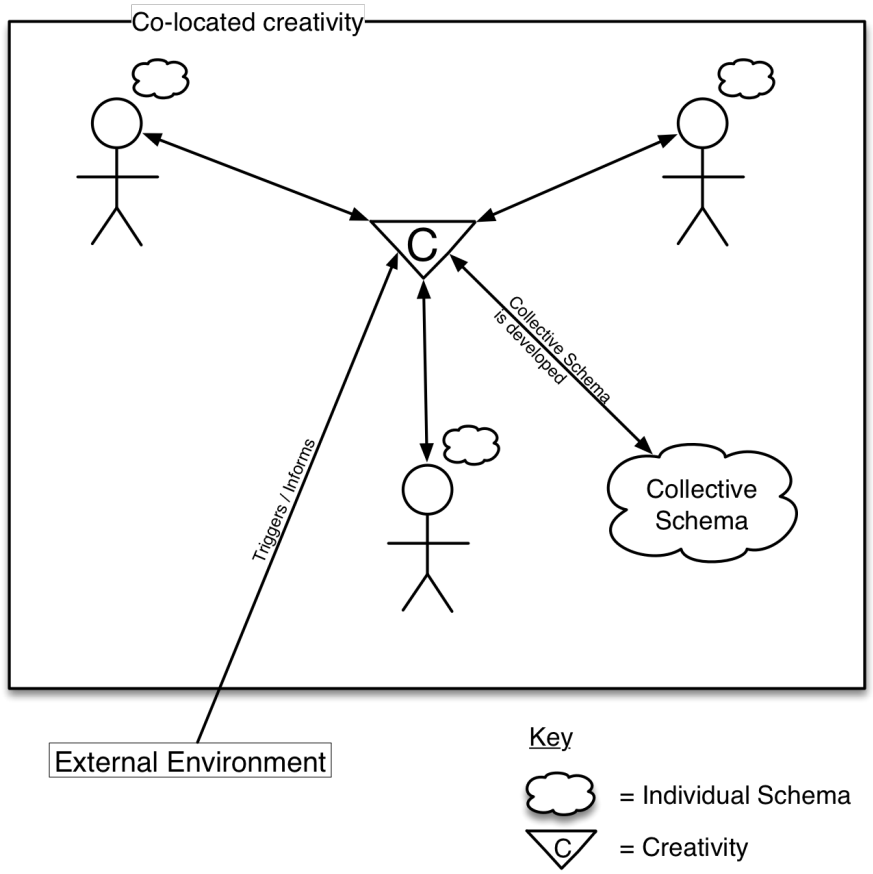


Figure 2.7: Co-located creativity

A team is often used in situations where the phenomenon, or task in question is sufficiently complex such that no single individual has absolute information sufficient to resolve the situation. Figure 2.7 shows how the system has evolved; there are now three individuals each with their own schema. On top of this, there is a collective schema being developed. This relationship between the individual and collective schema is what makes team creativity complex.

In Figure 2.6, the Individual's schema is revised by any new source of information e.g., a conversation with a colleague; only the Individual's understanding of the phenomenon has changed. However, in a Team (as in figure 2.7) each individual is trying to respond to the phenomenon by themselves, aided by interactions with the other team members (within the work system). On top of this the team is attempting to come to an agreement of how best to describe the

phenomenon and its characteristics (and possibly respond). This is represented by the Collective Schema. Ultimately the creativity of the team is affected by the ability of team members to explain to each other their own current schema. Through these interactions the individuals schemas develop slowly, increasing in similarity as the collective schema develops. Further to this there are factors of politics and power at play; it may be that one of the individuals in the team has the capacity to make a decision that overrules the others, even if they do not have a fully informed understanding.

Team creativity is further complicated by the introduction of a virtual team context (see figure 2.8). Virtual teams collaborate using a mixture of synchronous (e.g., video conferencing) and asynchronous (e.g., email) communication tools. The richness and immediacy of feedback afforded by these tools ultimately impacts upon the creative processes of the team.

The extent to which a virtual team is distributed also affects its creativity. It is possible in a fully distributed team for all of the team members to work from separate locations (see figure 2.9). Such teams may never physically meet if they are working across vast geographic distances. Or, by contrast they might work from separate locations for much of their work but actually meet physically for certain tasks e.g., monthly catch-up sessions. Figure 2.8 demonstrates the flexibility of virtual working, showing both an individual working separately and then sub-groups of a team who happen to be co-located. This sort of working occurs when an organisation forms a team across multiple sites. The sites are physically distributed and consequently the team has to work virtually for all of the team members to collaborate. Such teams can sub-divide tasks based by site, such that team members who are co-located address specific sub-tasks and report their findings back to the wider virtual team. It is this flexibility that makes virtual teams so appealing to organisations. It also demonstrates the complexity of exploring the creativity within such a team. The team in figure 2.8 is creative at an individual level, with all team members developing their own schemas of understanding. There is then the overall Team Collective Schema which enables the sharing and refinement of information leading to action. At this point the model is quite similar to that in figure 2.7, however this model is

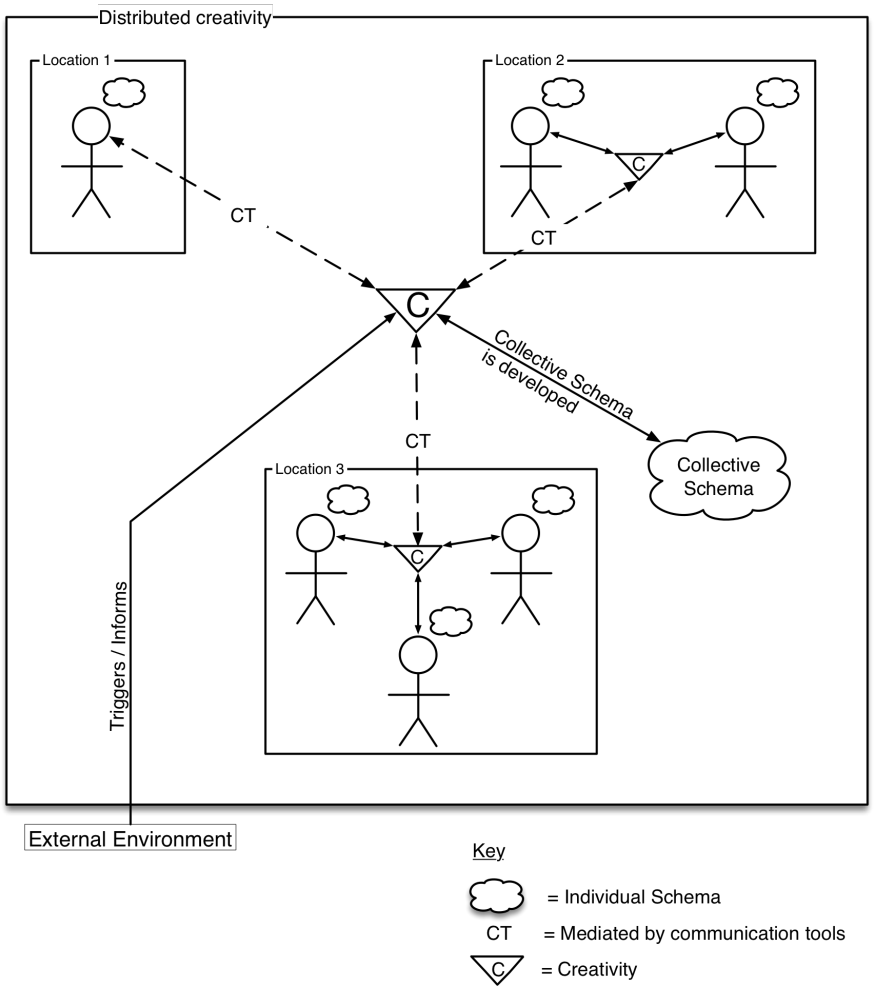


Figure 2.8: Distributed creativity

further complicated by the potential for sub-teams to have their own additional collective schema e.g., The group of team members in Location 3 in figure 2.8.

Many organisations will adopt a flexible form of virtual working, as demonstrated in Figure 2.8. However, as previously discussed, some organisations will operate fully distributed teams (see Figure 2.9) in which all team members work from separate locations. This represents the most extreme form of virtual working and it is these teams that my research will be exploring because their work environment and practises are so different to traditional co-located teams.

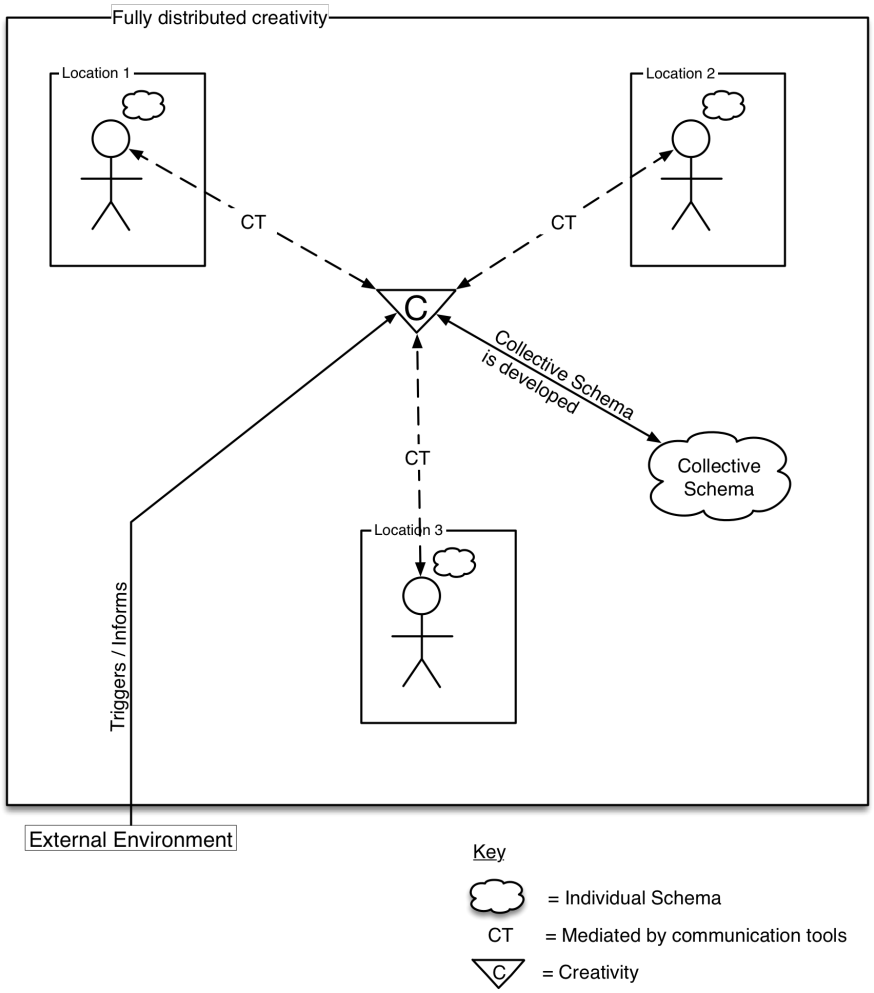


Figure 2.9: Fully distributed creativity

2.3.5 Summary

This section has reviewed the major research into creativity that informs this thesis. In particular it highlights the close relationship between creativity and sensemaking. The rest of this thesis therefore treats sensemaking as a key aspect of creativity and vice versa.

Section 2.2 introduced an overview of the breadth of research into virtual ways of working. Section 2.3 has then helped to provide an overview of what consistitutes creativity. Sections 2.3.1.1 and 2.3.3 have explored the overlap between divergent thinking and sensemaking that form the focus of this thesis. Section 2.3.4 has then helped to illustrate how creative processes are affected by the environment.

This section has introduced creativity, the focus of interest in this thesis. The section has outlined briefly the ambiguous nature of creativity. The area of divergent thinking research in particular is explored, this describes the framing of creativity most associated with organisations; one where creativity is key to either problem solving or to innovation. Sensemaking research is then discussed because it represents the underlying socio-cognitive process inherent in this organisational framing of creativity.

2.4 Chapter Summary

This chapter has reviewed the related research (see figure 2.1). The broad area of virtual work research has been introduced and the lack of any meaningful comparison between co-located and virtual environments highlighted. The complexities of defining exactly what constitutes creativity and how best to measure it have also been discussed and the particular organisation-focused framing of creativity used throughout this thesis introduced. The new emergent field of creativity science is explored. The concept of sensemaking is then introduced providing further detail about how teams develop an understanding of ambiguous creative situations, and it is shown that that it can be used interchangeably with the organisational form of creativity in this thesis.

I have highlighted the motivation for this research, namely the limited range of work that compares the performance of teams in virtual and co-located environments [92]. This would seem to be an essential component in the on-going debate on the adoption of virtual working methods.

I have described how the ambiguous nature of creativity gives rise to problems of definition and interpretation. Because of this ambiguity I outline the specific framing of creativity that this work relates to, namely the view of creativity employed by organisations; where creativity can pertain to both innovation and problem solving.

The lack of an accepted definition of creativity results in a complex discussion around how best to study creativity. Modern approaches within the creativity science domain have a tendency to either use quantitative approaches to focus on very specific areas of creativity or instead provide methods of evaluating creativity support tools. The tests originating from the Psychology research of the 1960s use a mixture of qualitative and quantitative means and therefore provide a broader indication of creative performance. In this thesis I therefore borrow from Torrance's [8] and Guilford's [87] established methods of analysing creativity.

Both the Torrance Tests of Creative Thinking [8] and Guilford's Alternative Uses Test [87] are paper-based tests designed for individuals. The TTCT will

therefore need to be adapted to be used by teams. Guilford's Alternative Uses tests is already widely used with teams without any additional alterations.

These adapted forms will need to be further extended so that virtual teams are able to complete them. The most pragmatic approach is to develop digital collaborative forms of the TTCT and Guilford's alternative uses test so that Co-located and Virtual teams are both able to complete them equally. None of the existing tools reviewed in this chapter provides an adaptation of the TTCT or Guilford's Alternative Uses test. Nor do any of the tools reviewed provide the functionality necessary to facilitate the development of such a tool. It is therefore necessary to develop a new testing platform for these adapted forms of the test. Furthermore, the interactions afforded by the paper versions of these tests will need to reproduced to provide an accurate adaption into a digital collaborative format.

2.5 Research Questions

Research Question 1 Do virtual or co-located teams perform creative tasks better?

By better I mean, is there a difference in either the overall performance or approach taken by co-located and virtual teams when addressing collaborative creative tasks. This question is motivated by the limited research comparing co-located and virtual team performance. It seeks to to build on the work of Kanawattanachi et al. [7] by providing further evidence of the type of socio-cognitive processes that virtual teams can perform. Creativity in particular is chosen because it is a key team function in organisations. Research Question 1 is addressed in chapter 6.

There are number of related sub-questions that enable me to address RQ1. These questions emphasise the TTCT in particular because it comprises multiple activities and thus provides a broader indication of creativity to base this research on. Additional measures like Guilford's Alternative Uses are included but the TTCT represents the core gauge of creative performance.

RQ 1.1 Can the TTCT be adapted to be used with teams? The TTCT and Guilford's Alternative Uses test both provide established means of measuring creativity performance. The latter is regularly used with teams without adaptation. The TTCT therefore needs to be adapted to be used with teams.

RQ 1.2 Can an adaptation of the TTCT be developed for use by both Virtual and Co-located teams? It is going to be necessary to further extend the aforementioned adaptation of the TTCT for teams so that virtual teams and co-located teams can complete the test. This means developing a digital form of the TTCT to enable synchronous collaboration from multiple locations.

RQ 1.3 Can a digital form of the TTCT be designed to provide co-located and virtual teams with identical experiences? The nature of the TTCT is heavily reliant on drawing interactions. It is therefore key that any digital adaptation be carefully designed to provide a drawing experience as close to that of paper as possible.

Chapter 3

Methodological considerations and research design

The previous chapter identifies gaps in the current body of knowledge; in particular the lack of comparison between the creativity of virtual and co-located teams. This chapter explores the methodological considerations that inform the research approach used. To begin with, the broadly interpretive stance taken in this research is outlined (§ 3.1). Section 3.2 then discusses the rationale that has led to the mixed-method experimental research approach employed and how the interpretive stance informs this approach.

3.1 Epistemological position

Epistemology is the theory of knowledge; how we develop knowledge; how we differentiate between absolute knowledge (fact or truth) and belief (justified or otherwise) [139, 140, 141, 142]. The position employed affects the type of knowledge that can be generated by research, and the conclusions that can be drawn.

I use a broadly interpretive stance to inform the design of the method employed in this thesis. Interpretivism provides a way to "help researchers understand human thought and action in social and organisational contexts" [143]. Interpretivism therefore provides a good fit with my research into how teams collaborate creatively, especially given that such forms of creativity are typically action-orientated.

Interpretivism proposes that knowledge is socially constructed, that the researcher is influenced by and influences the participants under study. Interpretivism also acknowledges that context plays a core part in the interpretation of participants actions and decisions. Interpretive approaches have become increasingly popular within the fields of CSCW and C&C for studying the complex interactions of virtual teams [144]. Klein and Myers [143] suggest that:

> "IS research can be classified as interpretive if it is assumed that our knowledge of reality is gained only through social constructions such as language, consciousness, shared meanings, documents, tools, and other artifacts. Interpretive research does not predefine dependent and independent variables, but focuses on the complexity of human sense making as the situation emerges (Kaplan and Maxwell 1994); it attempts to understand phenomena through the meanings that people assign to them (Boland 1985, 1991;Deetz 1996; Orlikowski and Baroudi 1991). Interpretive methods of research in IS are aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context (Walsham 1993, pp. 4-5)." [143]

A broadly interpretive stance provides a good fit for this research because it allows both for the capture of wider contextual information and the analysis of

the complex interactions that occur during virtual collaborative creativity. In the section that follows I outline the research design used for this study and discuss how it is informed by an interpretive stance.

3.2 Research Design

This section summarises the early stages of research (section 3.2.1) that inform the final research design (section 3.2.2).

3.2.1 Early stages of research

The initial plan for this research was to develop a series of case studies from observations mimicking the approach used by Weick [117]. I intended to observe both co-located and virtual teams and then contrast case studies to derive an understanding of the differences between the two. I approached a number of different organisations, from local businesses to multinationals. However, whilst the majority of organisations were interested in the research most were not happy to have their 'creativity' nor 'sensemaking' processes observed, assessed, or reviewed in any way. The chief concern cited by these organisations was the potential of being compared at some level with competitors, despite assurances of confidentiality. After several months negotiation I secured access to one organisation, a games team working on a project called Excalibur.

The Excalibur team were fully distributed, and consisted of a team of volunteers working together to develop an open source (and unofficial) Star Trek game. They collaborated via an online forum and were more than happy to provide me with access to this in order to study how they negotiated meaning during online discussions.

Studying the Excalibur team provided a fascinating insight into asynchronous virtual team sensemaking (see Shreeve et al. [145]). However, this study highlighted a number of methodological issues in my planned research approach.

Firstly, the Excalibur team communicated almost exclusively via a forum, this meant that most decision making was asynchronous. Whilst it is interesting to be able to demonstrate how asynchronous sensemaking occurs, most organisations tend to revert to synchronous communication tools to address important tasks or problems.

Secondly, drawing comparisons between environments was looking increasingly unlikely without access to multiple organisations.

Finally, comparison between case studies is problematic. This is especially true when exploring creativity or sensemaking processes where the tasks being addressed vary in terms of complexity. Such factors would ultimately introduce limitations to any findings produced.

In the face of these complexities it became apparent that another approach was necessary to address the previously outlined research questions. The experimental approach developed following this initial stage provides the necessary means of controlling team, task, distribution and other factors to study the underlying creativity.

3.2.2 Research design

This thesis uses an experimental mixed-method approach to gather data on team creativity. Teams of three participants complete six creativity activities using the CreativeTeams tool (see section 4.2 for more details). These activities are completed in either a co-located or virtual environment.

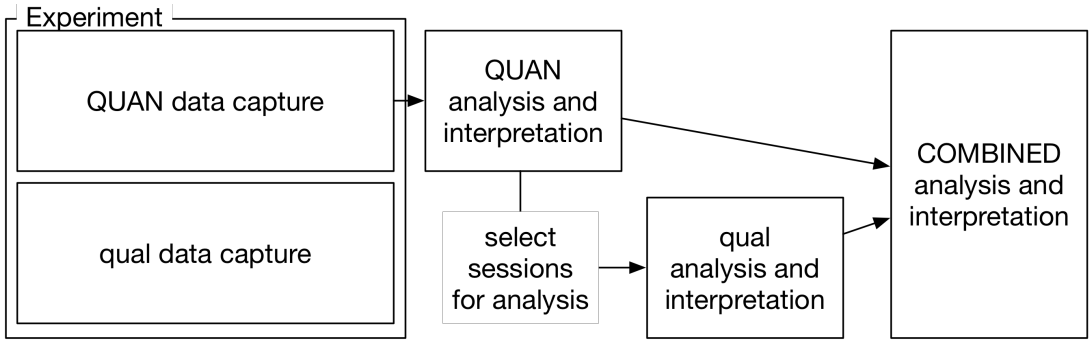


Figure 3.1: My mixed method research design

The experiment generates both quantitative and qualitative data. The outputs of four of the six creative activities can be scored to provide an indication of creative performance. Sessions are filmed to capture the teams verbal and physical (body language) interactions. Furthermore, the actual drawing process is recorded providing a video of the creative interactions during the activities.

Figure 3.1 illustrates this process with both quantitative data (creative performance scores) and qualitative data (filming, drawing processes) being captured concurrently during the experiment.

The scores generated are assessed along with meta data generated by the CreativeTeams tool to establish the difference in the creative performance of co-located and virtual teams. Qualitative analysis is then used to explore any sessions of note identified during the quantitative analysis stage.

Mixed method approaches synthesise quantitative (quan/QUAN) and qualitative (qual/QUAN) methods to derive knowledge. Mixed methods is often represented as the third research paradigm [146] or methodological movement [147]. Creswell and Plano Clark [148] suggest that the design of a mixed method approach is informed by four key decisions:

1. **The level of interaction between strands**. They [148] suggest that strands are either *independent*, with no interaction until the interpretation phase; or, *interactive* when quantitative and qualitative strands mix at some stage prior to interpretation.

   In the experimental approach used both quan and qual data are gathered concurrently. However, the two strands are analysed and interpreted separately. The quan strand interpretation informs the selection of aspects for analysis in the qual strand.

2. **The relative priority of the strands**. That is, are quantitative and qualitative methods of equal importance to the research. Priority tends to be shown by capitalising QUAL or QUAN to show emphasis. Both can be equal: *QUAN + QUAL*. Or emphasis can exist either way: *QUAN + qual* or *QUAL + quan*.

   In this study the **QUAN** strand is prioritised over the **qual** strand. This is because the psychometric tests that have been adapted are well established and extensively tested. This increases the reliability of the QUAN results. The qual strand meanwhile attempts to explore the underlying socio-cognitive processes. The design of the experiment attempts to stimulate these processes, however there is no guarantee that they are actually present.

3. **The timing of the strands**. This relates to the order of the research strands, with timing being either *concurrent, sequential or multiphase.*

   Both QUAN and qual data will be captured concurrently during the experiments. The QUAN analysis and interpretation will then take place. This will allow RQ1 to be addressed, it will also highlight any unexpected or contrary relationships. These will then be assessed using a qual approach.

4. **The procedure for mixing the strands**. This relates to where and how quan and qual strands mix. It is suggested that strands can mix either during interpretation, analysis, data collection or at the level of design.

   QUAN AND qual strands follow a largely sequential pattern following the data capture phase. The QUAN strand will address RQ1. However, the interpretations of both QUAN and qual strands need to be combined to develop a richer more effective understanding of creativity.

Babones [149] suggests that quantitative approaches are readily compatible with interpretive approaches, noting that "key tenets of interpretive quantitative methodology are the triangulation of research results arrived at by analysing data from multiple perspectives, the integration of measurement and modelling into a more holistic process of discovery and the need to think reflexively about the manner in which data came into existence." [149]. The research design outlined here triangulates the quantitative study of creativity by using TTCT, Guilford's Alternative Uses test and the Design Challenge activity designed by myself (which I will explain in more detail in section 4.1) to explore creative performance from multiple perspectives. Furthermore, this research design sets out to supplement these findings with additional quantitative data gathered from video recordings of interactions and the drawing process themselves. These sources are combined during the analysis to explore the co-creation of drawings and test responses. The complexities and implications of these interactions is then reflected upon in section 7.4.

This research is not looking for causality but rather to explore if there are any differences between the two environments in the narrow context by which creativity is framed in this study. There is little apriori theorisation because

of the lack of previous related research to build upon. I assume that creativity is socially constructed and will remain so throughout this study. I purposefully combine quantitative and qualitative approaches to explore the tension that exists between performance and social co-creation. The use of a quantitative approach provides a structure from which to begin to address RQ1. It also provides a more refined context to focus the exploration of the underlying interactions that occur as the teams collaborate on these creative activities.

3.2.3 Measuring creativity

One of the major areas of creativity research is on how best to measure creativity. Section 2.3.1 has highlighted the many different ways that creativity can be framed [150, 151], each proposing different approaches for evaluating creative performance. It is for this reason that this thesis adopts Torrance's [8] definition of creativity as:

> " A process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypothesis about the deficiencies: testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results". [8].

This definition clearly provides a good fit with the organisational framing of creativity used in this thesis. The subjective nature of creativity and lack of an agreed definition results in a wide variety of approaches that purport to measure creativity. Some techniques rely on expert markers to evaluate creative performance by scoring it on a scale. However, in order to produce reliable results such approaches generally require multiple expert markers who can demonstrate consistent scoring. Other methods try to be more objective by trying to produce a lexicon of common outputs.

These factors begin to briefly demonstrate the complexity involved in attempting to measure creativity. In this research we borrow from the body of research on psychometric testing of creativity to produce as objective a measure

of creativity as possible. Plucker et al. [150] suggest that existing psychometric assessment techniques tend to explore one of four broad categories: *Creative processes; Personality and behavioural correlates of creativity; Characteristics of creative products; And, Attributes of creativity-fostering environments.*

The psychometric testing approaches relating to creative process best fit this thesis. These provide measurements of divergent thinking. That is, ideational forms of creativity. Divergent thinking is often criticised because it reduces creativity into two logical strands: A divergent exploratory or idea generating phase, and the counter convergent refining phase. Divergent thinking therefore assumes that creativity has a purpose, it cannot exist for its own sake. It also best describes the creativity we encounter most commonly. Guilford [152] observes, "most of our problem solving in everyday life involves divergent thinking" [152]. This is especially true in organisations where action is emphasised.

3.2.3.1 Measuring Divergent Thinking

Divergent thinking is generally accredited to Guilford's [70] Structure of Intellect Model. In this model, Guilford [70] introduces 24 distinct types of Divergent Thinking and then proposes a number of means to identify which are relevant. Whilst the concept of divergent thinking has been widely adopted, Guilford's [70] complex SOI model has been largely superseded. Much of the work that followed Guilford's [70] model has proposed assessing divergent thinking in terms of three key aspects:*Originality, Fluency and Flexibility* [153]. Originality quantifies the novelty of a response. These values are typically established by developing a lexicon of responses to a given prompt and then grading them from least to most commonly encountered. Fluency relates to the number of ideas generated and flexibility to the variety of themes that ideas are drawn from. Such scoring approaches are often criticised with Runco et al. [153] noting: "There are several problems with the conventional scoring system. Originality and flexibility scores are, for example, often confounded by the number of ideas given by an examinee (Hocevar, 1979; Runco, 1986). Additionally, the conventional scoring system is time-consuming and labour-intensive: All responses need to be compiled and compared in order to derive the originality and flexibility scores. To allow these

comparisons, ideas are usually placed on a lexicon - a list of all ideas given by all examinees. In additions to being time consuming and labour-intensive, the decisions about categorising ideas are often highly subjective" [153].

However, despite these criticisms this style of scoring mechanism remains dominant. This research incorporates four creative activities that measure divergent thinking. Three of these (*Picture Construction, Picture Completion and Parallel Lines*) are adaptations of the Figural component of the Torrance Tests of Creative Thinking (TTCT) [154]. The fourth, *The Alternative Uses Test* is reproduced from the TTCT verbal tests but originates from Guilford's research [70].

3.2.3.2 The Torrance Tests of Creative Thinking

The Torrance Tests of Creative Thinking (TTCT) [8] are an extensively used and critiqued means of assessing creativity. This series of tests builds upon Guilford's [70] Structure of Intellect model. Despite being developed in the 1970s the tool remains in use today and has been re-normed four times. Unfortunately the most recent versions of TTCT are now owned under license by a company in the U.S. who are unwilling to provide a copy of the latest version of the test for research purposes. The method used in this thesis is therefore based on a copy of the 1972 Torrance Tests of Creative Thinking Figural Guide A booklet [154] that was borrowed from the British Library. I have then used the later 1974 Torrance Tests of Creative Thinking Norms-Technical Manual [8] (also borrowed from the British Library) for further guidance on how to administer and score the tests. The extensive critique by Kim [9] reveals that the content of the figural tests have not changed since the 1972 version, but that the flexibility scoring metric has been dropped. The flexibility metric explores the many different themes that a participant has drawn their inspiration from i.e., did a participant continuously produce drawings of cars or did their drawing span a wide array of categories. Whilst this seems like a sensible metric Torrance [155] has since concluded that it is of little use and I have therefore not applied this scoring method.

The TTCT was originally designed to identify individual creativity and was split into two distinct sections *Figural* and *Verbal* with each section exploring different forms of creativity. The figural tests explore drawn responses to a given

stimulus. The verbal tests explore verbal reasoning based on a given stimulus. Torrance [8] suggests that both should be assessed to gain as full an understanding of an individual's creativity as possible.

The TTCT was designed to be administered to individuals, although Torrance notes that group applications of the figural tests are viable. The nature of the verbal tests suggests that for the most part they can only be applied to individuals. Furthermore, the versions of the test available do not include all of the prompts that Torrance uses for the verbal test making it impossible to score. I have therefore not sought to adapt these for this study. Instead I assume that verbal creativity is demonstrated through team dialogue and interactions.

The TTCT Figural exists in two forms Part A and Part B, they contain slightly different variations of the same tasks. I have adapted the Part A form to measure team creativity. The TTCT Figural Part A tests consist of three creative activities:

1. **Picture construction**
   The participant is asked to place an oval shaped sticker (figure 3.2) wherever they please on a blank page and then use the shape as the basis for a drawing. Torrance [8] states that with this particular test "an effort is made to elicit an original response by asking subjects to try to think of something that no one else in the group will produce. Elaboration is encouraged by the instructions to add ideas that will make the picture tell as complete and as interesting a story as possible. Thus the product is evaluated for its originality and elaboration" [8].
2. **Picture Completion**
   In this activity participants are presented with ten incomplete figures (see figure 3.3) and asked to complete as many as they can, again producing responses that nobody else would think of. Torrance [8] comments that"an incomplete figure sets up in an individual tensions to complete it in the simplest and easiest way possible. Thus, to produce an original response, the subject usually has to control his tensions and delay gratification of this impulse to closure" [8].

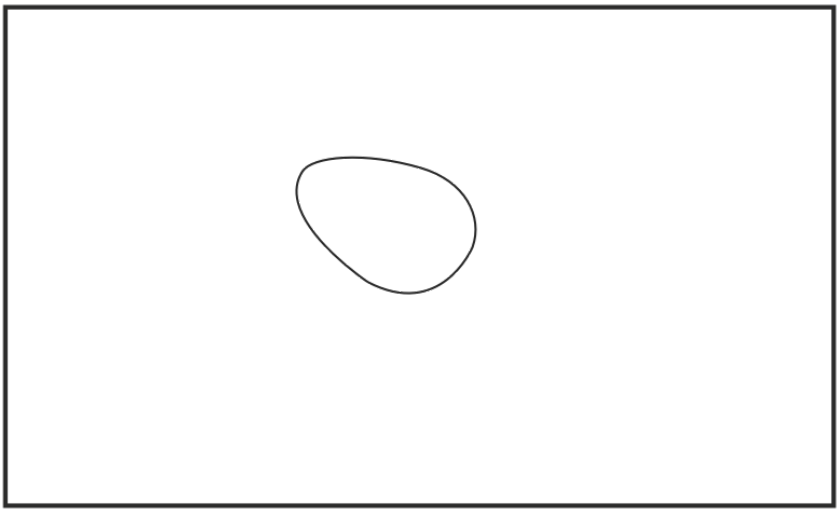


Figure 3.2: Example of Picture Construction starting shape placement
Reproduced from TTCT Figural Part A, 1972 [154]

3. **Parallel Lines**

   This task introduces yet another figural variation. In this activity participants are asked to complete as many of a possible 30 incomplete figures as possible (figure 3.4). The key difference here is that the 30 incomplete pictures are all identical - two parallel vertical lines. Torrance [8] comments that "theoretically, the incomplete parallel lines elicit the creative tendency to bring structure and completeness to whatever is incomplete" [8].

These three activities emphasise different aspects of divergent thinking. The Picture Construction activity challenges the participant to produce only one drawing from a prompt that they control and with as much detail as possible in 10 minutes. The Picture Completion task differs by presenting the participants with a series of fixed but incomplete shapes. Participants have to balance the natural urge to want to complete them all whilst still producing novel (rather than obvious) responses to the shapes in 10 minutes. Finally, the parallel lines activity forces participants to try and think of multiple responses to an identical

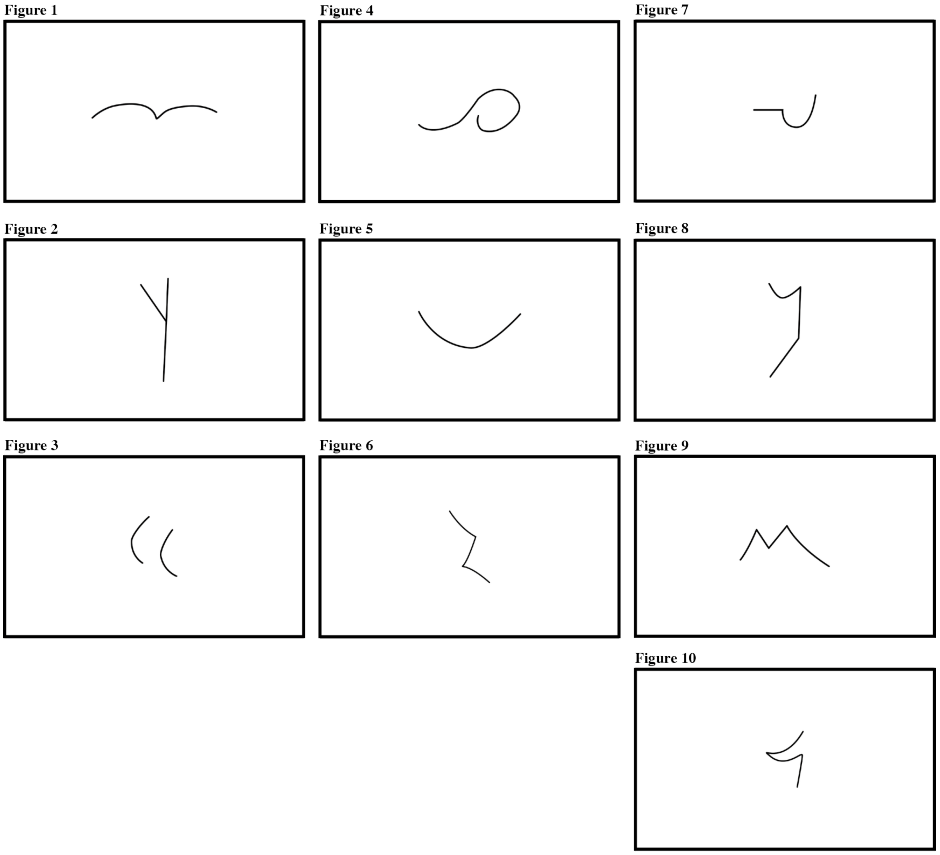


Figure 3.3: Picture Completion Starting Shapes
Reproduced from TTCT Figural Part A, 1972 [154]

prompt, again within 10 minutes. The challenge for the participant is to be able to consistently come up with original responses to the prompt.

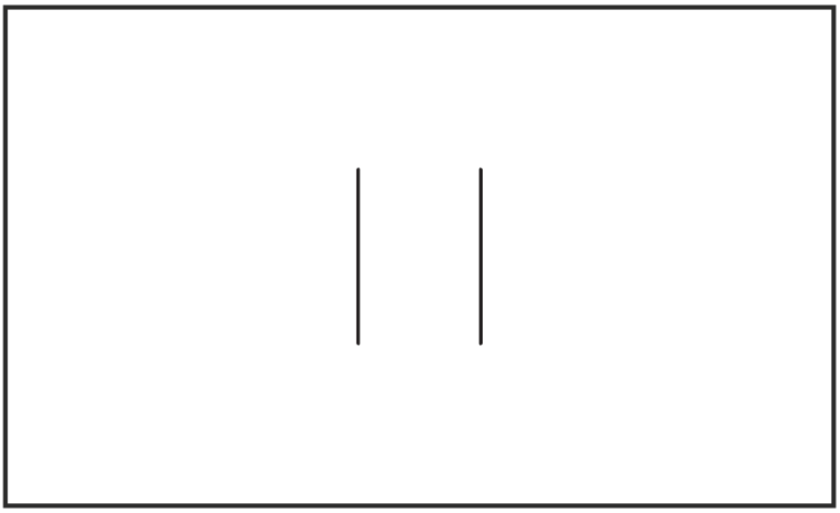


Figure 3.4: Parallel Lines Starting Shape
Reproduced from TTCT Figural Part A, 1972 [154]

The TTCT has been extensively critiqued, most recently by Kim [9] and Plucker et al. [150]. A key criticism of this approach is it's reliance on Divergent Thinking as a means of measuring creativity, with Plucker et al. [150] concluding "a better way forward almost certainly involves strategies that move well beyond divergent thinking, such as multifacted, multimodel assessment systems" [150]. This critique fits with advice received from other experts in the field; namely that TTCT provides a valuable insight to creativity, but that it should where possible be considered alongside other measures of creativity. It is for this reason that we also measuring creativity via Guilford's [156] alternative uses test and additional design challenge and design questions activities of my own design.

3.2.3.3 Guilford's Alternative Uses Test

One of Torrance's verbal creativity activities [155] is based on Guilford's [156] Brick test. This test explores the ability of an individual to generate multiple responses to a given prompt. This is similar to the parallel lines activity but the responses are listed rather than drawn. This enables teams to demonstrate

non-figural creativity. Torrance [155] asks participants to list alternative uses aloud. Such an approach may cause problems with teams, so instead teams are provided with a simple text entry system in my adaptation of this TTCT activity. Anything entered is then added to a shared list of responses. Torrance [155] also asks participants to think of uses for a cardboard box rather than a brick, and provides the associated lexicon of common responses. The team version also uses a cardboard box as the prompt as I feel that participants will be able to think of more uses for a cardboard box. This test is especially challenging for teams because they will reach a list of obvious responses very quickly, the challenge is for them then to collaborate to identify more unusual uses.

3.2.3.4 The Design Challenge and Design Questions activities

Two additional activities have been devised in order to derive a more rounded understanding of the creativity of teams. This follows advice not only from experts in the field but also from critiques of the TTCT [9, 150]. The development of these activities is discussed in more detail in section 4.1.

The Design Challenge

The design challenge provides teams with a minimal design brief from a UK outdoor manufacturer. It asks teams to try and design a new and unique outdoor chair. This is a classic design task. It is difficult because the familiarity with the object necessitates extensive idea generation in order to produce a new and unusual response. Teams are provided with both a digital sketchbook environment to develop ideas and told that they can use a simple text tool to add additional details.

Design Questions

This activity provides teams with the same design brief as the design challenge activity. Teams are asked to review the brief and generate a list of questions that they would like the main stakeholder to address in order for them to be

able to produce a better design. This is scored against a lexicon of the questions generated by a group of design professionals who have also completed this activity.

3.3 Chapter Summary

This chapter has highlighted the interpretive epistemology employed, and introduced the mixed method approach taken in this research. I have briefly discussed the need for an experimental approach and outlined how I intend to measure creativity.

The next chapter introduces the experimental method used and describes both the development of the CreativeTeams tool and the final version of tool itself in more detail.

Chapter 4

Method

This chapter describes the method used in this research. The adaptation of the TTCT activities is discussed and the development of the CreativeTeams tool described in section 4.1. The CreativeTeams tool used is then described in detail in section 4.2. Section 4.3 then describes the study itself including the recruitment of participants and emulation of co-located and virtual environments.

Figure 4.1 provides an overview of the study method from the recruitment of participants to the analysis stage (covered in Chapter 6).

Participants were recruited and then split into either co-located or virtual teams. Each group completed six creative activities using the CreativeTeams tool: Picture Construction, Picture Completion, Parallel Lines, Alternative Uses, Design Challenge and Design Questions.

Two types of metric were produced by the CreativeTeams tool. Firstly, meta data that provides information on the number of responses given (Torrance calls this Fluency [8]), time spent drawing and count of drawing/erasing actions.

Alongside this, a number of metrics were generated by manually scoring test outputs: Originality, Elaboration, Title Originality and Marker Assessed Creativity. Multiple markers were used in this manual scoring process because of the potential subjectivity of markers. In addition to these metrics, there were video recordings of the teams' interactions and footage of the actual team drawing process.

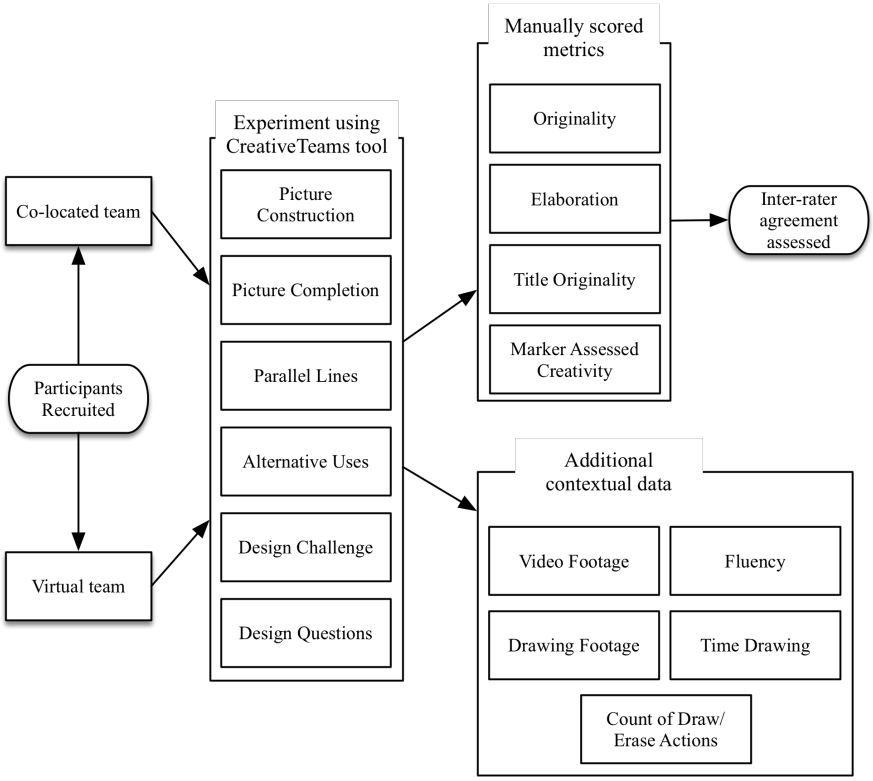


Figure 4.1: Experiment Method

4.1 Designing the CreativeTeams tool

The CreativeTeams tool is key to this thesis. This section describes how the tool was developed and tested before being used to run the experiment described in section 4.3. The tool was developed to satisfy the series of requirements listed in section 4.1.1. These have been developed both from the research questions listed in section 2.5 and have emerged during the early testing and prototyping. Section 4.1.2 then describes how the TTCT was adapted, the Design Challenge developed and the CreativeTeams prototypes. Section 4.1.3 then describes in more detail the design of the tools interactions and affordances both to support creativity and provide a good adaptation of the TTCT.

Figure 4.2 provides a summary of the chronological process of development. This overview illustrates how the adaptation of the TTCT and development of the Design challenge fit into the development of the CreativeTeams platform.

4.1.1 Requirements

The CreativeTeams tool has been developed through a series of iterations. The following high-level requirements were developed to help steer the development of the CreativeTeams tool:

R1 - Collect evidence of team creativity The focus of this research is ultimately on establishing the creative performance of teams. *R1* is therefore the need to establish a way of measuring the creativity of teams that is applicable in both co-located and virtual environments. There are three prerequisites for addressing this requirement:

R1.1 - Develop an electronic distributed version of TTCT I have chosen to use the TTCT as the basis for measuring creative performance. It is therefore necessary to adapt the current paper-based test for individuals so it can be completed by co-located and virtual teams alike.

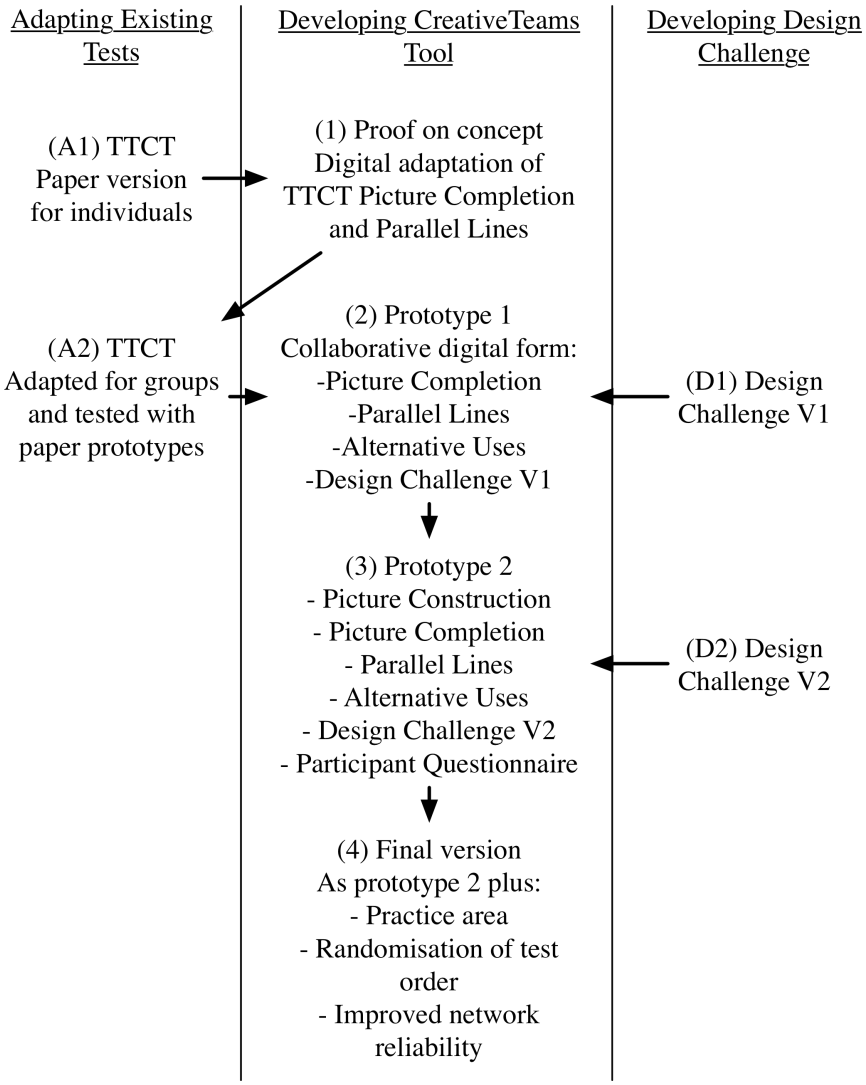


Figure 4.2: CreativeTeams development process

R1.2 - Develop supplementary creativity measures Section 3.2.3 discussed how the TTCT provides a good heuristic of creative performance but that additional measures should be used alongside to provide a more rigorous triangulation of creative performance.

One of these additional measures is Guilford's Alternative Uses test - an established and widely used test. The version being used is Torrance's minor tweak to this test that features in the TTCT Verbal

tests. These tests are commonly used with teams and so very little adaptation is required.

Both TTCT and Guilford's Alternative Uses Test present participants with abstract prompts to gauge their creative performance. Such approaches bear little resemblance to the creative tasks that occur within organisations. There is a need therefore to develop a non-abstract measure of creativity that utilises a scenario-based approach in order to explore creativity prompted by a problem more closely aligned to that experienced in an organisation itself.

R1.3 - Develop comprehensive testing platform The nature of virtual teams makes it impossible to manually administer the various tests. It is therefore vital that a single comprehensive platform is developed containing synchronous digital forms of the tests developed to address R1.1 and R1.2.

R2 - Design platform experience to support collaborative creativity A digital testing platform is needed to enable virtual teams to collaborate. The design of such a system and the way that users interact with it may have implications on the study of creativity. The following high-level non-functional requirements have been developed to inform the design of this platform in order to provide an effective digital analogue of the creative interactions that would occur on paper:

R2.1 - Provide a synchronous testing experience It is vital that participants can collaborate together effectively. A synchronous experience is therefore needed so that participants can see what each other are contributing in real-time. This will need to include designing for the immediacy of feedback necessary to draw together.

R2.2 - Mimic affordances of drawing on paper The design of the drawing tool should mimic the affordances of completing a paper-based version of the test as closely as possible. This is vital to ensure that

the test provides a good adaptation of the original TTCT. Such affordances should be informed by advice on the development of digital sketchbooks [102].

R2.3 - Mimic the affordances of the paper-based tests Teams should encounter the same key interactions that exist in the paper version of the test e.g., the capacity to switch between and return to the various starting shapes available during the picture completion activity.

R2.4 - Provide a seamless testing process The test should provide a seamless experience so that teams can be left to complete the test with as little interaction from the test administrator as possible (to reduce likelihood of bias during the test).

The sections that follow describe how the CreativeTeams Tool has been developed to address each of these requirements.

4.1.2 R1: Collecting evidence of team creativity

This thesis sets out to measure and compare the creativity of co-located and virtual teams. As discussed in section 3.2.3 there are many different approaches for evaluating creativity proposed. I have chosen to base this research on the Torrence Tests of Creative Thinking (TTCT). The TTCT are well established and to-date have been re-normed four times [9]. The tests consist of two test sections *Figural* and *Verbal*. Each was designed and developed to explore different aspects of an individuals' creativity. The *figural* tests investigate the relationship between an individuals creativity and material or boundary objects. These tests consist of a series of drawing related tasks which ask participants to draw responses to printed prompts. The *verbal* tests explore the verbal reasoning of the individual. These tests involve participants being asked to generate questions related to a given drawing.

I make the domain assumption that a successful adaptation of the figural component of the TTCT will provide a good heuristic for creative performance. However, as noted in section 3.2.3, the overall advice is to supplement the TTCT with additional measures in order to gather an increasingly accurate representation of creative performance. It is for this reason that Guilfords Alternative Uses activity is incorporated along with the newly developed Design Challenge.

In this section I outline the steps that have led to the development of the CreativeTeams tool used in this thesis.

4.1.2.1 R1.1 - Developing an electronic version of TTCT

The TTCT exists as a paper-based test for individuals. There are a number of steps that need to be completed in order to adapt it to be used with virtual teams. The first step involves establishing whether the test can be adapted into a digital form for individuals. The second step involves exploring how to adapt the test into a team format, this involves developing paper prototypes and using them with teams before evolving these into digital collaborative tools.

Developing an electronic adaptation of the TTCT for individuals

A proof of concept tool was developed to explore whether a digital form of the TTCT could be reproduced. The tool reproduces the Picture Completion and Parallel Lines activities, including the ability to switch between canvases. The proof on concept tool was accessed via a browser, and hosted on a university server for simplicity. Participants interacted with the canvas using touchpads/mice on their laptops. The tool was tested by 5 computing students (including the author). The tool demonstrated that the tests could be completed. However, network latency issues meant that the drawing process became less responsive as drawings became more complex. Movement between different canvases was often slow and testing across different browsers and screen resolutions often introduced artefacts in the drawings. Nonetheless the interactions completed by the participants were extremely similar to those performed on paper. Future iterations of the tool would need to use a more accurate means of drawing digitally in order to make the drawing experience more natural (i.e., not with a mouse) and would need to use an improved architecture to remove latency issues.

Developing a paper-based adaptation of TTCT for teams

The TTCT are paper based tests, the first challenge was therefore to consider how best to adapt a paper test into a collaborative format. Co-located teams were asked to complete enlarged paper based copies of the TTCT figural test. Teams were able to complete the paper prototypes (see two examples in figures 4.3 and 4.4).

Feedback from teams completing these paper prototypes suggest that they could collaborate on these drawings, and that the quality of dialogue rather than artistic ability played a key part in developing original responses.

Teams reported difficulties with multiple people trying to draw on a single piece of paper. Furthermore, this prototyping only demonstrated how co-located teams could complete these tests together. Virtual teams would be unable to complete the test in the same way. A digital implementation would be needed to enable virtual teams to have the same collaborative drawing experience.

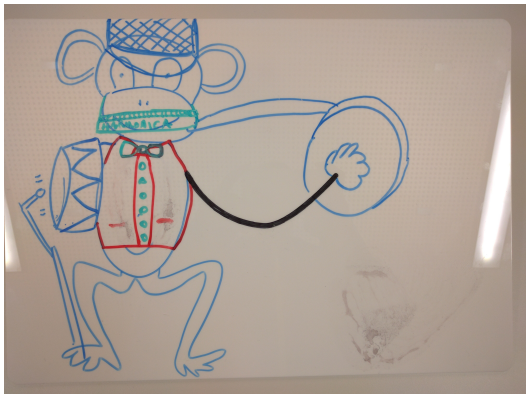


Figure 4.3: Example of picture completion paper prototype

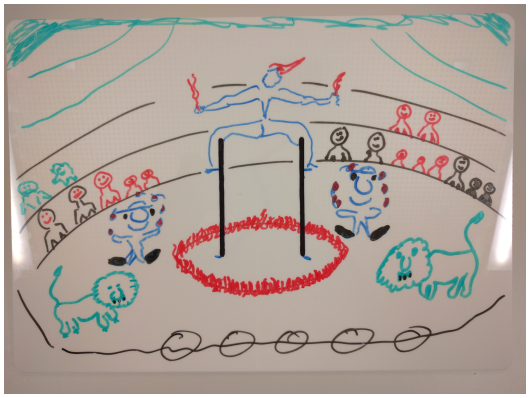


Figure 4.4: Example of parallel lines paper prototype

4.1.2.2 R1.2 - Developing supplementary measures of creativity

The TTCT and Guilford's Alternative Uses test provide two approaches of measuring creative performance. In order for effective triangulation of creativity a third was needed. However, the majority of creativity measures utilise abstract challenges. I therefore decided to develop my own alternative scenario-based activity for teams to complete. The motivation behind this was to present teams with the type of creativity challenge that they might encounter in an organisational setting.

The initial exploration for scenario-based activities involved providing student teams with the type of real-world problem solving exercises often used by recruiters. However, this was problematic because the most realistic exercises assumed a level of experience that the teams didn't have. Teams of students faced with these exercises were unable to relate to the problems. When less complex scenarios were employed teams inherently understood the tasks given to them and therefore only demonstrated very basic collaboration. Following these initial stages I set about developing my own scenarios to be presented to the teams to complete.

Design Challenge V1

The initial plan was to make use of Feather et al.'s [157] meeting scheduler scenario. This is widely used within HCI research. In the early adaptation teams were presented with the following:

> "Your team has been asked to generate initial designs and descriptions for a new meeting scheduler. The client has requested a radical new design. They want to differentiate themselves from other systems (e.g. Outlook, Google Calendar, Doodle).
>
> Please generate designs using the drawing system. You can create as many pages as you need and use the text function to add descriptions to your drawings to help the client understand your design.
>
> The client has provided the following description of the system's basic requirements:
>
> The purpose of the meeting scheduler system is to support the organisation of meetings - that is, to determine, for each meeting request, a meeting date and location so that most of the intended participants will effectively participate. The meeting date and location should thus be as convenient as possible to all participants. Information about the meeting should also be made available as early as possible to all potential participants. The intended system should considerably reduce the amount of overhead usually incurred in organising meetings where potential attendees are distributed over many different places.
>
> The client suggests that the system be able to take into account the following, in order to suggest the most suitable time and place for the meeting:
>
> - Participant Flexibility
> - Meeting significance (how important is this meeting?)
> - Participant importance (who is key to the success of the meeting?)

- Which dates participants are free
- Which dates participants are busy
- Which location people are likely to be in
- Which rooms and resources are available to book

Consider that the system will require different information (and provide) to different stakeholders (e.g. Meeting organiser, Meeting Participant etc).

This system should be usable by non-experts. ”

I anticipated that such a brief would encourage extensive dialogue amongst teams. I specifically ran this scenario with two differing teams, the first consisted of PhD students specialising in HCI, the second consisted of PhD students with a design background (see example in figure 4.5). The feedback from both teams was unanimous, neither could actually think of ideas that didn't currently exist. Somehow the overall familiarity with existing tools prevented teams from seeing beyond the calendar and doodle type tools with which they interacted every day. The designers in particular struggled to get beyond discussing what constituted a meeting scheduler. Both teams agreed that a simpler design brief was needed in order to give teams the freedom to design unique responses.

Design Challenge V2

The second scenario is inspired by the work by Mattingly [116] who challenged students on her design course to design a new chair and then analysed both their output and process for creativity. A similar task is regularly used by the RCA in their first year art courses. A chair provides a far simpler and more familiar object than the meeting scheduler used in Scenario 1 and so I anticipated that it would provide a suitable non-abstract challenge for teams to collaborate on. In order to further encourage creativity teams were provided with a deliberately ambiguous brief:

“An outdoor equipment company wants to release a new portable chair, suitable for hikers, tourists or attending music festivals, which

is easily mobile but that can withstand the British weather. They would like you to create an initial design. Please draw your chair and add descriptions to supplement your design. Use as many pages as you like to provide as much detail and information about the chair as possible. The company specifically want this chair to be the most innovative in the market - they would like you to design a portable chair that nobody else would think of."

This scenario was tested with a team of ten consisting of HCI and design researchers. The participants spent an extensive amount of time discussing the task before drawing responses. They all reported finding the test a good challenge and counterpoint to the other tests to be incorporated in the CreativeTeams tool.

The testers also suggested treating the brief as a requirements gathering exercise, noting the lack of detail in the brief. They suggested adding a second related exercise that would present teams with the same brief and then challenge them to list questions that they would want to outdoor company to answer to gain a greater understanding of the brief. This suggestion resulted in the Design Questions activity (see section 4.2.7 for more details).

4.1.2.3 R1.3 - Develop comprehensive testing platform

A digital platform was needed so that virtual teams could complete the aforementioned activities. The specialist affordances that the TTCT, Guilford's Alternative Uses test and the Design Challenge introduce meant that an entirely new platform needed to be developed. This was done through a series of iterations over the course of 24 months. The development of the CreativeTeams tool started with the proof of concept and 2 prototypes (described here) before arriving at the final version of the tool used to gather the data used in this thesis.

Prototype 1

The first full prototype offered more more functionality than the proof of concept. The prototype was designed to be used by virtual teams completing the activities

on iPads. These were specified because they have a consistent screen resolution and offer a responsive touch screen enabling a more natural drawing interaction. The tool was written with the following functionality:

- The Picture Completion and Parallel Lines activities were available in full, with teams able to switch through the multiple canvases (starting shapes) associated with each activity.
- Teams were given a time limit for each activity and seamlessly transitioned between one activity and the next.
- The tool produced the finished drawings as .png outputs for further analysis.
- A listing function was created for capturing text based responses during the Alternative Uses activity.
- The first iteration of the design challenge activity was included. This asked teams to generate a design based on Feather et al.'s [157] meeting scheduler tool exercise. Teams were presented with a simple storyboard style canvas to draw on (see example in figure 4.5).

Three co-located teams of three participants tested prototype 1. They found the activities much better to complete when the transition between activities was automated by the tool. As previously discussed, they also reported a number of problems with design challenge V1. They also suggested that the drawing tool should not be divided into a film strip but should instead act as a blank sketchbook with pages that teams could move forwards and backwards through.

Prototype 2

The second prototype refined the tool and included additional functionality:

- The mechanism for starting the Picture Construction activity was added. This enabled teams to move and rotate an oval shape on the canvas, choosing where to place it before turning it into a drawing.

Figure 4.5: Design Challenge prototype 1 example

- The second iteration of the Design Challenge was introduced. This asked teams to design a new (and novel) type of chair for use outdoors.
- The film strip canvas used in the Design Challenge V1 was replaced with a digital sketchbook of multiple blank pages for teams to use.
- Finally, the participant questionnaire was added.

Final version of the CreativeTeams tool

The final version of the tool included three additional features:

- A new function was included to randomise the order in which teams completed activities.
- The practice area was designed and added to the start of the test. This provides teams with five minutes to practice using the drawing tool.

- A dedicated wireless router was introduced to the test environment to improve the responsiveness of the drawing environment.

I discuss the final version of the tool in more detail in section 4.2.

4.1.3 R2: Designing a platform experience to support collaborative creativity

Adapting the TTCT into a format for co-located and virtual teams alike represented a major challenge. The main problem related to how teams would be able to draw together synchronously as if on a shared piece of paper. There are a wide variety of shared drawing tools available like Paper by FiftyThree [158], Google Draw [159] and Twiddla [160]. However, these tools all share the same weaknesses. Firstly such tools available assume that all drawings start with a blank canvas. However, the TTCT provides prompts (starting shapes) for participants to start their drawings with, along with other affordances (e.g., the starting shape placement during the Picture Construction activity). The majority of existing tools do not support this function. A second problem relates to the need to add time constraints. The TTCT includes multiple activities, each with a different time limit. The only way to impose a time limit would be to manually intervene between activities which may have affected participant performance. Finally, whilst many of these tools provide a collaborative drawing environment they were unable to accommodate both the drawing and text based responses required for an adaptation of the TTCT and supplementary tests.

4.1.3.1 R2.1 - Provide a synchronous testing experience

A synchronous testing environment is key to supporting the creativity of virtual teams. Such an environment will need to allow virtual teams to collaborate and have exactly the same experience as co-located teams. This means designing the system to provide as responsive an environment for collaboration as possible. Collaborative tools such as Google Docs achieve this by using an extensive server infrastructure to repeat interactions between devices, keeping them in sync in

near-to real time. The CreativeTeams tool is only designed as an experimental tool and is as such not intended to be production-ready. My plan is to study both co-located and virtual teams within the confines of Lancaster University. This means that I am able to use a simplified architecture (see figure 4.9) to achieve the same synchronicity. This architecture uses a single server operating on the local university network running Node.JS to keep participants devices (also on the local network) in sync with the minimum latency. A dedicated wireless access point is used to provide the participants iPads with a dedicated connection to further increase the robustness of the architecture. The design of the architecture in this way means that each participant experiences a near-seamless synchronous experience as they collaborate to complete the activities.

4.1.3.2 R2.2 - Mimic affordances of drawing on paper

The original TTCT asks participants to draw their responses in paper answer booklets. The drawn responses are then scored according to Torrance's given lexicon. It is therefore vital that the digital form of the TTCT provide participants with a drawing experience as similar to the paper based experience as possible so the same mark scheme can be applied. The HCI experience and affordances therein have all been carefully designed so that participants encounter an experience that is as close as possible to working on paper.

Designing shared drawing tool interactions

The shared drawing tool (see figure 4.6) is a key mechanism in four of the creativity activities (Picture Construction, Picture Completion, Parallel Lines and Design Challenge).

The tool enables participants to draw collaboratively in real-time allowing them to see exactly what all participants are adding to the drawing. They are therefore able to respond either by drawing or erasing appropriately. The drawing tool and its affordances have been informed by the paper prototyping of the TTCT for groups. From this prototyping it became apparent which interactions would need to be replicated in a digital collaborative equivalent.

Figure 4.6: Shared drawing function example

The ability to draw on a paper-like surface was the first key affordance that needed to be replicated. A simple HTML5 canvas used on an iPad provides this key interaction. The iPad enables participants to draw using a touch interaction akin to using a pen or pencil. Participants are provided with Fifty Three Pencils [161] to further emulate the experience of drawing on paper. When used on an iPad participants encounter an almost A4 sized canvas that they are able to draw on using what feel like a regular pencil and which produces a responsive line, effectively mimicking the process of drawing on paper.

Teams who took part in the paper prototyping varied in the way that they collaborated on drawings, some teams took it in turns to draw, passing the canvas from one participant to another to complete their drawing. Other teams sought to draw simultaneously with participants crowding around the canvas to complete their drawing. In order to replicate this the CreativeTeams tool is built to synchronise the drawings of all teams members. Each team member works on their own iPad but they actually collaborate on only one canvas. The multiple HTML5 canvases are kept in sync by reporting the touch interactions of each participant

to a Node.JS server which then synchronises the drawing across all iPads. The result is a seamless real-time collaborative drawing platform mimicking the collaborative drawing of co-located teams but with the additional functionality to enable participants to actually work from different locations in real-time.

There are many off the shelf iPad based drawing applications and collaborative drawing applications. These tools vary in their complexity, with tools like Paper by Fifty Three aiming to provide budding artists with every tool imaginable. I have specifically chosen to keep the functionality of the CreativeTeams tool at a minimum, this follows guidance from O'Neill [102] who suggests that only the most basic functionality (draw, erase, undo and redo) are necessary for artists to produce effective work with digital sketchbooks. Participants are therefore presented with a variety of pencil sizes, eraser sizes and undo and redo buttons along the bottom of the drawing tool.

I did consider allowing participants to vary the line colour used in their drawings, this would have improved the realism of the drawing process. However, I instead fixed the colour used by each participant throughout the study in order to simplify identification of participant involvement during the analysis process. It should be noted that whilst some teams during testing did want to be able to vary the colour in use none considered it a key inhibitor to creativity.

Designing shared listing tool interactions

The shared listing function enables team members to add (and edit) to a single shared list of ideas or questions. Both the Alternative Uses and Design Questions activities ask teams to list their responses. This simple tool has been provided to help teams to record their responses so they can be marked. Whilst teams are encouraged to verbalise their questions or ideas, they are informed that only the written lists will be scored.

The shared listing tool borrows design elements from common spreadsheet tools that participants are likely to be familiar with. Participants are provided with a box at the top of the screen in which to type their question along with an optional explanation if they so wish. The add button then adds this text to the list. Each participants contributions are represented in the colour they have been

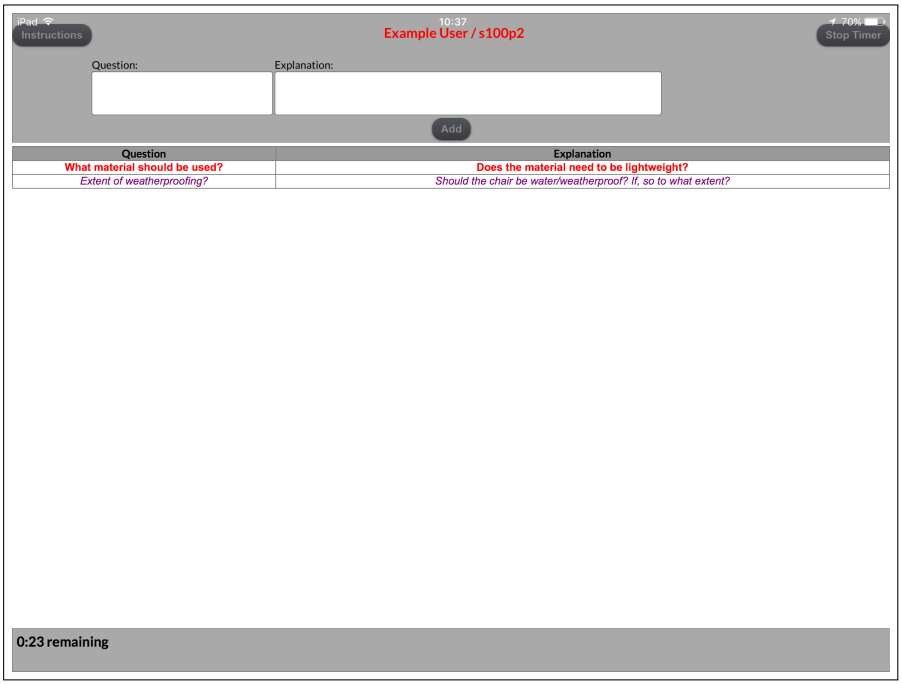


Figure 4.7: Shared listing tool example

using throughout the drawing process. If participants want to edit or remove an existing entry then they can simply click on the list to edit as per typical spreadsheet interaction. I have purposefully designed the interactions to be as similar to Google Sheets or Microsoft Excel as possible so there are no barriers to learning that may impair participants interactions with this tool.

4.1.3.3 R2.3 - Mimic the affordances of the paper-based tests

The TTCT Figural activities have specific affordances of their own that need to be reproduced digitally such that they are readily apparent to the participants (although Torrance's original instructions are also included). The Picture Completion activity provides participants with a page with a number of boxes printed on it, each with a different starting shape in it (e.g., figure 3.3). The Parallel Lines test is presented in a similar fashion but with each box containing exactly the same pair of parallel lines. Participants are then asked to draw their responses within these boxes.

In the CreativeTeams tool this affordance is recreated by treating each of these different starting shapes as a page in a digital sketchbook. Participants are then presented with forward and backward buttons that allow them to switch through the different pages and select which drawing they want to work on. Likewise, they are able to return to drawings that they have previously been working on. In this way participants are able to choose which drawing they want to work on in much the same way as the paper based test. They are also able to switch freely between the drawings as they would be able to on paper, ignoring, adding and returning to drawings as they wish. Each of these pages utilises the aforementioned drawing tool ensuring that participants experience the same drawing experience as they would if working together on a paper version of the test.

The paper-based version of the Picture Completion and Parallel Lines activities also asks participants to give each of their drawings a title, providing a short section under each box for a title. This is reproduced in the digital version with a button in the bottom left of the screen that says 'Add title' and presents participants with a simple text box in which to add their title. This is then displayed at the bottom of their drawing. Participants are free to edit these titles as they see fit using the title button.

The paper-based form of the Picture Construction activity includes a more complex interaction. The paper based version presents the participant with a blank box in which to create their drawing. However, the participant is also provided with a a sticky oval shaped piece of coloured paper and told to place it anywhere in the box and use it as the basis for their drawing. Whilst this is a relatively simple interaction for individuals it is more complex for teams.

In the digital adaptation (see figure 4.8) teams are presented with a shared canvas with the oval shape displayed upon it. However, only one team member is able to move and rotate the shape. Once the shape is in the desired location the participant controlling the placement can click 'Place shape', this then locks the shape to that location and turns the canvas into the standard shared drawing canvas. I acknowledge that only having one participant move the shape does not provide quite the same interaction as would be afforded to a co-located team operating a paper-based adaptation of the activity. However, in testing it became apparent that this compromise was not an issue because the teams were more

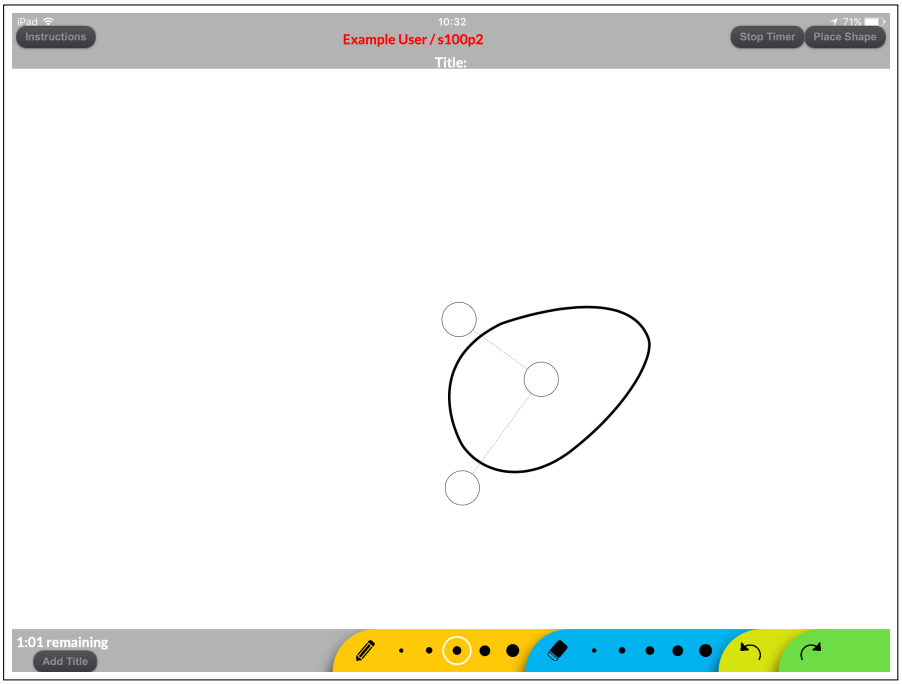


Figure 4.8: Picture Construction Shape Placement

concerned with discussing the best location of the shape, in which case having only one person who could move the shape was only a minor limitation.

4.1.3.4 R2.4 - Provide a seamless testing process

It is necessary for teams to complete these activities with as little interaction as possible with the test administrator. Firstly, because there isn't a practical way for an administrator to intervene with a virtual team operating from multiple location. Secondly, because there is a risk that the test administrator affects the test participants with each and every interaction, ultimately influencing performance.

In order to overcome these issues I have designed the teams experience to be as seamless as possible. The CreativeTeams comprises time to practice with the drawing tool followed by six activities in a random order (Picture Construction, Picture Completion, Parallel Lines, Alternative Uses, Design Challenge and Design Questions) and a closing questionnaire. Once the participants have signed in

the entire process appears seamless, the tool itself guides them through each activity providing them with experience. This means that once a team has started there is little need for interaction with the test administrator. This means that virtual teams and co-located teams have the same self-contained testing experience with minimal chance that interactions with the test administrator affect their performance.

Implicit in the overall design is the need for the tool to be flexible to changes in circumstance. This includes (but is not limited to) the addition of features to enable late arrivals to join the game and designing the system to be robust to network latency issues. Such features further reduce the need for interaction with the test administrator and increase the likelihood that any creativity exhibited by teams is their own.

4.2 The CreativeTeams Tool

This section provides a detailed description of the final CreativeTeams tool iteration used to gather the data in this thesis.

The CreativeTeams tool is an HTML 5 webapp comprised of six creativity activities designed to be completed by teams on iPads. The six creativity activities are synchronised using Node.js by a centralised server. All interactions (touch and text) are recorded in a MySQL database on the server.

A centralised server is used to improve the responsiveness of the system over the local area network. This was highlighted as a priority over more robust alternative implementations (e.g., using an Amazon S3 setup) that could introduce additional problems in the synchronisation of drawings.

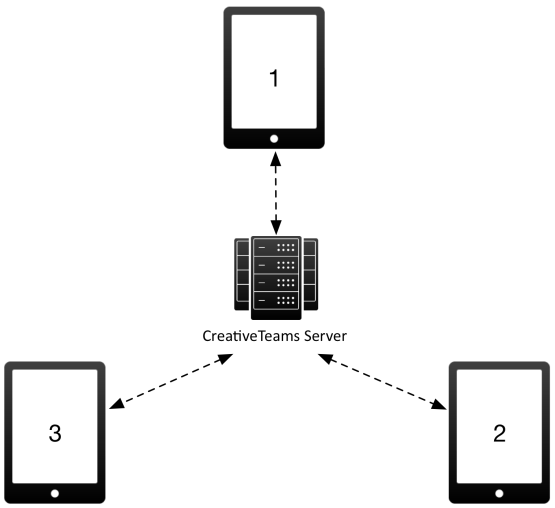


Figure 4.9: Overview of CreativeTeams Architecture

The six creativity activities are completed in a random order and are prefaced with a practice activity and followed by a participant questionnaire. The six tests are: *Picture Construction, Picture Completion, Parallel Lines, Alternative Uses, Design Challenge* and *Design Questions*.

The CreativeTeams tool utilises two main interactive functions: A shared drawing tool and shared listing tool. The shared drawing tool is used for the Picture Construction, Picture Completion, Parallel Lines and Design Challenge

activities. The listing tool is used in the Alternative uses and Design questions activities.

CreativeTeams has a number of consistent UI features throughout (see example of layout in figure 4.10). The bottom left corner of the screen always displays the time remaining for a task. When using the drawing tool a button is displayed in the bottom left hand corner that allows titles or descriptions to be added and edited. The instructions for each test are always available during a test in the top left of the screen. Participants are able to open these instructions when needed and they are displayed on their device. The top centre of the screen displays the users access code and nickname in their drawing colour. Finally the top right corner of the screen is used for extra functions. In the practice area a button appears to start the test once the five minutes available to practice have expired. In other drawing tasks buttons are shown in the top right of the screen displaying 'next' and 'previous' to facilitate switching between canvases.

Each activity starts with a screen displaying the instructions. Once each participant has read these instructions they can select a button to say that they are ready, once all the participants have pressed this then the test begins.

Four of the six creativity activities are adaptations of the TTCT tests (Picture Construction, Picture Completion, Parallel Lines and Alternative Uses).

Order	Test	Type	Origin	Time Limit
Start	Practice Area	Drawing	New	5
Random	Picture Construction	Drawing	TTCT	10
	Picture Completion	Drawing	TTCT	10
	Parallel Lines	Drawing	TTCT	10
	Alternative Uses	Text	TTCT, Guilford	5
	Design Challenge	Drawing	New	10
	Design Questions	Text	New	5
End	Questionnaire	n/a	New	n/a

Table 4.1: CreativeTeams activities

Table 4.1 lists the sections of the final test, their origins and time limits.

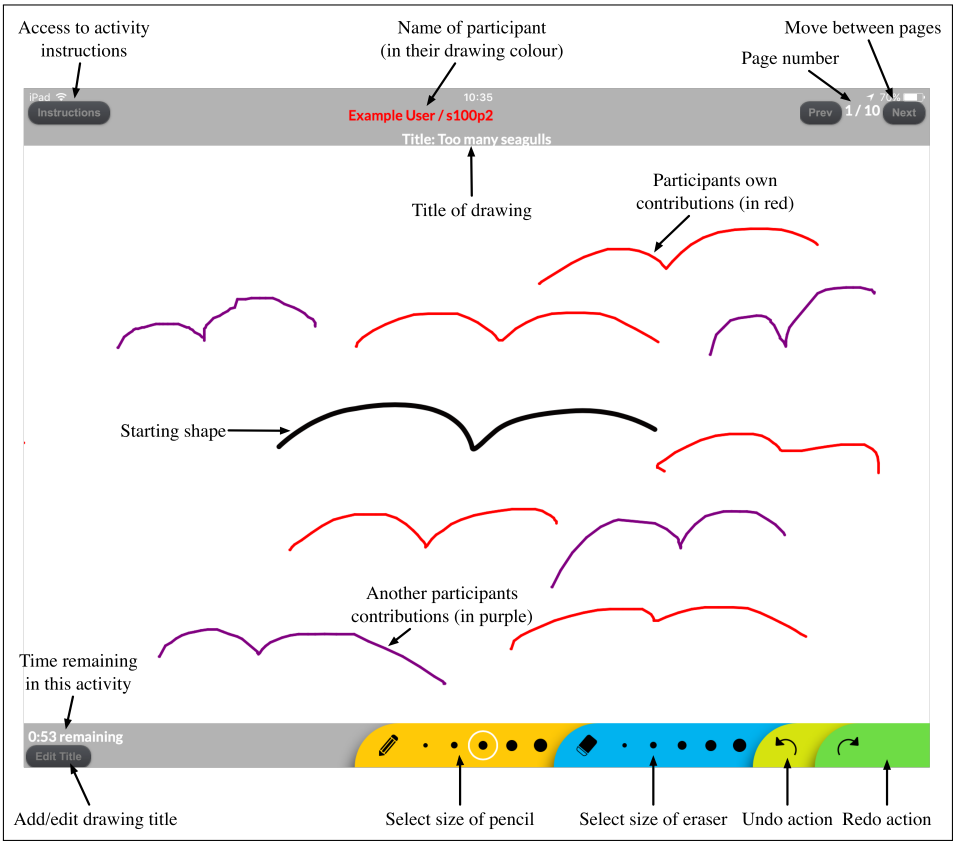


Figure 4.10: User interface example

4.2.1 The Practice Area

The practice area is designed both to familiarise teams with the drawing tool and as an icebreaker to stimulate conversation.

Figure 4.11 shows a screenshot of the practice area. The dinosaur is provided to get teams thinking about drawing to a prompt. Before entering The Practice Area the team members are introduced to each other and the test administrator reads them the following instructions:

> *" Welcome to the CreativeTeams study, thank you for agreeing to take part. This study is exploring how you work together as a team. No aspect of your individual work is being assessed - I am only interested*

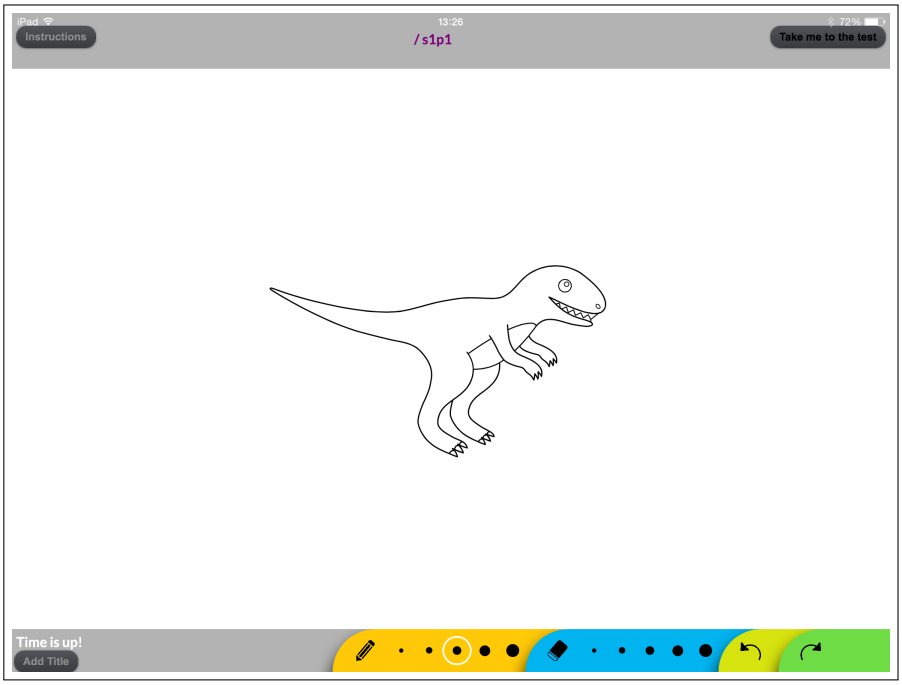


Figure 4.11: The Practice Area

in your performance as a team.

This study explores the creativity of teams, and whether teams are affected by their environment. Your team is completing the study in a co-located/virtual environment, whilst others have completed it in a virtual/co-located environment. We will be comparing the performance of teams in both locations to see if there is any difference in performance.

The study consists of six sub-tests. Four of these tests are drawing related and use the same drawing tool. Don't worry, the quality of the drawing isn't being judged just the ideas produced. The other two tests are text based and involve generating ideas together and adding them to a shared list. At the start of each test you will be presented with instructions. These instructions can be viewed at any time using the

button in the top left hand corner of the screen. Time remaining for each test will be shown in the bottom left of the screen.

In a few minutes you will be able to log into the test on your iPads using the access codes provided. You will then enter the practice area for the test. The practice area is a copy of the drawing tool you will be using in the test and you will have five minutes to practice using it. The tool is a collaborative drawing tool - you all share the same canvas. This means you can see and delete each others drawing contributions. You are each assigned a different colour to draw with throughout the test, these colours are fixed before you start and can't be changed. This is to make the analysis easier. You are asked to add either titles or descriptions to your drawings depending on the test. To do this you can use the 'Add title/description' button in the bottom left next to the time remaining clock. For some of the drawing tests there will be additional functionality available, this appears as a button in the top right hand corner of the screen. Additional functions involve the tool acting as a digital notebook, in which case the functionality allows you to switch forwards and backwards between pages. For the picture construction activity it allows the shape mover to fix the position of the shape. This will become apparent when you read the test instructions. Nothing that you produce in the practice area is recorded or marked, it is just there for you to practice using the tool.

With the text based tools you will be presented with a text box that you can enter ideas into. You can do this simultaneously. Each idea is added to a shared list that will appear on the screen. You can click on each others ideas and edit them as you see fit.

I will be available whilst you use the practice area for you to ask

any questions about how to use the tool. After that I will leave you to complete the tests. I will be available if you encounter any problems during the test."

Participants are given 5 minutes in the practice area. The area is a working example of the shared drawing canvas used by several of the Tests in the CreativeTeams system.

4.2.2 Creative Activity 1: Picture Construction

The picture construction test asks teams to draw a response to an oval shaped prompt *that nobody else would think of.* An example of this is figure 4.12. At the start of the activity the team is given the ability to choose where the prompt (an oval shape) is placed. In the paper based version of the test the participant is given a sticker that they can place on a page before creating their drawing. In our adaptation one of the team members is given the ability to move and rotate the shape. Once they team is happy with the placement the shape is fixed in place and the team can begin drawing. The team only have to complete this one drawing and they are given ten minutes in which to place the shape and complete their drawing. They are also asked to give the drawing a title.

4.2.3 Creative Activity 2: Picture Completion

In this activity teams are provided with 10 separate canvases that they can switch between at any stage (whilst maintaining their drawings). See example in figure 4.13. Each canvas contains a different incomplete shape. The team is asked to turn these shapes into drawings *that nobody else would think of.* Teams are also asked to add detail to help elaborate the story in their drawing. Teams are given ten minutes in total to complete as many (or as few) canvases as they choose. They are also asked to give each canvas a title. The original starting shapes can be found in section 3.2.3.2.

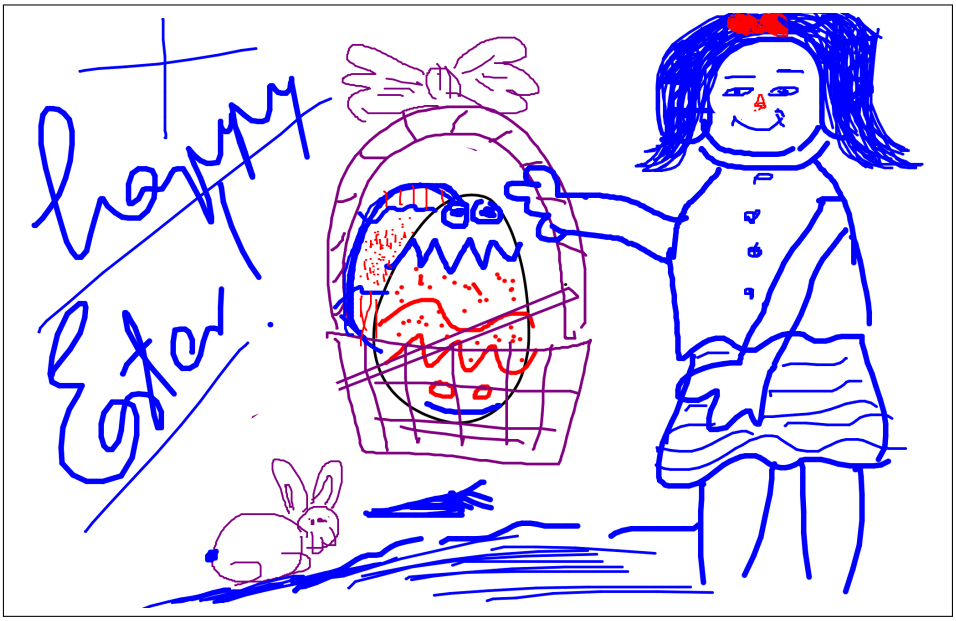


Figure 4.12: Picture Construction: Easter egg hunt and the little girl

4.2.4 Creative Activity 3: Parallel Lines

This activity is similar to the Picture Completion task, however teams are presented with 30 identical canvases, each containing two parallel vertical lines. See example in figure 4.14. Teams have ten minutes to complete as many (or as few) canvases as they choose. The original starting shape can be found in section 3.2.3.2.

4.2.5 Creative Activity 4: The Alternative Uses Test

The Alternative Uses test is commonly used to explore divergent thinking. It asks participants to list as many uses for a common object as possible. It is based upon Guilford's [156] Brick test. Torrance [8] incorporates this test as part of his verbal reasoning test. Torrance suggests asking participants to list uses for a cardboard box.

Teams are asked to generate alternative uses for cardboard boxes. They are given five minutes to do so. Each participant is shown a screen with a text entry

Figure 4.13: Picture Completion: The man with the map

box in which to enter their idea (see figure 4.15). The teams ideas are added to a shared list.

4.2.6 Creative Activity 5: The Design Challenge

The design challenge consists of two parts: a design task, and a feedback task. The design challenge asks participants to design a new type of chair for hiking or visiting music festivals in the UK. This task is included as a counter to the abstract nature of the TTCT tests. That is, to investigate the creative process (and product) that occurs when working with a less abstract scenario. However, participants still have to employ discipline to avoid generating designs that they are already familiar with. Teams are presented with the following short brief:

"An outdoor equipment company wants to release a new portable chair, suitable for hikers, tourists or attending music festivals, which

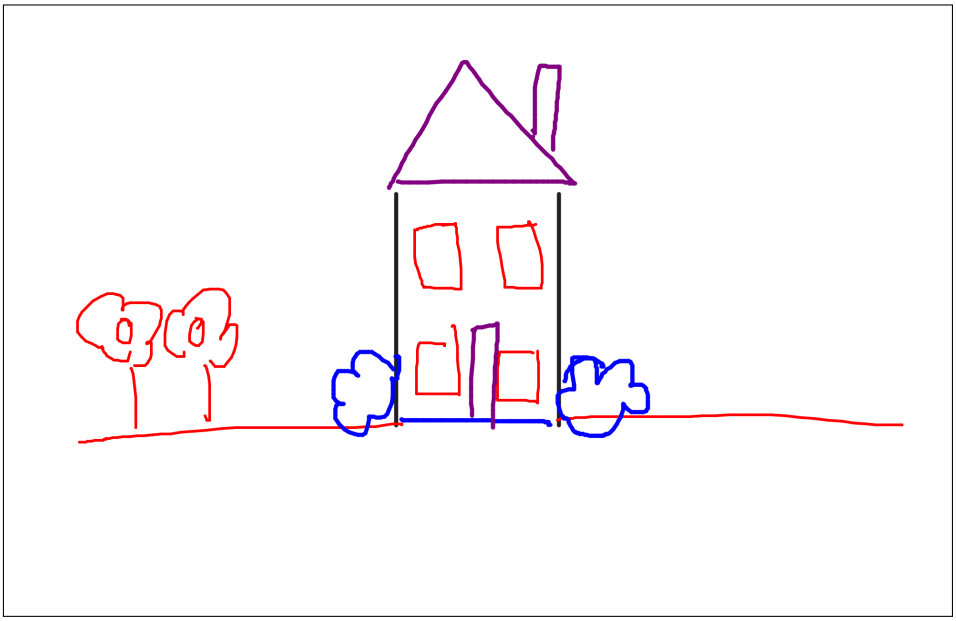


Figure 4.14: Parallel lines: House

is easily mobile but that can withstand the British weather. They would like you to create an initial design. Please draw your chair and add descriptions to supplement your design. Use as many pages as you like to provide as much detail and information about the chair as possible. The company specifically want this chair to be the most innovative in the market - they would like you to design a portable chair that nobody else would think of."

Teams are given 10 minutes to discuss, plan and draw their designs. They are given access to the same drawing tool as before, in this activity the tool acts as a sketchbook with as many blank pages available as the team requires. The drawing title function has also changed and is now a free text field so teams can add in detailed descriptions if they so choose.

This test is similar to the TTCT Picture Completion test as the teams have to draw to a prompt, however this time the prompt is based on their own experiences of chairs. This challenges the teams to overcome their previous experiences in

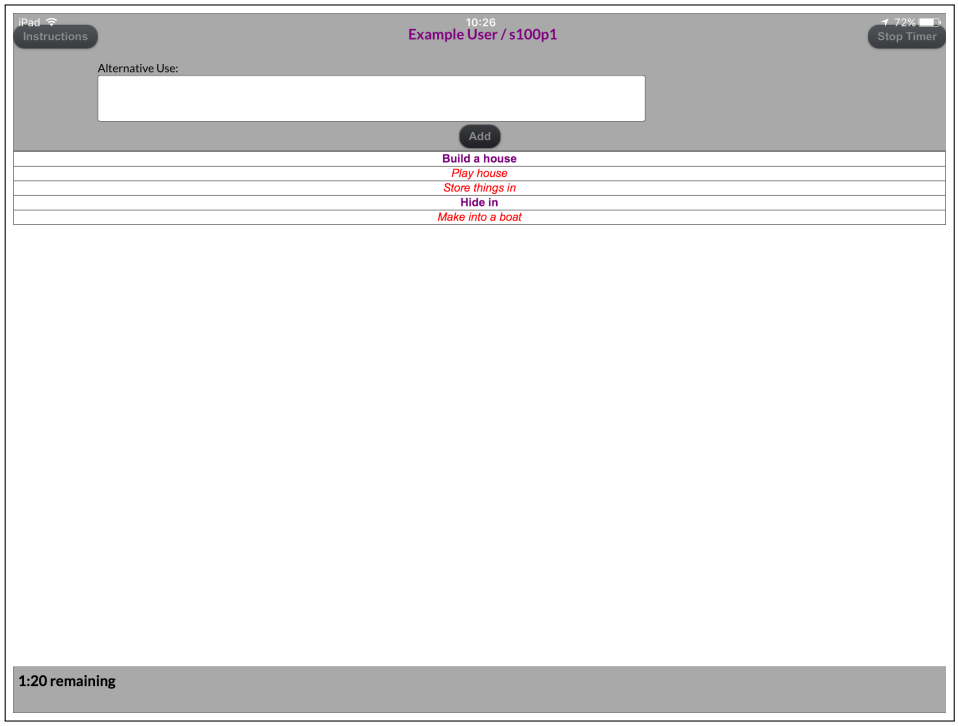


Figure 4.15: Alternative uses example

order to produce something that fulfils the brief.

The test does not stipulate what has to actually be produced. It is therefore possible for the tool to be used for creative-cueing with the actual ideas only being verbally discussed.

4.2.7 Creative Activity 6: Design Questions

The design questions test is closely related to the design challenge. In this test participants are provided with the same brief as the design challenge. Teams are asked to imagine that they are the designer who has received the brief. They are then asked to generate additional questions that a designer might want answered given the very short brief.

> *"An outdoor equipment company wants to release a new portable chair, suitable for hikers, tourists or attending music festivals, which*

is easily mobile but that can withstand the British weather.

This is a very broad design brief, and your team has been asked to help refine it. Please can you list as many questions or pieces or information that the outdoor equipment company should provide about the chair to help create an improved requirements specification."

Participants are then presented with a text input box to add questions to. These are added to a shared list displaying all team members contributions.

4.2.8 Participant Questionnaire

The series of creative activities concludes with a short questionnaire. The questionnaire gathers data on:

- Participant details: Name, Email address, Gender, Age
- Information relating to their education: What is their role at the university e.g., Undergraduate Student. What is their main area of study?
- Information that may affect their performance during the study: To what extent have participants studied art? Have they ever heard of the TTCT before starting the test? How well do they know their team mates? Is English their first language, and what is their home country?

The last category of these is the most important. As we have discussed in section 4.3.3 identifying artistic ability may help explain the creative performance of some teams. Likewise, anyone who is familiar with the Torrance test will be able to manipulate their teams responses. The interactions of teams is heavily reliant on verbal interaction so it is possible that the creative performance of teams with non-english speakers may be impaired. Finally, the cultural background of participants may affect the content of their drawing and it is for this reason that we ask for their home country. The full questionnaire can be found in Appendix E.

4.3 Experiment Setup

This section provides an overview of how the experimental context was designed, this includes: How co-located and virtual working environments were emulated, the size of the teams recruited and the process of participant selection.

4.3.1 Emulating co-located and virtual working environments

The emulated co-located environment used in this experiment consists of a standard meeting room at Lancaster University. The room consists of a single table with up to six chairs. A camera with a fisheye lens is placed in the corner of the room and participants are seated facing towards the camera (see figures 4.16 and 4.17). Participants are all within close proximity and are therefore able to communicate freely and observe each others' body language. Axtell et al. [162] suggest that co-located teams benefit from immediacy of feedback (e.g., facial expressions can be read to see if colleagues understand or agree with a statement).

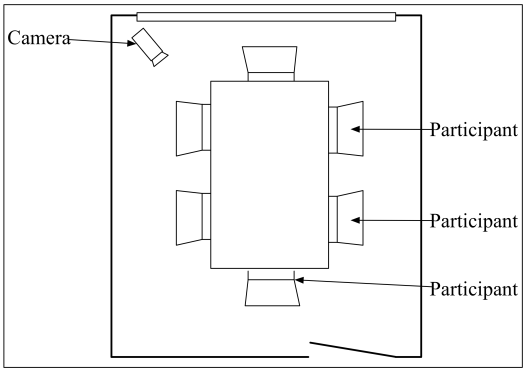


Figure 4.16: The co-located environment room layout

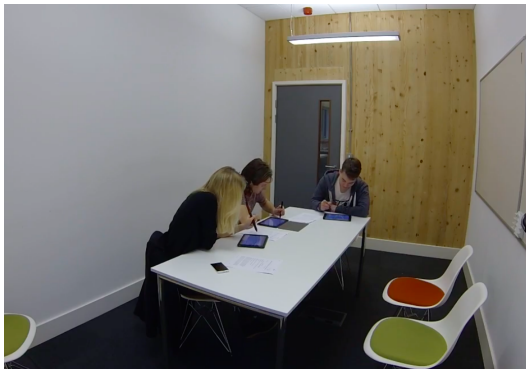


Figure 4.17: An example of a co-located team

Virtual teams are emulated by placing each team member in separate meeting rooms within the same building (see figure 4.18). Researchers have found that co-located team functions break down as soon as participants are outside their

immediate area [162], this can be in a different room or the same room but with several metres of separation. The complete separation of the team mimics that of a fully distributed team. Such teams represent the most extreme form of virtual working but also offer the most flexibility.

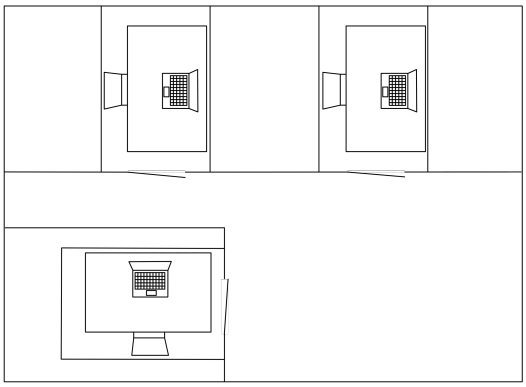


Figure 4.18: The virtual team environment room layout

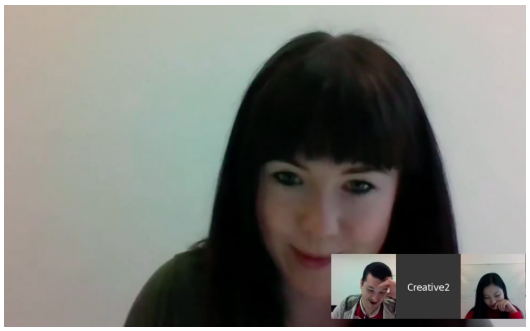


Figure 4.19: An example of virtual team collaboration via google hangout

The professional virtual teams that I have talked to reported that they used synchronous tools (e.g., video conferencing) when working on complex tasks. Virtual team members are therefore provided with a laptop connected to a Google Hangout (see figure 4.19) to collaborate. A copy is taken of the Google Hangout video feed for analysis of team interactions.

All of the teams complete the same six creative activities using the CreativeTeams tool on iPads. This ensures that both co-located and virtual teams address the same actvites in the same manner.

4.3.2 Team size

There is extensive debate within management research about team sizes (e.g., [163, 164, 165, 166, 167]). However, there is little consensus around ideal team size. Most research concedes that team performance starts to be impaired in teams that are larger than 8 people. Research also suggests that ideal team size for productivity lies somewhere between 3 - 6 team members. Based on this and due to hardware limitations my research is based on a team size of 3.

4.3.3 Participant selection

Participants were purposively selected from the Lancaster University population for this study. A total of 108 participants took part in the final version of the study and a further 42 took part in the developmental testing of the tool. Participants were recruited via posters displayed on campus and emails distributed amongst departments. Participants were informed that they would be taking part in a creativity study lasting 1 hour and would be recompensed for their time with a £10 Amazon gift voucher.

The 108 participants were placed into 36 teams of three and they all completed the test. However, six teams encountered issues with lag due to a network upgrade which made collaborative drawing unreliable. The data from these six teams is therefore considered unreliable and has been excluded from further analysis. All research from here on in is based on the data from the 30 remaining teams that did not encounter issues. 17 of these teams completed the task in a co-located environment, whilst the remaining 13 worked as virtual teams. Table 4.2 summarises the split of the 90 participants that made up these 30 teams by their role at Lancaster University and gender.

	Undergrad	Masters	PhD	Postdoc	Total
Female	20	19	12	1	52
Male	18	6	14	0	38
Total	38	25	26	1	90

Table 4.2: Summary of participant split by employment and gender

Participants studied a range of disciplines (see table 4.3), with some PhD students identifying with multiple disciplines. The majority of students were from a Business / Management, Computer Science or Art and Design background. All participants were asked if they had any experience of the Torrance Tests of Creative Thinking. None had. However, it is possible for students studying in Art and Design disciplines to have an advantage when drawing (something key to several of the activities). Participants were therefore asked to assess their artistic experience using an 8 point scale (see table 4.4) in order to identify any bias that may be introduced by artistic ability.

Discipline	**Count**
Accounting and Finance	1
Art and Design	14
Biology	2
Business / Management	34
Chemistry	2
Computer Science	21
Economics	4
Engineering	2
English	3
Geography	3
Linguistics	5
Maths	3
Physics	10
Psychology	2
Sociology	4
Total Disciplines	116

Table 4.3: Discipline of study that participants most closely associated with

Description of experience	**Code**	**Count**
No formal training - finger painting as a kid	1	48
Enthusiastic amateur - I keep drawing, doodling and painting as a hobby	2	11
I studied art to GCSE or Equivalent (Age 16)	3	12
I studied art to A-level or Equivalent (Age 18)	4	8
I'm doing / I've done a degree in art	5	1
I'm doing / I've done a related art degree (I will get / have got a BA in a related field)	6	4
I'm studying for / have got a masters in art	7	5
I've worked in a professional capacity as an artist, illustrator or similar	8	1

Table 4.4: Summary of participants previous artistic experience

Figure 4.20 illustrates the average artistic ability of teams based on participants' self-reported artistic experience (see table 4.4). A visual analysis of the figure suggests a wide variety of abilities, with teams 4, 18 and 24 demonstrating well above-average artistic experience. The co-located team average is 2.176 and virtual team average of 2.538. The potential bias introduced by artistic experience is discussed in more detail in section 6.4.

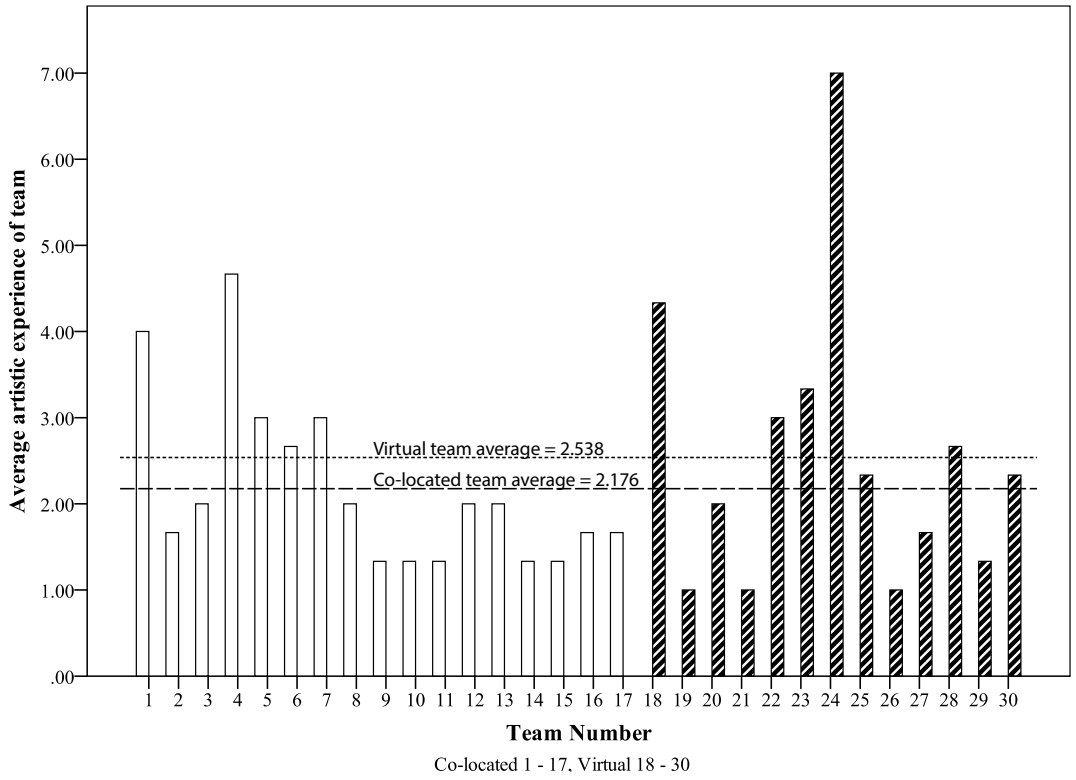


Figure 4.20: Average team artistic experience

4.4 Chapter summary

This chapter has discussed how the CreativeTeams tool has been developed and designed in order to provide teams with a testing experience equal to that of the original paper based tests. The final iteration of the CreativeTeams tool used in these studies has been described in detail. Finally, the experimental setup including how co-located and virtual environments have been emulated, how participants were recruited and why a team size of three is used. The next chapter describes the method used for manually scoring scoring outputs and then assesses the reliability of these scores.

Chapter 5

Scoring creativity and establishing inter-rater agreement

This chapter describes how Originality, Elaboration, Title Originality and Marker-Assessed Creativity metrics are generated. These metrics are generated by manually scoring each teams' activity outputs. This chapter describes the scoring method and assesses the reliability of these metrics by calculating inter-rater agreement. Table 5.1 illustrates the activities and scored metrics generated.

This chapter is structured into two main sections. Section 5.1 describes in detail how the creative activity outputs are scored. Section 5.2 then reviews inter-rater agreement for the multi-marked outputs. This data is then used in chapter 6 to address research question 1: *Do virtual or co-located teams perform creative tasks better?* by contrasting the performance metrics of co-located and virtual teams.

5.1 Scoring CreativeTeams outputs

There are a number of metrics produced from the CreativeTeams experiment. Some of these are meta data from the tool itself that are collected automatically (Fluency, Time spent drawing, Number of Drawing/Erasing Actions). The remaining metrics (Originality, Elaboration, Title Originality and Marker Assessed Creativity) are manually scored, predominately using methods devised by Torrance [8]. This section describes the manual scoring method.

Creative Activity	Markers	Originality (scored against rubric)	Elaboration (count of detail)	Title Originality	Marker assessed creativity
Picture Construction	A & B	✓	✓	✓	✓
Picture Completion	A & B	✓	✓	✓	✓
Parallel Lines	A & B	✓	✓		✓
Alternative Uses	A & C	✓	✓		
Design Questions	A & C	✓			

Table 5.1: Summary of quantitative outputs by test and Marker

Originality, Elaboration and Title Originality are all scored according to Torrance's [154] guide and rubrics. Marker assessed creativity is a new metric devised to assess the suggestion [168] that it is better to assess creativity using expert markers instead of using a rubric based approach.

The generation of these metrics is at risk of marker bias. Markers have to interpret both the output (be it a drawing or text response) and the scoring guide (often a rubric). Multiple markers are therefore used in order to negate these threats to validity. Three markers were used (see table 5.1) to score the activities. Marker A is the author of this thesis and has experience marking undergraduate Management coursework. Marker B is another academic with extensive experience marking undergraduate Art and Design coursework. Finally, Marker C is a Doctor of Physics with experience marking on undergraduate courses. Markers

A and B have marked all of the outputs from the Picture Construction, Picture Completion and Parallel Lines activities. Marker B was selected because of their experience in evaluating artwork which may be useful in the scoring of the drawn outputs. Markers A and C marked the remaining text based Alternative Uses and Design Question activity outputs.

5.1.1 Originality

Originality provides an indication of the novelty of a response to a given stimulus (usually a starting shape). The 1972 version of the test that was used for this experiment includes a rubric of common responses derived from the results of 500 participants. Common responses on this list score zero whilst more unusual responses score more highly. Each drawing is scored against this lexicon. Responses not on the list automatically score the highest originality score for that particular test and I have asked markers to add an additional code to indicate that the response is not on the original rubric. In his guide for scorers Torrance [8] describes originality in terms of 'creative strength', noting that:

> *"It may also prove helpful to think of responses showing no creative strength as requiring little intellectual energy; little energy is necessary to give obvious, common, and learned responses. In contrast, more intellectual energy is required to give responses that go beyond what is learned, practised, habitual, and away from the obvious and commonplace. Hence, these latter responses are thought of as 'showing creative strength'."*

Picture construction, Picture Completion, Parallel Lines, Alternative uses and Design Questions all have slightly different scales for originality defined by Torrance [154]. The following subsections describe in detail how originality is scored for each activity.

The markers practised by scoring a number of the prototype team outputs. Following discussion of the originality scoring method we decided to clarify Torrance's [154] instructions by stating that: *'The scoring of originality is based upon*

Figure 5.1: Picture Construction: Salvador Dali on holiday in Holland

the primary use of the starting shape'. This means that it is the response to the prompt that is compared against Torrance's [154] given lexicon. In figure 5.1 the prompt is the black wave in the centre. The team here have incorporated this into a moustache and it is this that we would score for originality, not any other part of the drawing. All of the rubrics along with examples of how to score outputs have been reproduced from Torrance's [154] guide and can be found in appendix B.

Picture construction originality is scored out of 5. Torrance [154] explains that originality scores are derived by categorising over 3,000 individuals responses to the same response. From this he has identified responses that occur in more than 5% of records and gives them a corresponding originality score of 0. Responses identified in 4-4.99% score 1, 3-3.99% score 2, 2-2.99% score 3, 1-1.99% score 4 [154]. Finally, "All other responses showing imagination and creative strength are credited with five points" [154].

Picture completion originality is scored out of 2 by Torrance [154], with re-

sponses found in more than 5% of records scoring 0 and responses found in 2 - 4.99% of records scoring 1. All other responses (<2%) score 2.

Parallel lines originality is scored on a scale from 0 - 3. Responses found in greater than 20% of records score 0, 5-19.99% score 1, 2-4.99 score 2 and less than 2% score 3.

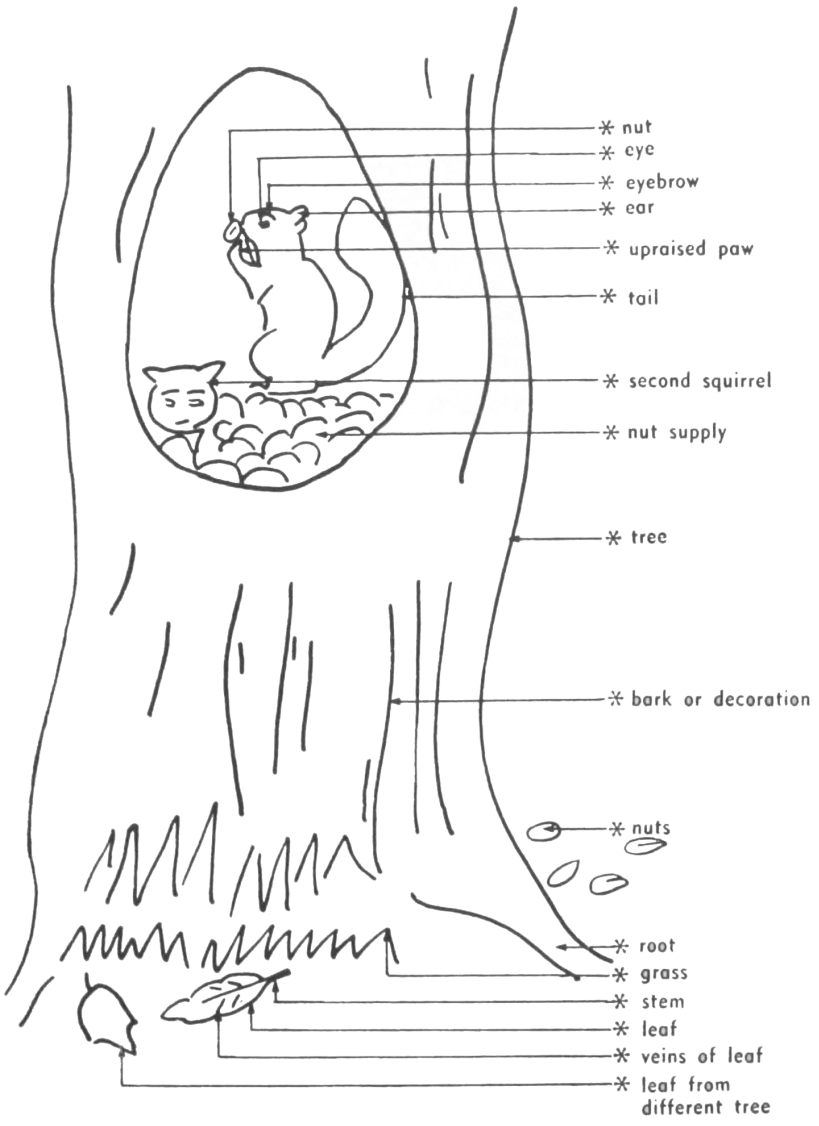
Alternative uses is marked by comparing textural responses against a lexicon drawn up by Torrance [155]. Common responses are given 0, less common 1 and those demonstrating 'creative strength' 2.

It is important to note that the version of the Torrance test that this experiment is based upon is now over 40 years old. It is possible that changes in education and culture in the intervening period (along with the use of teams) increase the likelihood that responses are produced that do not fit Torrance's original criteria. Both markers therefore record a description of the main focus of a response in order to address these potential shortfalls. In doing so I can start to identify appropriate contemporary originality scores for teams addressing the tests.

The Design Questions activity has been developed as part of the thesis and so no lexicon of common responses exists. Instead 10 professional designers were given the same design brief as the teams and asked to list all the questions they would want to see completed. Their responses have been compiled into a list of expert questions. Each question generated by a team that matches this list scores 1 point, 2 points are awarded for every sensible response not on the list. A score of 0 is given for responses that are not actually questions or where the meaning is unclear.

5.1.2 Elaboration

Elaboration scoring attempts to quantify the level of detail provided within responses (usually drawings). Each aspect of a drawing scores one point, these are then totalled to give the elaboration score. Multiple items in a drawing (e.g., a crowd of people) score once for the original plus one additional point to indicate multiple, therein no additional marks are given for multiples. Figure 5.2 shows Torrance's [154] example of scoring a picture construction response.



Title: Fall Festival in Squirrel Land
Elaboration Score: 19
Note: The basic response here is the Squirrel Hole or Nest.

Figure 5.2: Picture Construction Elaboration Scoring Example, taken from Torrance (1972) [154]

Torrance's [154] scoring method allows for the quantification of level of detail in drawn test outputs. However, scoring requires interpretation of drawings. The markers worked through three practice tests and discussed key scoring differences before scoring the final 30 teams outputs. The instructions used (repeated here verbatim) are taken from Torrance's [154] scoring guide:

"Credit is given for each pertinent detail (idea) added to the original stimulus figure itself, to its boundaries and/or to the surrounding space. However, the basic response itself must be meaningful before elaboration has any worth, or can be scored.

One point is given for:

1. *Each essential detail of the total response; but once that class of detail is scored, further responses of the same class are not counted. In other words each additional idea that contributes to the story the picture tells is given an elaboration point, but further representations of the idea are not.*
2. *Color, when it adds an idea to the basic response.*
3. *Deliberate shading (not just going over the lines again).*
4. *Each major variation (not of quantity) of design which is meaningful with reference to the total response.*
5. *Each elaboration in the title beyond the minimum descriptive label.*

If a line breaks one part of the picture into two, count the two parts. If the line has meaning (e.g., belt, cuff, seam, neck scarf, window piece etc.) given an additional point for that item."

The CreativeTeams tool does not give participants the ability to select multiple colours. Each team member is given one fixed colour throughout to aid further analysis. The CreativeTeams scoring therefore does not take colour into account.

Elaboration can also be scored for the alternative uses responses. However

Torrance [155] notes that this is often of little value. Text responses are given a point for each additional level of detail given in a response. Torrance [155] provides the following scoring example describing different uses for cardboard boxes:

		Score
1.	*Store food in them*	*0*
2.	*Make club house out of some high ones* for small children*	*1*
3.	*Paint* them and use them for trash cans in the garage**	*2*
4.	*Make a Halloween robot* costume out of them*	*1*
5.	*Make a boat with a giant* platic lined* box*	*2*
6.	*Grind them up* and make new ones*	*1*
7.	*Large cereal boxes can be covered* with plain white paper* and made so that it looks like a ship*	*2*

5.1.3 Title Originality

Title originality is an optional metric suggested by Torrance [154] that is applicable to Picture Construction and Picture Completion drawings. Torrance's [154] instructions are reproduced here verbatim:

> *"Titles are evaluated on a scale ranging from zero to three on originality or cleverness according to the following criteria:*
>
> *0. Obvious class titles, such as 'Man','Egg','Rabbit' etc.*
>
> *1. Simple descriptive title at a concrete level, involving a modifier plus a class, such as 'Man with a big ear,''A speckled egg,''An easter rabbit,'etc.*

2. *Imaginative, descriptive title in which the modifier goes beyond the concrete, physical description, such as 'Uncle John's Frozen Ear,''The speckled egg of Mars,''The rabbit that tricked uncle Remus,'etc.*

3. *Abstract but appropriate title, going beyond what can be seen and telling a story, such as 'Might Giovanni of the Frozen alps,''A bird in a cage with a thousand eyes,''Princess Mona's Golden bunny,'etc. "*

5.1.4 Marker assessed creativity

Marker assessed creativity has been developed as an alternative way of scoring the originality of test outputs. It has been purposefully included as a counterpart to Torrance's Originality metric [154] following suggestions that expert markers are the best judges of creativity [150, 153] instead of evaluation via a predetermined rubric.

Markers are asked to judge each output by their own experience and give outputs a score of either 0: No creativity shown/predictable outcome, 1: Some creativity shown, 2: Highly creative/I would not have thought of that myself.

By generating these scores it is possible to directly compare the assessment of the same outputs by both rubric and expert marker based.

5.2 Inter-rater agreement

The outputs from the 30 teams that completed the activities without any technical issues have been scored by two markers each for Originality, Elaboration, Title Originality and Marker Assessed Creativity (see table 5.1). Picture Construction, Picture Completion and Parallel Lines activities have been scored by Markers A and B. The Alternative Uses Test and Design Questions Test have been scored by Markers A and C. This section assess the inter-rater reliability to determine the quality of the metrics and their suitability for further analysis.

The assessment of inter-rater agreement is necessary to evaluate the reliability of the scores generated. Torrance's [154] scoring criteria can be affected by marker bias. There is a risk if only one marker is used that their scoring of responses would change over the course of marking. This risk is mitigated by the use of two markers. Inter-rater agreement compares the scores given by both markers to assess whether there are any statistically significant differences in the consistency of scoring. If both markers have interpreted and applied the scoring criteria in the same way then the same scoring trend will exist throughout and there will be a high level of inter-rater agreement. These scores can then be considered reliable (in so much that the criteria has been interpreted and applied by two markers successfully). The two markers scores can then be used to develop an adjusted set of scores for further analysis.

SPSS v23.03 for Mac OSX 10.11.6 was used to calculate all of the statistics in this section.

5.2.1 Statistical Methods Used

Cohen's Kappa and Intra-class correlation coefficient calculations have been used to assess the level of agreement between markers.

5.2.1.1 Cohen's Kappa

Cohen's Kappa is used to establish the agreement of two or more marker's categorical scores. That is, scores that are selected from a rubric e.g., Originality.

The calculation helps to measure the proportion of agreement between markers that is over and above the level of agreement that may occur purely by chance. There are a number of assumptions of Cohen's Kappa that must be fulfilled:

1. Responses must be categorical and categories must be mutually exclusive.
2. Response data must be paired observations from the same phenomenon, meaning both raters assess the same observations.
3. Each response variable must have the same number of categories. A cross-tabulation must be square e.g., 4 x 4 categories, not 3 x 4 categories.
4. The two raters must score independently.
5. The two raters must be fixed, both marking the data in its entirety.

Originality and Marker Assessed Creativity scores both fulfil these criteria.

Cohen's Kappa returns a value ranging from -1 to +1. A value of 0 suggests that the likelihood that markers agree is no better than chance. I.e., if the two markers scored at random with no guidance then there would still inevitably be some scenarios where the markers return the same score purely by chance. A score less than 0 is rare and indicates where markers actively disagree about scores. Scores greater than 0 indicate where markers return the same score more often than they would be expected to purely by chance. Altman [169] suggests a series of categories for interpreting k values (see table 5.2).

k value	Interpretation
0 <0.2	Poor
0.21 - 0.4	Fair
0.41 - 0.6	Moderate
0.61 - 0.8	Good
0.81 - 1.0	Very good

Table 5.2: Interpretation of *k values [169]*

It is important to note that the calculation of Cohen's Kappa is highly dependent on the marginal distributions used for the calculation of chance, this means that it is impossible to compare k-values in most situations. k-values can therefore only be assessed in isolation, on a per-activity basis.

5.2.1.2 Intra-Class Correlation Coefficient

Intra-Class Correlation Coefficient $(2, k)$ is used to assess the consistency with which markers score. There are two main assumptions that must be fulfilled:

1. Response data must be paired observations from the same phenomenon, meaning both raters assess the same observations.

2. Markers must have been selected at random from a wider population of valid candidates.

The ICC$(2, k)$ calculation looks for consistency in the scoring of markers rather than absolute agreement. This is especially important when assessing continuous variables like elaboration scores that do not necessarily fulfil the Cohen's Kappa Assumption of identical category sizes.

ICC$(2, k)$ provides an indicator of agreement by comparing observed variance with expected variance if the judges scored randomly. ICC$(2, k)$ is interpreted as the proportional reduction in this variance. Higher scores indicate reduced error variance and consequently higher agreement. LeBreton and Senter [170] propose using the following boundaries when interpreting inter-rater agreement scores (see table 5.3).

Level of IRA	Substantive Interpretation
.00 - .30	Lack of agreement
.31 - .50	Weak agreement
.51 - .70	Moderate agreement
.71 - .90	Strong agreement
.91 - 1.00	Very strong agreement

Table 5.3: Interpretation of inter-rater agreement values, reproduced from LeBreton and Senter (2007) [170]

5.2.2 Assessing inter-rater agreement

5.2.2.1 Originality

Originality provides an indication of novelty by comparing the focus of a teams drawn response against a rubric of common or expected responses. Responses that are less common return higher scores.

Table 5.4 shows the Cohen's Kappa values calculated comparing the scores from the two markers used.

	N	Kappa Value	Approximate Significance
Picture Construction	30	.767	.000
Picture Completion	215	.781	.000
Parallel Lines	281	.735	.000
Alternative Uses	762	.685	.000
Design Questions	327	.494	.000

Table 5.4: Summary of Cohen's Kappa values comparing marker originality scores

Picture Construction originality is scored on a six point scale from low originality (scoring 0) to high originality (scoring 5). Cohen's Kappa comparing the Originality scores of markers A and B show that there was a good level of agreement, k=.767, p<.0005 (see table 5.4). In total the markers agreed on the scores of 25 of the 30 picture construction drawings available.

Picture completion originality is scored on a three point scale from 0 (low originality), to 2 (high originality). Cohen's Kappa was calculated to determine the level of agreement between the scores produced by Markers A and B. There was a good level of agreement, k=.781, p<.0005 (see table 5.4). In total the markers agreed upon the scores of 184 out of a possible 215 Picture Completion drawings.

Parallel Lines originality is scored on a four point scale from 0 (low originality) to 3 (high originality). The Cohen's Kappa calculated suggests a good level of agreement, k=.735, p<.0005 (see table 5.4). Markers A and B scored 229 of 281 Parallel Lines drawings the same.

Alternative Uses originality is scored on a three point scale from 0 (low originality) to 2 (high originality) based on interpretation Torrance's rubric [155]. The Cohen's Kappa calculated suggests a good level of agreement, $k = .685$, $p < .0005$ (see table 5.4). Markers A and C scored 603 of 762 listed alternative uses the same.

The Design Questions responses are scored for originality by comparing them against a list of questions compiled by expert designers given the same task. Responses are then graded 0 if the response is not a question, or illegible, they given a score of 1 if the questions is on the expert designers list of questions. Finally responses that are legible and are not on the expert designers list score 2. The Cohen's Kappa calculated comparing scores of Markers A and C suggest a weak level of agreement only, $k = .494$, $p < .0005$. Markers A and C agreed on 246 of 327 responses.

Scoring the design questions responses is made complicated by the similarity of responses. For example, the experts have listed, 'Do you have a preference for chair materials?', teams have then listed many variations e.g.,'What type of fabric should we use?' that could relate to this question. It therefore seems likely that markers variation in agreement relates primarily to interpretation. It is possible that inter-rater agreement would improve with practice.

In conclusion, there is a good level of agreement between markers' Originality scoring of Picture Construction, Picture Completion, Parallel Lines and Alternative Uses. This supports Torrance's [155] observation that new markers are able to score TTCT outputs with a reasonable degree of consistency. It must be noted that these findings only confirm consistency in agreement between markers. It is still possible that markers have misinterpreted the scoring guide.

This high level of agreement suggests that the originality scores are reliable for these four activities. The next step is to transform the two markers scores into a single set for analysis. To create this, the markers discuss each instance where they have disagreed. In most instances the difference in scoring is due to selection of similar categories on the rubric to describe the same thing. For example, markers may be given a drawing of a box. Marker A may interpret this as a cardboard box on the rubric, whilst marker B may interpret the same drawing as a container using the rubric. Both markers recognised the same object

but have made slightly different interpretations of the rubric. By discussing these differences and altering their selections we arrive at a final single adjusted set of originality scores.

Markers did not agree on the Originality scoring of the Design Questions activity, demonstrating only a weak level of agreement. This suggests that this method of scoring in unreliable. This metric will be dropped from further analysis as a consequence.

5.2.2.2 Elaboration

Elaboration scores provide an indication of the level of detail within a response. This is a count of the additional details in a drawing, for textural responses it is a count of their relative complexity.

Table 5.5 summarises the Intra-Class Correlation Coefficient ICC$(2, k)$ comparing elaboration scores given by the various markers.

	Intraclass Correlation	95% Confidence Interval		Sig
		Lower Bound	Upper Bound	
Picture Construction	.942	.877	.972	.000
Picture Completion	.964	.953	.973	.000
Parallel Lines	.971	.964	.977	.000
Alternative Uses	.721	.678	.758	.000

Table 5.5: Summary of Inter-rater agreement elaboration scores using ICC$(2, k)$

Markers A and B demonstrate a very strong level of agreement when scoring the elaboration of Picture Construction outputs, ICC=.942 (CI .877 to .972), $p = .0000$ (see table 5.5). The close relationship between the two markers scores can be confirmed by visual analysis of figure 5.3.

The Picture Completion activity presents teams with up to ten different starting shapes to base their drawings on. Table 5.5 reports the ICC$(2, k)$ across all 10 drawings and indicates a very strong level of agreement between markers, ICC=.964 (CI .953 to .973), $p = .000$. However, each of the ten drawings uses a different starting shape, and consequently it can be argued that each drawing needs to be assessed differently. Table 5.6 therefore provides the ICC$(2, k)$ values for each of the ten possible starting shapes.

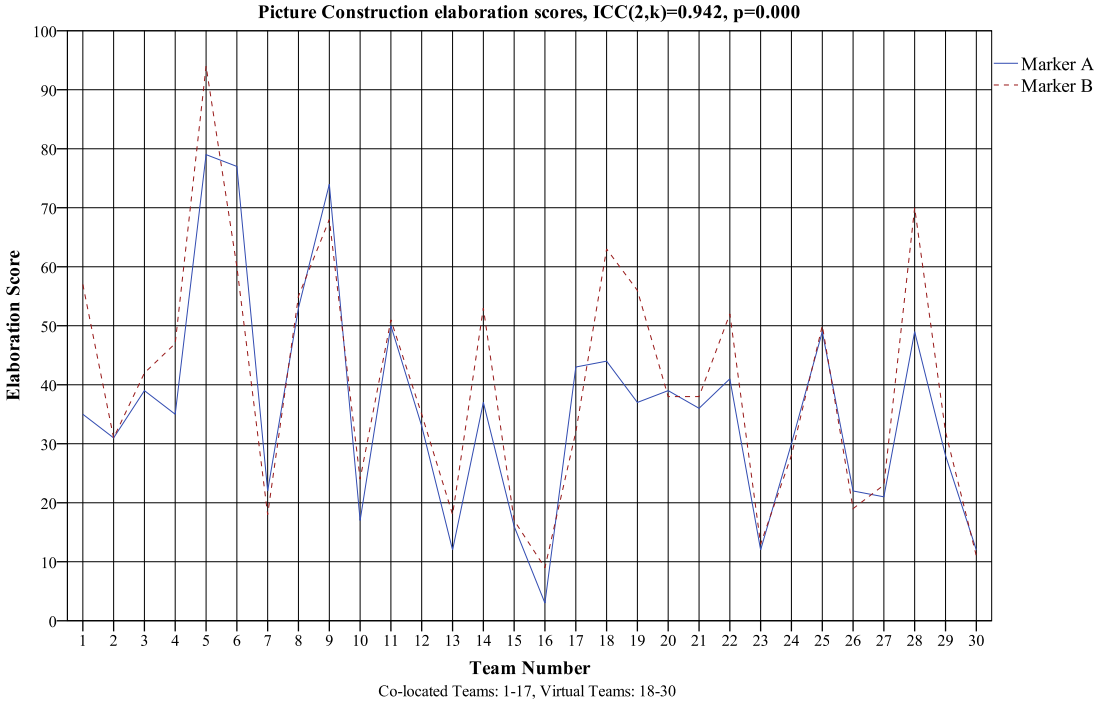


Figure 5.3: Marker elaboration scores by team for picture construction test

Drawing number	Intraclass Correlation$_b$	95% Confidence Interval		Sig
		Lower Bound	Upper Bound	
1	.975	.946	.988	.000
2	.984	.965	.992	.000
3	.920	.830	.963	.000
4	.959	.909	.981	.000
5	.957	.901	.982	.000
6	.976	.940	.990	.000
7	.979	.944	.992	.000
8	.964	.898	.988	.000
9	.985	.943	.996	.000
10	.863	.490	.963	.002

Table 5.6: Inter-rater agreement of picture completion elaboration scores per starting shape using ICC$(2, 2)$

The ICC$(2, k)$ scores in table 5.6 suggests that markers score the elaboration of outputs consistently with the lowest average intra-class correlation score still demonstrating a strong level of agreement, ICC$(2, k)$=.863, $p = .002$. It therefore

appears that Elaboration can be reliably scored.

The Parallel Lines outputs are all based on the same identical starting shapes, the ICC$(2, k)$ value is therefore calculated across all responses. Markers demonstrate very strong inter-rater agreement, ICC$(2, k)$ average=.971,$p = .000$.

Torrance [8] suggests that it is also possible to score Alternative Uses responses for elaboration. Although he notes that this is an optional metric requiring careful interpretation. Markers A and C demonstrate strong agreement, ICC$(2, k)$ average=.721, $p = .000$.

In summary the elaboration metric appears to be reliable with markers demonstrating strong to very strong ICC$(2, k)$ values for all elaboration scores. It should be noted that the ICC$(2, k)$ calculations here are looking for consistency. That is, strong correlation of trends rather than exact agreement of scores. The two markers scores are averaged to derive a the final elaboration data set for further analysis.

5.2.2.3 Title Originality

The Title originality metric is proposed by Torrance [154] to quantify the complexity of titles. Picture Construction and Picture Completion drawings are assessed using a simple guide that rates titles on a four point ordinal scale from 0 (low originality) to 3 (high originality). Table 5.7 provides a summary of the Cohen's Kappa values for markers A and B scoring of Title Originality.

	N	Kappa Value	Approximate Significance
Picture Construction	30	.405	.000
Picture Completion	214	.492	.000

Table 5.7: Summary of Cohen's Kappa values comparing Title Originality scores

There is only moderate agreement between markers scoring of Picture Construction titles, $k = .405$, $p < .0005$. Markers A and B agreed on the scoring for only 17 of 30 titles.

A comparison of scores for Picture Completion titles also suggests only moderate agreement between markers, $k = .492$, $p < .0005$. This is reflected in a

comparison of the actual scores given, with markers agreeing on only 136 of 214 title scores.

Title Originality cannot therefore be considered a reliable metric with only moderate ICC$(2, k)$ values returned. As such this metric has been dropped from further analysis.

5.2.2.4 Marker assessed creativity

Markers were asked to assess the creativity of each output themselves using a basic scoring system of 0: No creativity/Obvious response, 1: Some creativity, 2: Highly creative/would not have thought of yourself. This is in response to the suggestion that expert marker evaluation provides the best means of assessing creativity [153].

Table 5.8 shows the Cohen's Kappa values calculated by comparing the Marker Assessed Creativity scores.

	N	Kappa Value	Approximate Significance
Picture Construction	30	.427	.001
Picture Completion	215	.241	.000
Parallel Lines	287	.470	.000

Table 5.8: Summary of Cohen's Kappa values comparing Marker Assessed Creativity scores

The markers assessment of Picture Construction creativity demonstrate only moderate inter-rater agreement $k = .427$, $p = .001$. A comparison of the scores indicates that the two markers agreed on scores for 20 of the 30 outputs.

The two markers have slightly improved levels of agreement for Picture Completion outputs, demonstrating a fair level of agreement, $k = .241$, $p < .0005$. In the actual data this results in the markers providing the same scores for 101 of 215 possible drawings.

The creativity scoring of parallel lines drawings demonstrates a moderate level of agreement, $k = .470$, $p < .0005$. In comparison of the actual scores this results in the two markers agreeing on the scores of 185 of 287 outputs.

In conclusion, the analysis of Marker Assessed Creativity scores indicate only fair to moderate agreement between Markers A and B. Such weak agreement suggests that the two markers are unable to judge creativity consistently when using a rough scale. Such a finding contradicts the suggestions made by Runco [153]. The lack of agreement between markers suggests that the data is unreliable and unsuitable for processing into an adjusted data set.

It seems possible that marker background and experience are responsible for the the difference in inter-rater agreement between more structured metrics that use a rubric based scoring method (e.g., Originality) and more interpretive metrics (e.g., Marker Assessed Creativity). The interpretive methods used in the scoring of Marker Assessed Creativity and Title Originality present scorers with only a simple guide and rely on their own experiences to help them judge outputs. It appears therefore that the markers different backgrounds may prevent them interpreting these guides the same way. The difference in scoring occur despite markers having practised the scoring of a number of practice outputs. It seems reasonable to assume therefore that such unstructured scoring approaches will continue to produce less reliable metrics.

5.3 Chapter Summary

This chapter has described how the Originality, Elaboration, Title Originality and Marker Assessed Creativity metrics are scored by multiple markers. The different markers scores are then compared to establish the reliability of the metrics.

The inter-rater agreement analysis suggests that Originality and Elaboration can be reliably scored. The scoring of Originality for the Design Questions activity is the only exception and is therefore excluded from further analysis. The remaining Originality and Elaboration score are then processed to form single datasets for further analysis.

Markers have reviewed the small number of instances where they have selected different Originality scores. The reasoning behind these differences is discussed until they reach an agreed score. This results in the development of a single set of Adjusted Originality scores that both markers agree upon.

Markers demonstrate a high level of consistency in the scoring of Elaboration. This means that markers generally agree on which drawings are more or less detailed even if they don't give them exactly the same scores. Despite these differences the two markers are therefore consistent in their scoring. The two markers scores are then averaged to arrive at a single dataset that represents the level of Elaboration.

The Title Originality metric was not found to be reliable and has consequently been excluded from further analysis.

The Marker Assessed Creativity score was also found to be of limited reliability. It appears that markers are unable to agree on the scoring of creativity when they use a simple guide and their own experience rather than a structured rubric.

From this analysis it appears that Torrance's [8] scoring methods are generally reliable, resulting in high levels of inter-rater agreement. With the exception of the Title Originality Metric. It is probable that the relatively small sample size has had some effect on the reliability of scoring.

The reliability of scoring also seems to be impacted by the extent to which a scoring method is structured. For example, Originality is highly structured

- markers interpret outputs and derive the appropriate score from a rubric of finite responses. In this instance markers have to identify if the main response in the drawing is on that list or not. If the main response isn't on the list then markers have only one option, to rate the response as 'Highly Creative' with a maximum Originality score. The scoring of Elaboration is also highly structured focusing on a count of what is details are contained within a response. Whilst there is a certain degree of variation, markers are generally still able to assess when a response contains more or less detail. By contrast, the scoring of Title Originality and Marker Assessed Creativity both use more ambiguous scoring methods. Markers allot scores based on their personal interpretation, and this can vary from marker to marker and from drawing to drawing. For example, one marker may be of the opinion that the response drawn is remarkable, resulting in a high creativity score. By contrast another marker may find the same response predictable, resulting in a low score. Without more structured guidance such situations may be commonplace. One possible way to counteract this would be for markers to discuss their scoring at length to derive an understanding of each others' expectations. The markers did discuss the scoring of all metrics in this experiment. However, it is possible that they did not work through enough practice examples. By working through many examples though, it is possible that markers arrive at a scoring approach that becomes so structured (even if it is not written down) that it effectively mimics a rubric based approach regardless.

It must be noted that the more structured methods of scoring are not without issues, despite resulting in higher inter-rater reliability. Torrance's Originality metric assumes that Originality, and consequently creativity, are primarily concerned with novelty. His approach of developing rubrics by identifying common responses to the same stimulus from a large sample implies that common responses are not creative. It seems plausible that the response to the shape itself may be common, but that the level of additional detail surrounding the shape may make the overall response highly original. Whilst this extra detail may well result in a high Elaboration score, the overall creativity remains low. In this instance there appears to be a need for a further Originality-like metric. One Originality metric may relate to the response to the starting shape and the other to the overall originality of the response. It is arguable that the use of teams has

emphasised the limitations of the current Originality metric. Teams are likely to produce more complex responses to starting shapes, with more detail than individuals.

Chapter 6 that follows addresses RQ1: *"Do virtual or co-located teams perform creative tasks better?"* by comparing the performance of co-located and virtual teams using a number of metrics (including Adjusted Originality and Average Elaboration).

Chapter 6

Co-located vs Virtual Team Creative Performance

This chapter addresses research question 1 (*"Do virtual or co-located teams perform creative tasks better?"*) by comparing the Originality, Elaboration, Fluency, Stroke Count and Drawing Time metrics for co-located and virtual teams. These metrics are assessed across the Picture Construction, Picture Completion, Parallel Lines and Alternative Uses activities and represents the second major contribution of this thesis.

Note, neither Design Challenge nor Design Questions are analysed further. The Design Challenge is excluded because as explained in chapter 5, no appropriate means could be found of analysing the designs produced. It appears that the task given was not sufficiently complex nor were instructions specific enough (despite extensive prototyping of the activity). This resulted in outputs from teams that varied so much that comparison was not possible. The Design Questions data is excluded because as explained in chapter 5, only low inter-rater agreement was found, suggesting that these scores are unsuitable for further analysis. Both of these limitations are discussed in more detail in chapter 7.

Table 6.1 provides a summary of the Metrics used, Activity analysed and Method of comparison.

Metric	Creative Activities			
	Picture Construction	Picture Completion	Parallel lines	Alternative Uses
Originality (adjusted)	Mann-Whitney U			
Elaboration (averaged)	Mann-Whitney U, Independent Samples T-Test			
Fluency		Independent Samples T-Test		
Stroke Count	Independent Samples T-Test			
Drawing Time	Independent Samples T-Test			

Table 6.1: Summary of Metrics and Methods of assessment

This chapter starts with a discussion of statistical methods employed (section 6.1) before proceeding to analyse the creativity metrics (Originality, Elaboration, Fluency) in section 6.2. Table 6.1 provides a summary of the metrics used, activity analysed and method of comparison. Section 6.3 then compares how teams have used the tool using Stroke Count and Drawing Time metrics gathered from the CreativeTeam metadata. The key findings are then discussed before a further analysis of Team Utterances is performed in section 6.5. Section 6.6 summarises and concludes this chapter. Samples of the team drawings can be found in Appendix A and the data used in this analysis can be found in Appendix C.

6.1 Statistical methods used

The metrics being assessed fall into one of two data types: ordinal or continuous. Originality scores are ordinal data. That is, scores are based on a set scale where the higher the score the better. Elaboration, Fluency, Stroke Count and Drawing Time are all continuous data, that is they can be counted. These two distinct types require different methods of analysis.

6.1.1 Mann-Whitney U Test

The Mann-Whitney U test is used to identify statistically significant differences in the distribution of two data sets. It is particularly useful for analysing non-parametric data because the calculation uses a rank order based calculation rather than using actual data values. There are four key assumptions that have to be fulfilled:

1. The dependent variable must be either continuous or ordinal.
2. The independent variable should consist of two categorical and independent groups.
3. Markers should make observations independently.
4. Data should have similar shaped distributions.

* The last point is only applicable if measuring the differences of median values.

Mann-Whitney U statistical significance is calculated by SPSS producing either an asymptotic or exact (more accurate) significance value. SPSS chooses which calculation to run based on the sample size. Both asymptotic and exact statistical significance figures are interpreted the same way with a score of $> .05$ indicating that the distribution of the mean values are very similar. Conversely a score of $< .05$ is indicative of a statistically significant difference. Z-scores are also

reported. These provide an indication of the direction and strength of variation from a normal distribution.

The Kruskal-Wallis H test is another alternative means that could be employed to assess the non-parametric data. However, the calculation is more readily used when comparisons are being made between three or more groups of data. Whilst the Kruskal-Wallis H test can be applied to only two groups the Mann-Whitney U test is more commonly used.

6.1.2 Independent Samples T-Test

The Independent Samples T-Test is used to determine differences between the means of two independent groups measured using a continuous dependent variable. There are six main assumptions that data must fulfil in order to carry out this calculation:

1. The dependent variable should be measured at the continuous level.
2. There is only one independent variable consisting of two categorical groups.
3. There is independence of observations.
4. There should be no significant outliers in the data.
5. The dependent variable should be approximately normally distributed. However, there is a suggestion that normality has only a limited effect on the calculation.

   > "For practical purposes, the power of the t-test is not seriously invalidated even if the samples are from considerably non-normal populations." [171, p. 428].

6. There is homogeneity of variances i.e., the variance is equal in each group of the independent variable.

These criteria are satisfied in the calculations that follow. A note is made where data is not normally distributed. A calculated t-value $<.05$ indicates a

statistically significant difference in the means of the two independent groups. Effect size (Cohen's d [172]) is then calculated to identify the strength of the mean differences. Cohen [172] suggests interpreting effect size as: "small, $d = .2$," "medium, $d = .5$," or "large, $d = .8$". This test is accompanied by the Mann-Whitney U test because both are applicable to continuous data.

6.1.3 Somers' delta

Somers' delta (Somers'd) is a calculation used for determining the strength and direction of association between dependent and independent ordinal variables. It is suitable for used with non-parametric data. It is reported as a value from -1 to +1 indicating the strength and direction of the relationship. The Statistical significance is an indication of the reliability of this relationship.

6.1.4 Spearman's rank-order correlation

Spearman's rank-order correlation (Spearman's rho) shows the strength and direction of association between two continuous or ordinal variables. It is used instead of Pearson's product-moment correlation because Pearson's is for strictly linear relationships. Spearman's rho can be used with a wider range of distributions. Spearman's rho returns a value from -1 to +1 indicating the direction and strength of the relationship, along with an indication of statistical significance.

6.2 Analysis of creativity metrics

6.2.1 Originality

The *Originality* metric provides an indication of novelty by comparing the main content of the drawing against a rubric of common responses [154]. The calculations in this section use the adjusted originality data sets (see section 5.2 for more details).

Mann-Whitney U calculations are used to assess the originality scores of all four creative activities. Table 6.2 provides a summary of these calculations.

	Picture Construction	Picture Completion	Parallel Lines	Alternative Uses
Z	-.687	-1.245	-.086	-.187
Asymp. Sig. (2-tailed)	.492	.213	.932	.851
Exact Sig. (1-tailed)	.536	-	-	-
Mean rank (Co-located)	14.59	112.39	142.61	407.79
Mean rank (Virtual)	16.69	102.45	143.40	408.88

Table 6.2: Summary of Mann-Whitney U tests comparing co-located and virtual team originality scores

The values reported in table 6.2 suggest that location has no statistically significant impact on *Originality* scores. SPSS is used to generate these values and it chooses whether to use an asymptotic statistical significance or exact significance calculation based on the number of values being compared. The exact significance value is slightly more accurate but can only be calculated with smaller data sets, hence it is only reported for the Picture Construction activity where $n = 30$. The asymptotic significance still provides a valid indication of the relationship between co-located and virtual team scores. In this case a significance score of $>.05$ is returned for the comparison of co-located and virtual team adjusted originality scores across each activity. This suggests that the originality scores of co-located

and virtual teams are very similar to each other across all four activities. This trend is most easily seen in figure 6.1 which shows the originality scores for the Parallel Lines activity. Teams tend to complete the most drawings during this activity making the trend more visually obvious in comparison to the other activities. The Z value is also included to provide an indication of the strength and direction of variation from a normal distribution. In this case none of the activities have normally distributed originality scores.

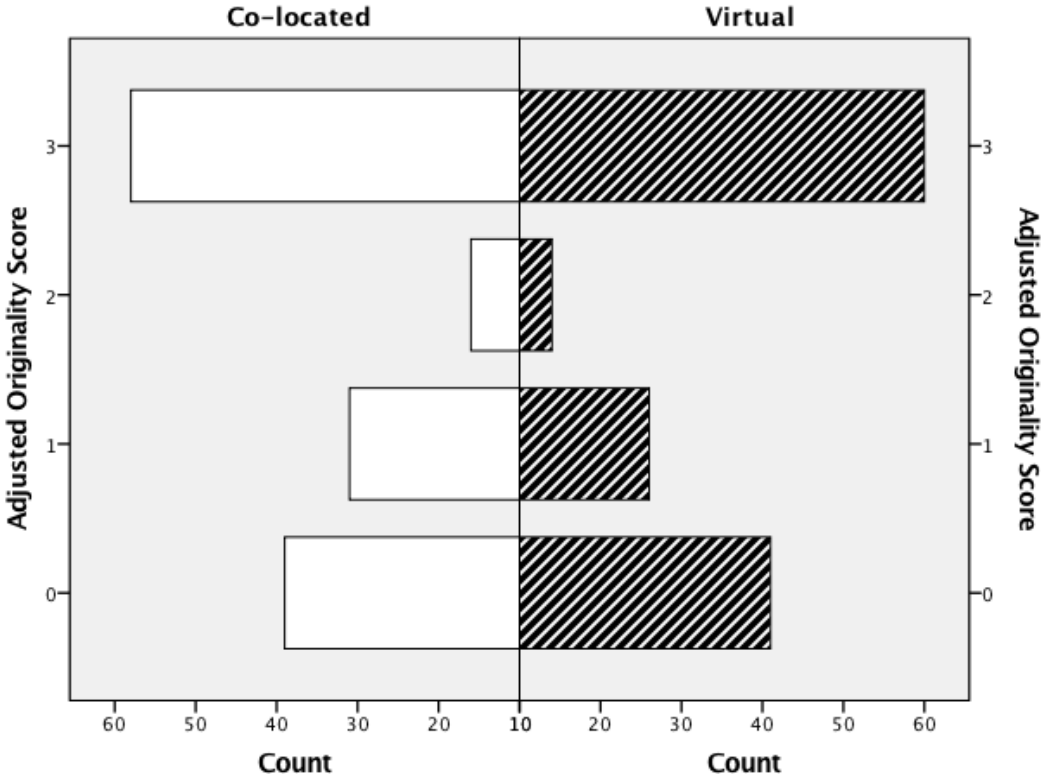


Figure 6.1: Distribution of parallel lines originality scores

The Mann-Whitney U calculations in table 6.2 indicate that teams returned extremely similar Originality scores regardless of location. However, these findings are highly reliant upon Torrance's 40 year old rubric [8, 154]. As such this rubric fails to take into account many obvious responses that are the result of recent popular culture. In the context of today, many responses are obvious but score highly for originality on Torrance's rubric because they weren't commonplace 40 years ago. For example, the starting shape for Picture Completion

drawing number 6 looks like a lightening bolt; many teams have turned this into Harry Potter (see figure 6.2). This is a fairly obvious response in contemporary culture. However it isn't covered by Torrance's [154] rubric. This means that there are a large number of responses given top marks (arguably undeservedly) that may skew the distribution of creativity scores.

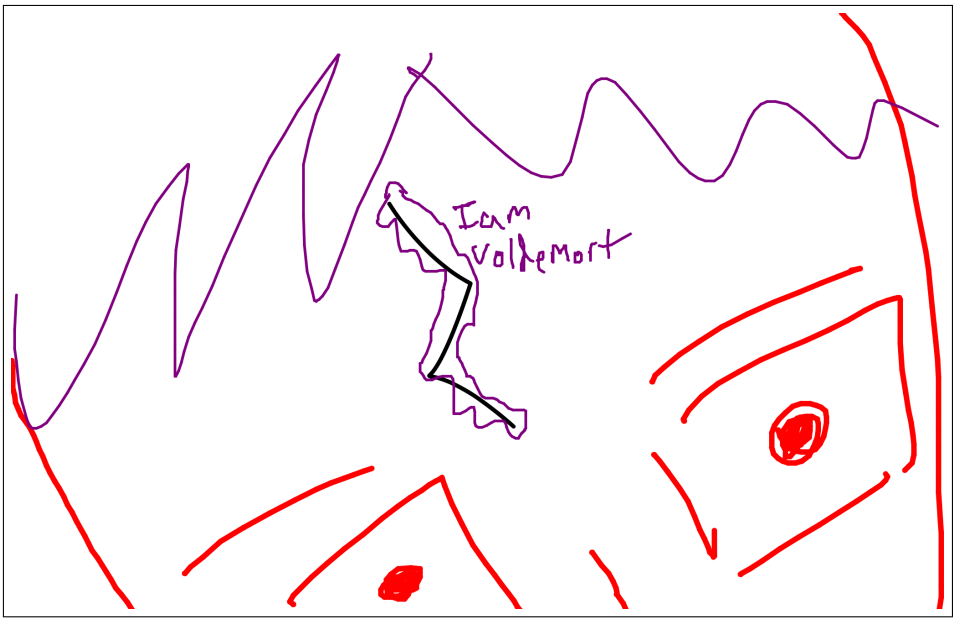


Figure 6.2: Picture Completion: Harry Potter by Team 30

I have re-run the Mann-Whitney U calculations for the drawing activities excluding those responses not on Torrance's [8, 154] rubrics. This is to explore whether the large number of 'highly creative' responses are only given this score owing to the age of the rubric. If this is the case then it is possible that this has had an impact on the true difference in co-located and virtual team originality. Table 6.3 provides the outputs from this alternative calculation. There remains no statistically significant differences between co-located and virtual team originality scores.

Both sets of Mann-Whitney U values and distribution figures (see tables 6.2 and 6.3) make it clear that there is very little difference between the Originality scores of co-located and virtual teams. None that are of any statistical significance. This is a significant finding as it suggests that the ability to think of

	Picture Construction	Picture Completion	Parallel Lines	Alternative Uses
Z	-.244	-.868	-.044	-.142
Asymp.Sig. (2-tailed)	.807	.386	.965	.887
Exact Sig. (1-tailed)	.851			
Mean rank (co-located)	10.25	66.60	100.67	317.68
Mean rank (Virtual)	10.88	71.51	100.53	319.53

Table 6.3: Comparison of co-located and virtual team originality Mann-Whitney U (responses that feature on TTCT rubric used only)

Original (novel) and therefore creative responses are not affected by working remotely via video link.

It is important to note that this finding is only applicable to this particular view of originality. That is, the idea that originality is the production of less common responses to the same given prompt. Furthermore, it is hard to determine the impact of communication via video conferencing. It is possible that the drawing tool itself provides such a responsive shared drawing experience that teams only need minimal verbal communication. Nevertheless, this finding still suggests that virtual teams can be as original as co-located teams provided they have appropriate tool support.

Three of the four activities assessed for Originality are drawing based. It is therefore possible that teams may produce more original responses if their team comprised of more experienced artists. Following the activity participants were asked to identify their artistic ability on a simple scale. This threat to validity is explored in more detail in section 6.4.

6.2.2 Elaboration

Elaboration scores provide an indication of the amount of detail in responses. The difference between co-located and virtual team scores are assessed using the average elaboration data (see section 5.2 for more details).

Both Mann-Whitney U (see table 6.4) and independent samples t-tests are used to identify significant differences in the elaboration scores of co-located and virtual teams.

	Picture construction	Picture completion	Parallel lines	Alternative Uses
Z	-.460	-1.089	-4.595	-3.763
Asymp. Sig. (2-tailed)	.645	.276	.000	.000
Exact Sig. (1-tailed)	.650	-	-	-
Mean rank (Co-located)	16.15	112.11	167.96	404.59
Mean rank (Virtual)	14.65	102.81	122.73	351.32

Table 6.4: Summary of Mann-Whitney U tests comparing co-located and virtual team elaboration scores

The analysis in table 6.4 produces conflicting results. The analysis finds no difference between co-located and virtual team elaboration scores during the Picture Construction ($p = .650$) and Picture Completion ($p = .276$) activities. However, there is a statistically significant difference in the elaboration scores produced during the Parallel Lines ($p = .000$) and Alternative Uses ($p = .000$) activities.

Figures 6.3 and 6.4 help to illustrate the differences in elaboration scores. The trends are more pronounced in the Picture Completion and Parallel Lines activities where a larger number of drawings have been completed. The virtual team trends are slightly less distinct $n = 13$ whereas $n = 17$ in the co-located data set.

Taking this into account, it is clear that the distribution of co-located and virtual team scores are very similar in Figure 6.3. By contrast, it is clear in Figure 6.4 that there are significant differences between co-located and virtual team elaboration scores, with a far higher number of the virtual team drawings receiving a lower (<10) elaboration score.

Independent samples t-tests corroborate these findings. There is no indication of statistically significant differences between the elaboration scores of co-located and virtual teams completing the Picture Construction activity, $t = .902$, $p =$

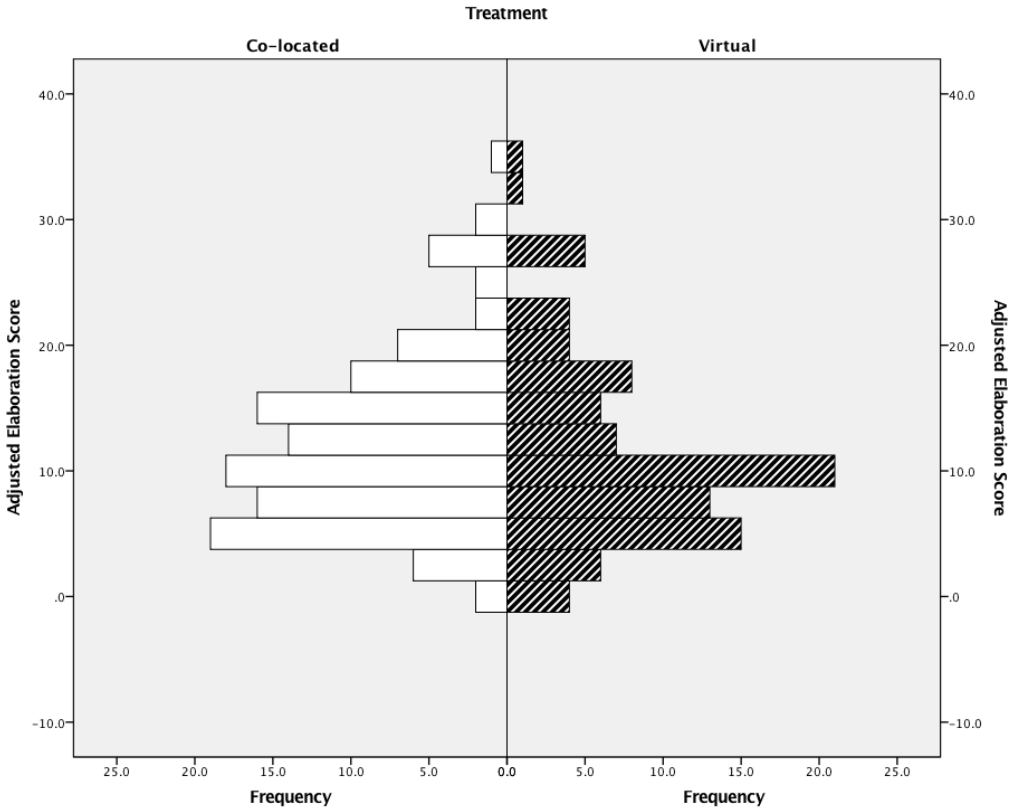


Figure 6.3: Distribution of Picture Completion Elaboration scores

.375. Nor were there statistically significant differences in the elaboration scores teams completing the Picture Completion test, $t = .812$, $p = .418$.

The t-test comparing the elaboration scores of teams completing the Parallel Lines activity supports the Mann-Whitney U calculations, suggesting that there are statistically significant differences in the elaboration scores of co-located and virtual teams, $t = 4.369$, $p = .000$ with a medium effect size, $d = .512$. The alternative uses activity also returns a statistically significant t-test, $t = 3.681, p = .000$.

Whilst the Alternative Uses elaboration scores return statistically significant differences, the data should be considered unreliable. Both markers reported finding the scoring of elaboration difficult owing to the typically short length of answers given by participants. This is why the majority of alternative uses score

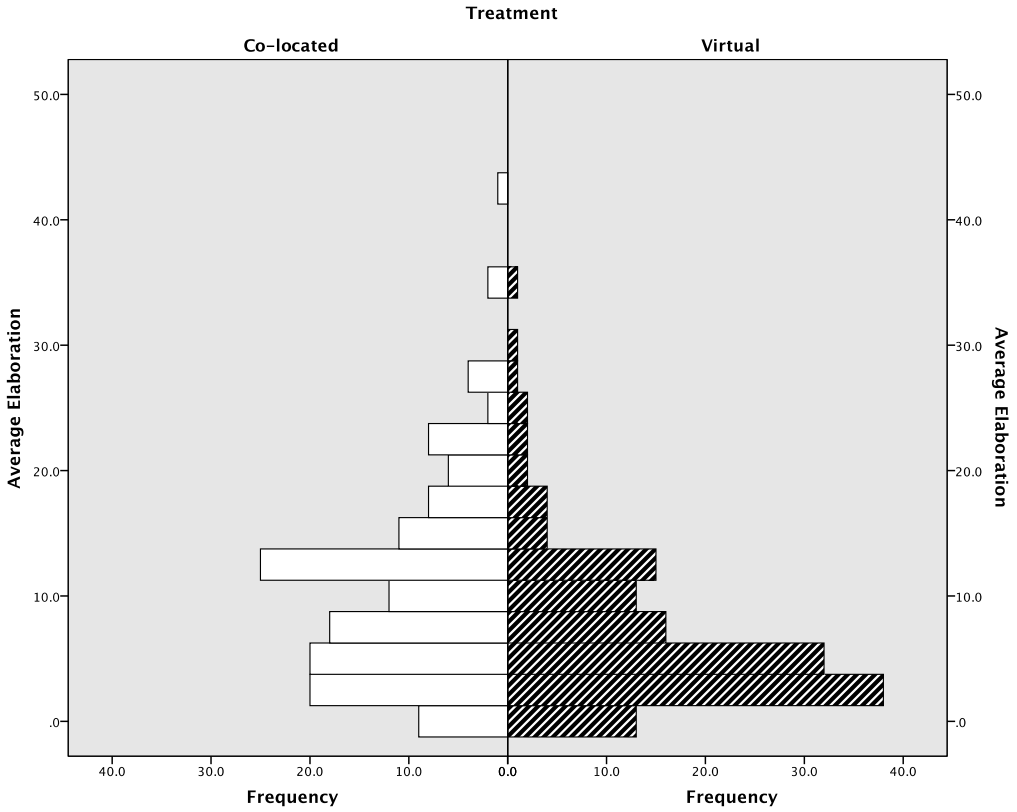


Figure 6.4: Distribution of Parallel Lines Elaboration scores

only 0 or 1 for elaboration (see figure 6.5). Torrance [155] specifically notes that the scoring of Alternative Uses elaboration is an optional metric, suggesting that it often returns little of significant value. The decision has therefore been taken to exclude this data set from further analysis.

In conclusion, there appears to be no statistically significant difference in co-located and virtual team elaboration scores when addressing the Picture Construction and Picture Completion tasks. This is confirmed by both Mann-Whitney U and Independent samples t-test. However, there does appear to be statistically significant differences between co-located and virtual team elaboration scores for the Parallel Lines activity.

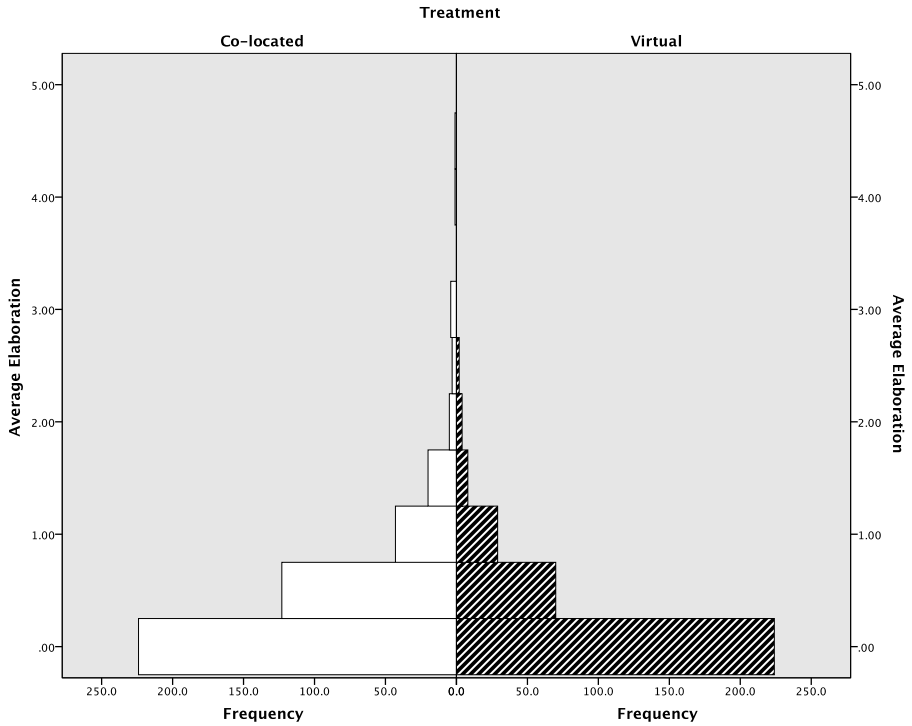


Figure 6.5: Distribution of Alternative Uses Elaboration scores

6.2.3 Fluency

Fluency represents a count of drawings completed, or items in a list. Performance is assessed using both Independent Samples T-Test and Mann-Whitney U to provide as accurate a comparison of performance as possible.

	t-value	Sig (2-tailed)	Mean Difference	Standard Error	Effect Size
Picture Completion	-.274	.786	-.262	.957	-.104
Parallel Lines	-1.267	.216	-2.579	2.036	-.467
Alternative Uses	-.239	.813	-.968	4.052	-.088

Table 6.5: T-tests comparing co-located and virtual team fluency

The t-values in table 6.5 suggest that there is no statistically significant difference in the number of drawings completed, or responses given by co-located and virtual teams. However, there is still quite a large mean difference for the Parallel Lines fluency scores. These findings are reflected in the effect sizes, with

only small effect sizes noted for the difference of co-located and virtual teams completing the Picture Completion and Alternative Uses activities. There is a larger, but still not significant effect size observed for the Parallel Lines activity.

Overall it seems that the number of drawings produced is not significantly affected by the environment in which the activities are completed. This is confirmed by Mann-Whitney U analysis of the same data in table 6.6.

	Picture completion	Parallel lines	Alternative Uses
Z	-.369	-1.050	-.419
Asymp. Sig. (2-tailed)	.712	.294	.675
Exact Sig. (1-tailed)	.742	.300	.680
Mean rank (Co-located)	15.00	14.03	14.91
Mean rank (Virtual)	16.15	17.42	16.27

Table 6.6: Mann-Whitney U tests comparing co-located and virtual team fluency

6.3 Analysis of CreativeTeams Metadata

A range of metadata is generated by the CreativeTeams tool as teams complete their activities. This data is highly reliable because it is generated by the tool itself as part of its processing. The data generated relates to touch interactions. Every time a user touches the iPad they generate a touch interaction that is recorded to the server database and used to synchronise the drawing with the other iPads.

6.3.1 Drawing Actions

Drawing actions are recorded as either drawing, erasing or title actions. In this analysis we report a combined figure of the total actions of teams to compare how co-located and virtual teams interact with the tool during the activities.

Table 6.7 reports the findings of an independent samples t-test comparing the number of actions performed by co-located and virtual teams across the three drawing activities. The t-values suggest that there are no statistically significant difference in the number of actions used by teams completing the Picture Construction ($t = .457, p = .651$) and Picture Completion ($t = .727, p = .468$) activities. However, there is a statistically significant difference in the number of actions used by co-located and virtual teams during the Parallel Lines activity ($t = 3.398, p = .001$). The associated effect sizes (see table 6.8) confirm the significance of this difference ($d = 4.799$). This is an important finding that reiterates the difference noted in section 6.2.2, namely that the virtual teams put less detail into their parallel lines responses than the co-located teams. These findings are corroborated by Mann-Whitney U test analyses (see table 6.9).

	t-value	Sig (2-tailed)	Mean difference	Standard Error
Picture Construction	.457	.651	689.729	1508.525
Picture Completion	.727	.468	148.890	204.843
Parallel Lines	3.398	.001	568.905	167.444

Table 6.7: Independent samples t-test results comparing total drawing actions of co-located and virtual teams

		N	Mean	Standard Deviation	Effect Size
Picture Construction	Co-located	17	13178.88	4033.852	.168
	Virtual	13	12489.15	4173.716	
Picture Completion	Co-located	120	1908.68	135.635	1.033
	Virtual	97	1759.79	154.129	
Parallel Lines	Co-located	147	1674.91	137.874	4.799
	Virtual	145	1106.01	95.016	

Table 6.8: Total drawing actions effect size

	Picture construction	Picture completion	Parallel lines
Mann-Whitney U	98.5	5373.5	8129.0
Z	-.502	-.971	-3.505
Asymp. Sig. (2-tailed)	.615	.332	.00
Exact Sig. (1-tailed)	.621	-	-
Mean rank (Co-located)	16.21	112.72	163.70
Mean rank (Virtual)	14.58	104.40	129.06

Table 6.9: Summary of Mann-Whitney U tests comparing co-located and virtual team actions

This analysis of the total actions performed by teams serves to confirm the elaboration analysis completed in section 6.2.2, showing that both co-located and virtual teams use roughly the same number of actions (and consequently are awarded similar elaboration scores) during the Picture Construction and Picture Completion activities. However, co-located teams tend to use more actions (and therefore tend to have a higher elaboration score) than virtual teams during the Parallel Lines activity. This is an interesting finding because the Parallel Lines activity and Picture Completion activity are relatively similar in nature.

6.3.2 Drawing Time

The drawing time metric provides an indication of the total time spent drawing. That is the total time spent interacting with the tool across the whole team. This means that the time displayed can often be larger than the total time limit of an activity because the metric includes the time spent drawing by the entire team, i.e., Total time drawing for team member 1 + 2 + 3.

Table 6.10 reports the independent samples t-test values comparing drawing times of co-located and Virtual teams. The reported t-values indicate no statistically significant difference in the drawing time when completing Picture Construction ($t = .965, p = .347$) and Picture Completion ($t = -.596, p = .552$) activities. However, a significant difference is reported for teams completing the parallel lines activity ($t = 3.453, p = .001$). The effect sizes reported in table 6.11 mean that whilst there is a significant difference in the time spent drawing by co-located and virtual teams completing the Parallel Lines activity, it is only of a small effect size.

	t-value	Sig (2-tailed)	Mean difference	Standard Error
Picture Construction	.965	.347	00:01:19	00:01:22
Picture Completion	-.596	.552	-00:00:09	00:00:15
Parallel Lines	3.453	.001	00:00:37	00:00:10

Table 6.10: Summary of Independent Samples T-Test results comparing total activity time of co-located and virtual teams

		N	Mean	Standard Deviation	Effect Size
Picture Construction	Co-located	17	00:20:21	00:02:37	.379
	Virtual	13	00:19:02	00:04:22	
Picture Completion	Co-located	120	00:01:50	00:01:37	-.079
	Virtual	97	00:01:59	00:02:11	
Parallel Lines	Co-located	147	00:01:37	00:01:47	.400
	Virtual	145	00:01:00	00:01:15	

Table 6.11: Activity time effect size

6.4 What about the impact of artistic ability?

The Picture Construction, Picture Completion and Parallel Lines activities are primarily drawing exercises. It is therefore possible for team performance to be affected if one or more participants are more accomplished artists. A team comprising multiple experienced artists may be more likely to produce responses that score highly. Because of this it is important to establish if artistic ability poses a threat to validity. Note, responses are only assessed for what the actual response is and not the quality of the drawing itself. This means that if two dreams draw the same response but one is a better representation then they will both receive the same originality score.

Participants are asked to rate their artistic experience on an 8-point scale at the end of the test (see table 4.4). Each team's responses are combined to provide a single score of artistic ability out of a possible 24. These scores are then used to calculate the correlation between artistic ability and Originality, Elaboration, Total Actions or Time Spent Drawing.

Table 6.12 reports the Somer's d correlation between team artistic experience and originality. Somer's d is used because it provides a means of assessing the strength and direction of a correlation in non-parametric data such as Artistic Experience and Originality.

The Somer's d calculation returns only weak relationships. Only the relationship between Picture Completion Originality and team artistic experience returns a statistically significant value. However, this response is such a weak relationship that it is likely to have a negligible impact on results.

	Somer's d	Approx. Significance
Picture Construction	.201	.268
Picture Completion	.148	.022
Parallel Lines	.041	.428

Table 6.12: Relationship between team artistic ability and Originality score

Table 6.13 reports the Spearman rank-order correlation used to compare team artistic experience against Elaboration scores. Spearman's rho is used instead of

Pearson's correlation coefficient because the data used here is not normally distributed. Again, only weak relationships are reported and none of any statistical significance. There is no indication of a relationship between the artistic ability of a team and their elaboration scores. Suggesting that activities are evaluating the creativity of the team with little impact resulting from the artistic abilities of individual team members.

	Spearman's rho	Sig. (2-tailed)
Picture Construction	.148	.434
Picture Completion	.070	.308
Parallel Lines	-.10	.090

Table 6.13: Relationship between team artistic experience and Elaboration score

An analysis of the Spearman's rank-order correlation between total drawing actions of a team and their artistic ability (see table 6.14) reveals only a weak relationship during the Parallel Lines activity. This indicates that teams with a greater level of artistic experience actually perform fewer drawing actions. It is possible that this is an indicator of increased efficiency with more experienced artists making fewer mistakes when drawing. However, the reported Spearman's rho is so weak for this finding to be considered negligible.

	Spearman's rho	Sig. (2-tailed)
Picture Construction	.122	.521
Picture Completion	.018	.794
Parallel Lines	-.202	.001

Table 6.14: Relationship between team artistic ability and total drawing actions

A similar relationship exists in a comparison of the relationship between artistic experience and time spent drawing (see table 6.15). Once again, the only meaningful relationship is a weak relationship during the Parallel lines activity. This confirms the finding in table 6.14 that as artistic ability increased, the amount of time spent drawing decreased very slightly during the Parallel Lines activity.

	Spearman's rho	Sig. (2-tailed)
Picture Construction	.183	.333
Picture Completion	.080	.251
Parallel Lines	-.161	.006

Table 6.15: Relationship between team artistic ability and time spent drawing

To summarise, there exist only a handful of extremely weak relationships between artistic experience and number of drawing actions / time spent drawing. These are such weak relationships that it seems that artistic experience does not affect team performance in any significant way.

6.5 Does the amount that teams talk matter?

The findings in this chapter have so far concluded that teams perform the same regardless of location across a variety of activities. However, there is one anomaly, that co-located teams generally use more detail than their virtual team counterparts during the Parallel Lines activity. This is confirmed by not only the elaboration scores, but time spent drawing and number of drawing actions performed using the tool.

This section therefore sets out to explore this difference further by assessing the actual conversations that teams have as they complete the Parallel Lines activity. These are contrasted with the team interactions during the Picture Completion activity. This activity is used for comparison because it shares the largest number of characteristics with the Parallel Lines activity. In both activities teams are asked to produce original responses to multiple given prompts within ten minutes. However, teams are given 30 identical shapes during the Parallel Lines activity rather than 10 different ones (during the Picture Completion activity). Complete video footage of 10 co-located and 10 virtual teams has been transcribed.

Transcriptions can be coded to identify the way that teams interact. Speech-act theory [173] can be used to identify the interactions that occur within teams. Speech-act theory [173] suggests that utterances are used to perform actions. Speech-acts consist of two parts: the *illocutionary act*, that is what the speaker is trying to do with their utterance e.g., asking a question; and the *perlocutionary effect* which is the way that the listener responds. So, does the listener recognise that a question has been asked and do they then respond appropriately? By coding utterances in this way a picture can be built up of the way that interactions occur. The *sensegiving, sensedemanding* and *sensebreaking* actions identified by Vlaar et al. [6] from their study of distributed team sensemaking can then be assessed to understand where teams are using interactions consistently to develop meaning.

The first step in this analysis involves coding team interactions to identify the number of utterances used by teams in their interactions (see table 6.16).

Each instance where a participant talks is considered an utterance. This provides some insight into the amount of dialogue that teams use whilst completing these activities.

Co-located Teams			Virtual Teams		
Team Number	Picture Completion	Parallel Lines	Team Number	Picture Completion	Parallel Lines
6	161	183	18	217	163
7	86	60	19	67	80
8	117	120	21	166	158
10	209	207	22	105	75
11	39	60	23	189	136
12	75	109	24	113	93
14	209	175	26	61	126
15	302	253	27	79	142
16	11	14	29	118	146
17	167	138	30	89	83
Total	1376.00	1319.00	Total	1204.00	1202.00
Average	137.60	131.90	Average	120.40	120.20
Standard deviation	89.06	74.32	Standard deviation	53.22	34.10

Table 6.16: Number of utterances performed by teams

Figure 6.6 compares the number of utterances performed by each team during the Picture Completion and Parallel Lines activities. The chart suggests that co-located teams use slightly more utterances (Picture Completion total= 1376, Parallel Lines= 1319) than virtual teams (Picture Completion total= 1204, Parallel Lines= 1202) during both activities. However, a comparison using independent samples t-test indicates that these minor differences are not statistically significant. The independent sample t-test indicates no statistically significant differences between co-located and virtual team performance during the Picture Completion activity ($t(18) = .524, p = .607$) or the Parallel Lines activity ($t(12.629) = .452, p = .659$).

A further test reveals that both co-located and virtual teams use similar number number of utterances during both activities. I.e., co-located teams use 137.60 utterances on average during the Picture Completion test and 131.90 during the Parallel Lines test; this is not a statistically significant difference $t(18) = .155, p = .878$. Likewise, the virtual teams use 120.40 utterances on

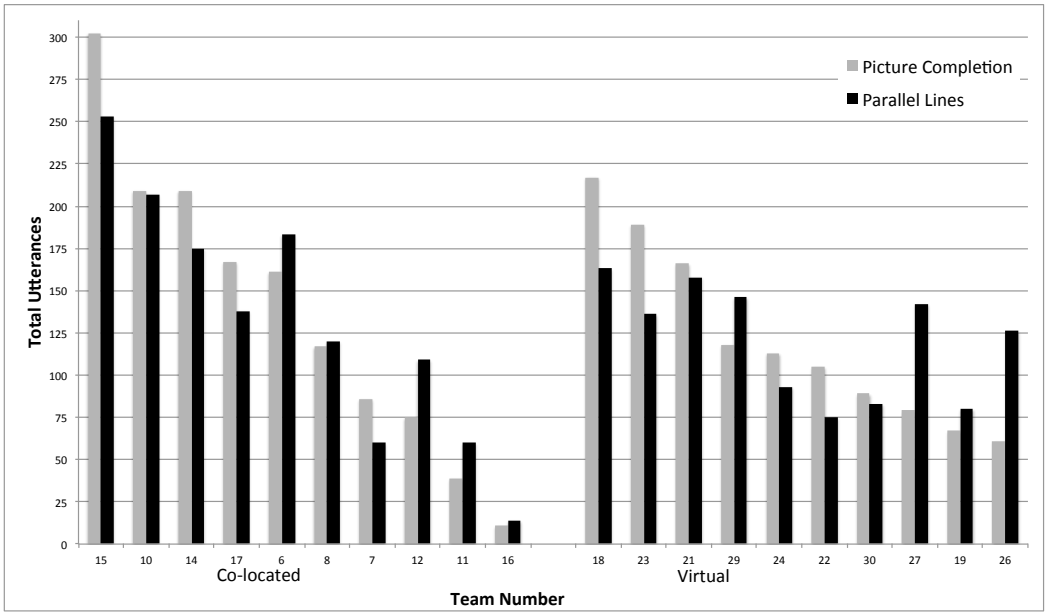


Figure 6.6: Comparison of total utterances performed by teams completing Picture Completion and Parallel Lines activities

average during the Picture Completion activity and 120.20 on average during the Parallel Lines activity. Again, this is not a statistically significant difference $t(18) = .010, p = .992$.

It appears therefore that co-located and virtual teams use almost the same amount of dialogue. And, more importantly that the amount of dialogue during the Parallel Lines activity is no different to that during the Picture Completion activity. Unfortunately this does not provide any further insight into why virtual teams put less detail into their Parallel Lines responses than their co-located peers.

Figures 6.7, 6.8, 6.9 and 6.10 explore whether there are any other possible correlations between the number of utterances and performance metrics. It is possible that the number of utterances has an impact on team originality, elaboration, fluency and total number of actions performed. However, these figures indicate no correlation between any of the performance metrics and number of utterances. This is further confirmed by the Spearman's rho calculations reported in table 6.17.

	Picture Completion	Parallel Lines
No. utterances vs Originality	$r_s = .112, p = .639$	$r_s = .176, p = .458$
No. utterances vs Elaboration	$r_s = .104, p = .663$	$r_s = .191, p = .420$
No. utterances vs Fluency	$r_s = .185, p = .454$	$r_s = .280, p = .232$
No. utterances vs Actions	$r_s = .290, p = .214$	$r_s = -.105, p = .659$

Table 6.17: Spearman's rho indicating strength of relationship between total number of utterances used and key performance metrics

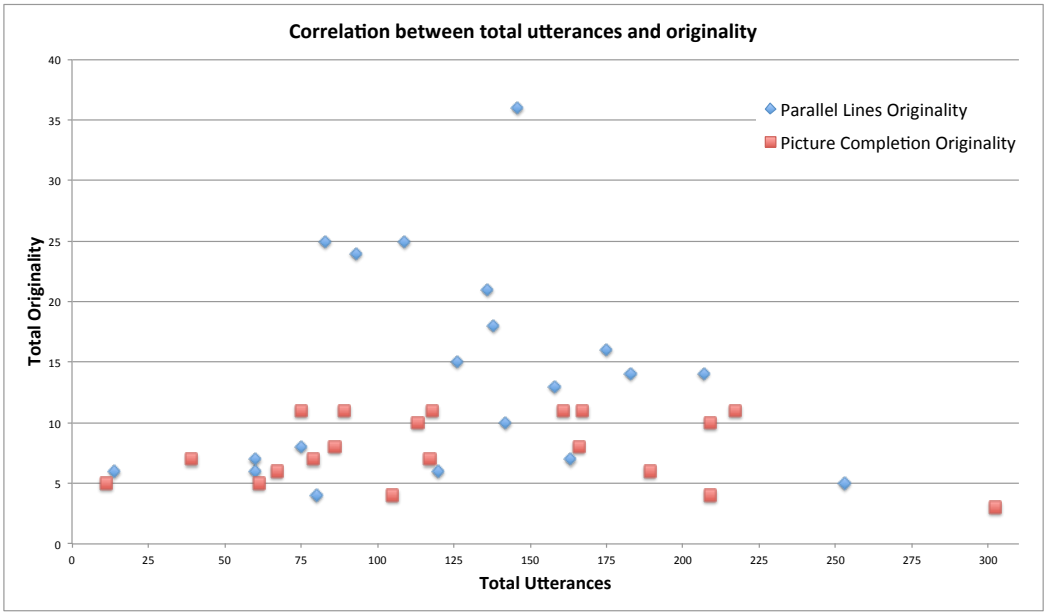


Figure 6.7: Comparing total utterances with total originality scores

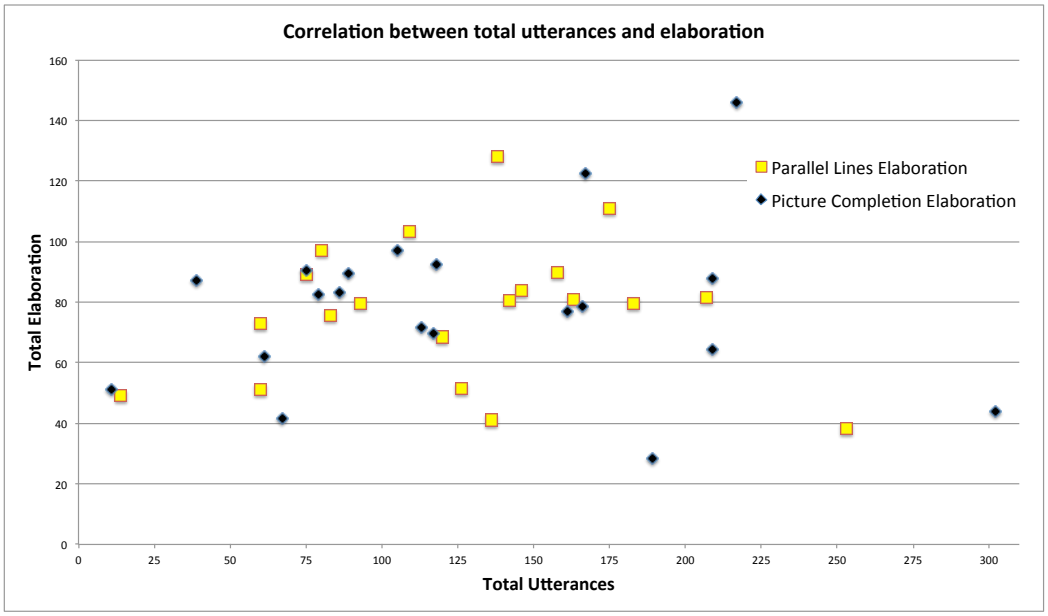


Figure 6.8: Comparing total utterances with total elaboration scores

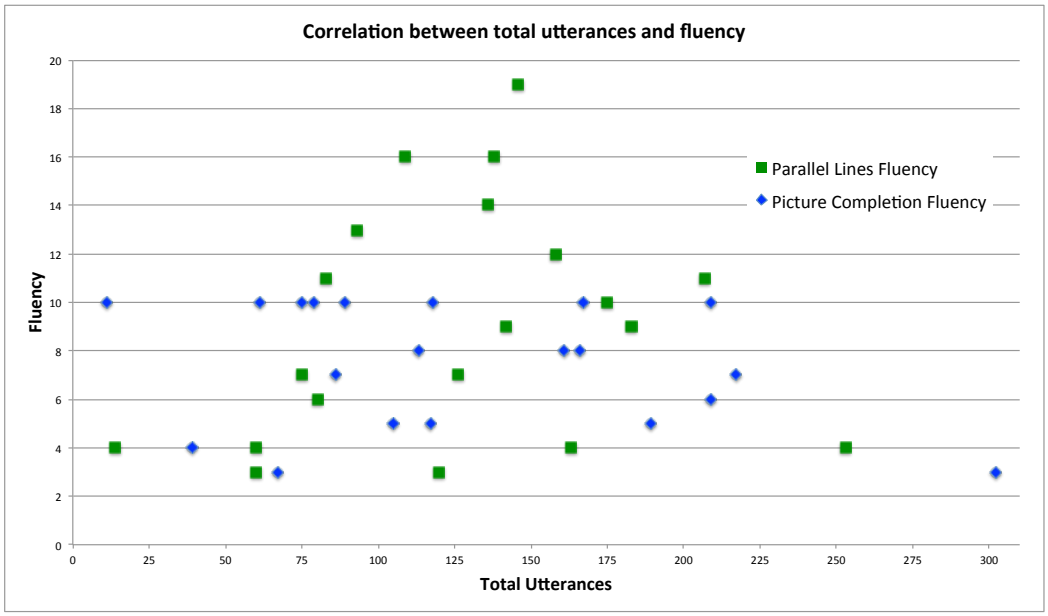


Figure 6.9: Comparing total utterances with fluency

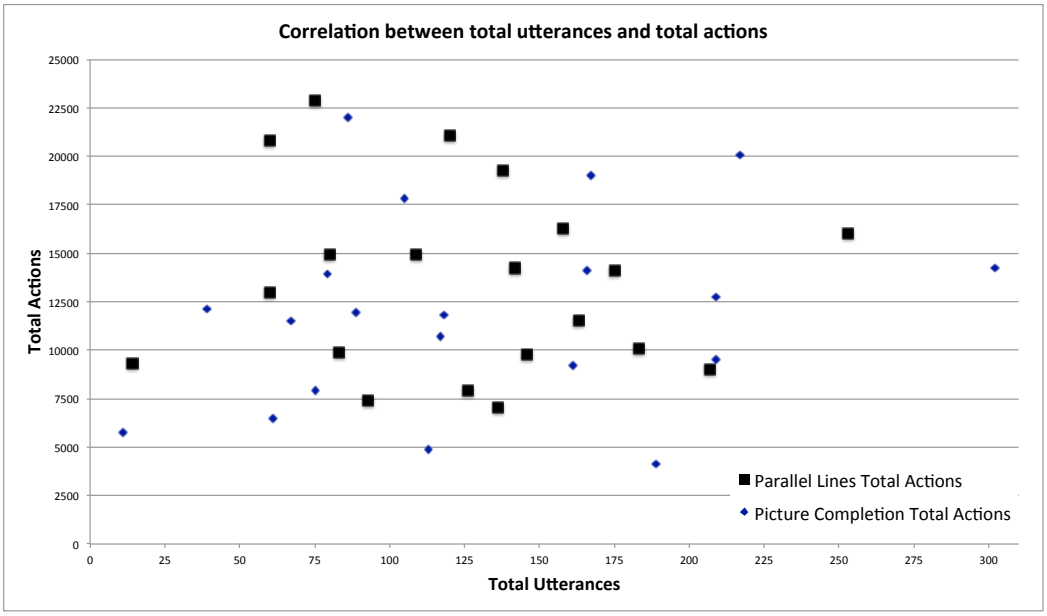


Figure 6.10: Comparing total utterances with total number of actions performed by teams using tool

The logical next step in this analysis is to explore what the teams are discussed using speech-act theory [173] and Vlaar et al's [6] *sensegiving, sensedemanding* and *sensebreaking* characteristics. However, this is problematic because it appears that these activities were not sufficiently complex to stimulate extensive dialogue. Yes, teams do talk but the majority only use dialogue to coordinate their drawing. Very few teams actually spend time considering what the most original response to a shape would be despite instructions to do so. Most teams use a leader-follower approach to complete these drawing activities. Here is an example taken from Team 18's dialogue during the Picture Completion activity:

Participant 2: Try to think of something really imaginative.

Participant 2: Does it have to be a drawing of something?

Participant 1: No

Participant 1: a window, I know it's obvious a window but..

Participant 2: Ok, has it got a balcony this window?

Participant 1: yeah

Participant 2: ok

Participant 3: Maybe there's some hanging baskets beneath that balcony Participant 2: Yeah, what is that?

Participant 3: It's supposed to be a hanging basketit's not that good.

Participant 3: Ah ok, I'll put some like flower in there

Participant 1: Oh yeah, I see it see it now. So you are looking outwards. Participant 1: Yeah

Participant 2: So maybe there's some mountains in the background

Participant 1: Oh yeah

Participant 2: Because there's always mountains.

This means that teams wait until someone either makes a suggestion or until someone starts drawing and then the rest of the team joins in. In these instances

there is no consideration of other ideas. For the most part it appears that teams have prioritised the need to complete as many of the drawings as possible above the need to produce original responses. This is a tension in the design of the activities deliberately put in place by Torrance [155]. However, this tension appears to be perpetuated by the team environment. Especially one with new teams where individuals may feel unable to raise the issue of generating more ideas.

6.6 Chapter Summary

This chapter reports on the study into the differences between co-located and virtual team creativity. Thirty seven teams completed the study using the CreativeTeams tool, with 30 teams (17 co-located, 13 virtual) producing reliable high quality data that has been analysed in this chapter.

The CreativeTeams tool itself is an adaptation of Torrance's [155] paper based creativity test for individuals. I have then adapted this test into a team format and worked with developers to turn this adaptation into a synchronous digital testing platform. I designed, tested and re-designed the various iterations of this platform to arrive at the current CreativeTeams tool. This research ultimately sets out to address research question 1: *" Do virtual or co-located teams perform creative tasks better? "* by comparing various performance metrics for the co-located and virtual teams. The findings in this chapter assess the TTCT data gathered during the Picture Construction, Picture Completion, Parallel Lines and Alternative Uses activities.

The first section of analysis in this chapter explores and compares the creative performance of teams in terms of Originality, Elaboration, Fluency, Number of drawing actions and Total time spent drawing.

A comparison of Originality scores reveals no statistically significant differences in co-located and virtual team performance.

Comparing the Elaboration scores of co-located and virtual teams reveals no statistically significant differences in performance during the Picture Construction and Picture Completion activities. However, the Mann-Whitney U calculation does return statistically significant results for teams completing the Parallel Lines and Alternative Uses activities. This result is verified by Independent Samples T-Tests.

This finding is unexpected, there is no obvious reason why elaboration performance should differ for only the Parallel Lines and Alternative Uses activities. There is no immediate indication of why virtual teams should address the Picture Construction and Picture Completion activities in a similar manner to co-located teams, but address the third drawing activity (Parallel Lines) differently. The

Alternative Uses elaboration data is on reflection found to be of limited use and is consequently dropped for further analysis (see section 6.2.2).

An analysis of Fluency scores suggests that there is no difference in the number of drawings completed by teams regardless of location.

The meta data provided by the tool goes on to support the findings above, Namely that there is no difference in the actual use of the tool for the Picture Construction and Picture Completion activities, but that co-located and virtual teams do interact with the tool differently during the Parallel Lines activity.

In conclusion, this chapter has established that teams can consistently complete the adapted version of the TTCT, and that the TTCT scoring method can still be applied to outputs produced by teams (despite differences in popular culture). This study has also revealed that co-located and virtual teams have similar creative performance in most activities. However, they seem to perform the Parallel Lines activity differently. The difference in performance is established not just in the elaboration scores given by markers but also by analysis of the drawing actions generated by interactions with the tool itself. There is no clear indication of why teams complete the Parallel lines activity differently (in comparison to the Picture Construction and Picture Completion drawing activities) despite exploring a range of other factors including number of utterances used by teams, number of actions performed and time spent drawing.

Chapter 7

Discussion

The previous chapter evaluated and contrasted the performance of co-located and virtual teams as they completed a series of team creativity tasks using the CreativeTeams tool. This chapter features a discussion of both the CreativeTeams tool and of the resultant study; both are key research contributions. The CreativeTeams tool provides a method of addressing the primary aim of this research. That is, to explore and highlight differences in the performance of co-located and virtual teams. The study then explores the impact that these two environments (co-located and virtual) have on complex team socio-cognition [174] and more specifically team creativity.

This research is motivated by the practical need for organisations to adopt virtual working, to reduce environmental impact from unnecessary commuting, improve employee work-life balance and to enable the formation of highly specialised teams from the global labour market. The CreativeTeams tool and study serve as a first step in establishing a field of research comparing these two very different environments objectively, such that a wider conversation can develop to help organisations adopt this means of working.

The chapter is structured in four sections: Firstly I review the research questions, then the key contributions from this research, threats to validity and a section reflecting on the study. I have specifically chosen to keep the threats to validity and reflections sections separate, the former to focus on a critique of

the study design and the latter to consider the interpretive implications of the approach.

7.1 Research questions revisited

The research described in this thesis has addressed the following research questions:

Research Question 1 Do virtual or co-located teams perform creative tasks better?

The study described in this thesis has compared the relative performance of co-located and virtual teams as they complete the TTCT Figural and Guilford's Alternative Uses test. The analysis indicates that there is no significant difference in terms of creative performance between either environment.

RQ 1.1 Can the TTCT be adapted to be used with teams? The development process described in section 4.1 outlines how I was able to adapt the TTCT into a format suitable for teams, testing the adaptation using paper prototypes. This demonstrates how the TTCT can be adapted to be used by teams. The study itself serves as further evidence to support this claim with no teams reporting any problems with the activities.

RQ 1.2 Can an adaptation of the TTCT be developed for use by both Virtual and Co-located teams? The CreativeTeams tool provides compelling evidence that the TTCT can indeed be adapted first to be used by teams and then further developed into a digital form enabling both co-located and virtual teams to collaborate on these tests. The consistency of the data produced by multiple teams further supports this claim that the adaptation is successful.

RQ 1.3 Can a digital form of the TTCT be designed to provide co-located and virtual teams with identical experiences? Key to the development of a collaborative form of the TTCT is the need to provide a user experience that emulates both the affordances of the paper based TTCT and also supports creative interactions. The CreativeTeams tool has been specifically designed to support these affordances, such that the

tool provides a good adaptation of the paper-based TTCT and also supports the underlying creativity. In doing so the tool ensures that co-located and virtual teams have exactly the same experience whilst using the tool, enabling the tool to provide a reliable comparison of the two environments.

7.2 Key Contributions

The key contributions in this thesis consist of two parts: The CreativeTeams Tool itself and the study.

7.2.1 The CreativeTeams Tool

The CreativeTeams Tool itself makes a number of important contributions to Creativity Science and Psychology research.

The initial prerequisite work adapting the TTCT from a test for individuals into a test for teams represents a contribution to the ongoing work on creativity measurement within Psychology and addresses RQ 1.1. Torrance noted that the test should in theory be applicable to teams [154] but never made the adaptation himself. Such a contribution is useful for the ongoing research that uses Torrance's test. Hopefully it will also serve to prompt a discussion within this area around how best to measure the Creativity of Teams; as this remains an understudied area, especially within Psychology.

The CreativeTeams tool takes this adaptation further by placing these activities within a platform that enables teams to complete the test from any location. The platform seeks to minimise boundaries to access by providing a simple synchronous drawing interface that mimicks drawing on paper by using iPads and digital pencils [161]. The lack of existing tools suitable for this purpose (see section 4.2) means that I have had to design, prototype and extensively test the CreativeTeams tool working with student developers at Lancaster University and The University of Auckland.

The extension of the adapted form of the TTCT into the fully fledged CreativeTeams tool addresses RQ 1.2 and represents a key contribution to Creativity Science. The tool contributes to the literature on the measurement of creativity. I have taken a widely used paper-based tool and not only extended it to be used with teams but also with virtual teams. Such an extension is extremely useful to both Creativity Science and Psychology researchers in this field, enabling them to explore other aspects of creativity and socio-cognition.

The tool is beneficial to the area of Creativity Science concerned with the development of new tools and methods. Researchers in this area could utilise the tool as a means of benchmarking and evaluating new tools and techniques. For example, it could be used to demonstrate how one form of video conferencing encourages creativity over another. Such a benchmarking tool would be useful for evaluating the wide range of tools that seek to improve virtual team collaboration.

The organisational framing of creativity represents another contribution to the area of Creativity Science. Little work to date has sought to explore the organisational perspective of creativity in particular. Given the importance of organisations I feel that this framing is an important contribution to this area, a prompt to ensure practical contributions are made.

The tool provides a platform to study a wider range of creativity-related interactions beyond the six activities included. The fact that the tool provides creative prompts (activities) and records the actual drawing process as teams address the activities means that it can be used to study a wide range of interactions and HCI aspects for improving our understanding of creativity and the design of creativity support tools.

The CreativeTeams Tool also extends the TTCT further by providing additional metadata on the drawing process (e.g., time spent drawing and number of draw/erase/undo/redo actions), which help to provide a further level of analysis. Such data opens news avenues for researching creativity both within Psychology and within Creativity Science. Analysis of metadata describing interactions provides an entirely new way of considering creative collaboration.

The analysis of dialogue during the study further extends the TTCT. Whilst the TTCT Verbal tests do analyse a form of verbal creativity, they are only applicable to individuals. The method of analysis used in this thesis therefore offers a first attempt at exploring the relationship between the dialogue of teams completing this test and creativity. The application of linguistic theory to assess socio-cognitive behaviour provides a demonstration of a new method that may prove valuable for other Creativity Science researchers.

The CreativeTeams tool provides a means of directly comparing the performance of co-located and virtual teams. This addresses the lack of research comparing the two environments as noted by Lopez and Guerrero [92]. This is a major contribution to Creativity Science literature as no previous work has been able to effectively compare the performance in the two environments. Such a contribution should help to foster further the dialogue around what virtual teams are capable of alongside discussion of how they can best be supported by tools and techniques.

The design of the tool to replicate the specific affordances of the TTCT expands the work within Creativity Science that has explored how to measure creativity. It demonstrates that traditional paper-based tests can be reproduced along with their specific affordances and used to evaluate the complex interactions associated with creativity. This opens the door to the wide array of Psychology and Creativity Science methods that explore creativity via paper-based approaches but that could be adapted to explore new environments.

Comparisons between teams using the tool and teams using the paper prototypes suggest that there is no difference in the way that they use the tool. Indeed, if anything the tool increases team participation because each team member has their own iPad to work on. Team members can therefore all access the drawing space simultaneously. I am therefore confident that the CreativeTeams tool provides a valid adaptation of the Figural aspects of the Torrance Tests of Creative Thinking.

The data gathered during the study provides evidence of the success of this adaptation. The fact that multiple markers have been able to score the outputs from this test consistently according to Torrance's [8] guidance suggests that results are being produced in line with Torrance's expectations.

Ultimately the CreativeTeams tool represents a key novel contribution because there are no other tools at present that measure team creativity, let alone virtual team creativity. The tool incorporates a number of additional activities, as suggested by interviews with experts and in accordance with Kim's [9] extensive review of TTCT. It provides a repeatable approach that produces consistent results and is applicable to virtual and co-located teams alike. This not only contributes to the discussion on measuring creativity within Psychology but makes a valuable contribution to the practitioner community within Creativity Science who can use the tool to help inform the design of future creativity support tools.

7.2.2 The Study

The study run as part of this thesis (and discussed in chapter 6), explores the differences between co-located and virtual teams creativity.

The main finding from this study is that the performance of the treatment group (virtual teams) does not significantly differ from that of the control group (co-located teams). Such a finding enables me to address research question 1: "Do virtual or co-located teams perform creative tasks better?". This finding is confirmed by a statistical comparison of the treatment and control groups across a range of metrics. This is a significant contribution to both Psychology and Creativity Science because it represents the first empirical comparison of co-located and virtual team creativity.

The Originality scores provide an indication of the novelty of responses. This is the most important metric because creativity is synonymous with the development of new things. It is therefore highly significant that there is no difference between the Originality scores of co-located and virtual teams across Picture Construction, Picture Completion, Parallel Lines and Alternative Uses activities. Such a finding contradicts many of the opinions expressed by the practitioner and academic communities [175, 176, 177, 178] who argue that virtual working can never perform as well as traditional co-located teams. More importantly this finding serves to support the work started by Girotra et al. [174] that argues that virtual teams are capable of complex socio-cognitive processes equal to co-located teams.

The Elaboration scores provide an indication of the level of detail in the drawings, and for the most part these scores demonstrate no discernible difference between co-located and virtual team performance. However, there are two activities during which co-located and virtual team performance differs: the Parallel Lines and Alternative Uses activities. The latter is highlighted by Torrance [8] as potentially problematic due to the application of the elaboration scoring technique to text responses. Torrance [8] notes that because of this reason it is often better to treat this as an optional and sometimes unreliable metric. It seems sensible therefore to dismiss the Alternative Uses data as unreliable.

However, the difference in co-located and virtual team Elaboration scores during the Parallel Lines activity remains anomalous. Further analysis has been carried out to try and understand why this difference occurs. First of all the meta data generated by the CreativeTeams tool has been assessed. This data confirms that virtual teams actually use fewer touch interactions and spend less time drawing when completing the Parallel Lines activity than their co-located counterparts. The amount of dialogue used by teams during this activity was then assessed to see if there was any difference in their verbal interactions. The number of utterances used by co-located and virtual teams was compared and no difference found. This suggests that co-located and virtual teams talk just as much despite putting in differing levels of detail into their responses. Furthermore, no difference is found in the number of utterances used when comparing dialogue during the Parallel lines activity with dialogue during the Picture Completion activity. This indicates that teams use the same level of interactions regardless of activity.

These contrary findings provide no clear indication as to why the teams should perform so differently in terms of the level of detail in drawings during the Parallel Lines activity when the same teams perform so consistently in the other activities. My hypothesis is that this particular activity does not adapt as well to the team environment as the others. This theory is based on my reading of the teams transcripts, during which it becomes apparent that many teams find the activity boring, repeatedly having to generate responses to the same starting shape. Indeed, some teams actually comment "Creativity requires inspiration" during this activity. The majority of teams completing the parallel lines activity also obsess about the need to complete as many of the possible 30 shapes as possible, in contrast with aiming to complete fewer responses but in more detail. Torrance [155] specifically designed this activity to create this tension but it is possible that it is compounded by the team environment. This is one explanation. However it still doesn't explain why the virtual teams put less detail into their drawings and yet still get the same Originality scores, which are arguably a more important indicator of creative performance.

In conclusion I am therefore unable to attribute a cause to the difference in these elaboration scores. It is an interesting outlier in the broad set of data

that otherwise indicates no difference between co-located and virtual team performance. This anomaly may be an indication that there are significant differences in performance that aren't reflected in the other metrics, it may be an indication of a problem with the implementation of this aspect of the tool (although no teams reported it as such), or it may be that the data itself is problematic. This represents a key opportunity for future research to explore whether this problem is repeatable, or to adapt the current activity and see if the trend remains. I would suggest changing the instructions given to teams and the removal of the visible canvas count during the activity as this seems to cause the most tension in teams. It is possible that such a simple tweak may remove the pressure to complete of as many of these drawings as possible that teams exhibit, hopefully increasing the reliability of this measure.

The study therefore results in two important findings. Firstly the study provides a strong indication that co-located and virtual teams perform similarly throughout the majority of the activities in the test. Secondly, there is an unexplained anomaly in the analysis, that co-located teams and virtual teams put significantly different levels of detail into their drawings during the Parallel Lines activity only.

These contributions and findings are significant for a number of fields. First of all, this is the first team study completed using a digitised team form of the Torrance Tests of Creative Thinking [8], and it therefore represents an important contribution to the area of Psychology research concerned with understanding and measuring creativity. In particular it builds on the work of Kim [9] who critiques the TTCT, ultimately concluding that it remains relevant but will require adaptation. Secondly, this work provides an important trigger for dialogue within the management and practitioner community about what virtual teams can achieve. In particular it provides a repeatable quantitative analysis of team performance in the two main work environments typically employed. Finally, this contribution should have a meaningful impact in the computer science community, providing an indication that virtual teams are capable of complex socio-cognitive processes above and beyond arduous development work.

7.3 Threats to validity

Inevitably with such a complex tool development and study there are multiple threats to validity. In this section threats to validity are discussed pertaining to either the CreativeTeams tool, or to the related study.

7.3.1 The CreativeTeams Tool

There are multiple threats to the validity of the CreativeTeams tool.

1. External threat: Generalisation. Does CreativeTeams actually measure creativity? Such a question is impossible to address with any certainty because there is no agreed definition of creativity, and no alternative measures of team creativity available for comparison. Taking these points into consideration the CreativeTeams tool currently provides a repeatable means of assessing novel and divergent thinking in teams.

2. External threat: Replication. Is the adaptation of the Torrance Tests of Creative Thinking [8] successful? That is, does the CreativeTeams adaptation actually provide a comparable measure of creativity to the original TTCT? Unfortunately it is impossible to know the answer to this question. Torrance based his work on the creativity of individuals, it is therefore impossible to compare any of his data with that gathered herein. I would argue however that the tool provides as near an imitation to the original paper based tool as possible. Working on iPads provides users with a simple shared canvas and practice time with the tool is provided to ensure participants understand how to use the tool. The CreativeTeams tool therefore provides a fair adaptation.

3. External threat: Replication. Not all of the Torrance Tests of Creative Thinking are included in the CreativeTeams tool. Whilst the tool does provide a good adaptation of the TTCT Figural activities it neglects the verbal part of the tests. The problem with a full adaptation lay in the nature of the verbal tests. The verbal tests ask individuals to list aloud responses

to a series of prompts. The CreativeTeams tool includes an adaptation of one of these activities - the Alternative Uses activity. However, I was unable to adapt the other two verbal activities because the original visual prompts that Torrance [155] based his work on were not available. That is, the original images that Torrance gave to his participants as prompts were not included in the Norms-Technical manual, nor in the copies of the scoring guides that I was able to access. Future work should therefore work to find a means of accessing versions of these activities and include them within the CreativeTeams suite to provide a fully digital collaborative form of The Torrance Tests of Creative Thinking.

4. Internal threat: History effect. Does the age of Torrance's [8] scoring guide affect the validity of the data? The problem being that Torrance's [8] scoring guide is based on the common responses produced by individual participants some 40 years ago. This introduces a problem for scoring because many teams produce responses that refer to contemporary popular culture. For example, many teams draw Harry Potter in response to one of the Picture Completion starting shapes that looks like a lightening bolt. In the current context this would not be considered an original response deserving a low originality score. However, Torrance's [8] scoring rubric does not include Harry Potter, and therefore this is given the maximum originality score. The risk here is that contemporary responses that aren't original actually skew the data, providing false interpretation of the data. To investigate the possible impact I repeated the Mann-Whitney U analysis with a data set that excluded all responses given high scores simply due to not being on Torrance's list (see table 6.3). The Mann-Whitney U results indicate that there remains no difference between co-located and virtual team originality. This demonstrates that the use of the older scoring rubric therefore seems unlikely to have a major impact on the analysis of Originality scores. However, future versions of the test should incorporate the development of a new rubric to increase the accuracy of scoring.

5. Internal threat: Activity design. The Design Challenge and Design Questions activities were meant to supplement the adapted TTCT activities.

On reflection, it appears that both activities were flawed despite a series of prototyping stages. The activities were meant to challenge teams to demonstrate scenario-based creativity and in particular to demonstrate creative dialogue. However, during the study teams interpreted the instructions too broadly, producing responses that were so varied as to be impossible to compare. Teams were asked to generate new and novel chair designs for use at music festivals and for hiking. Teams produced a wide variety of designs from regular folding chairs through to futuristic flying chairs. The main problem being that teams recorded their designs very differently (see examples in appendix A). Most used the drawing environment to aid their conversations. This meant that some teams have produced meaningful static drawn outputs that can be analysed, whilst others have used the tool only as an aid to dialogue. Such teams drew very little instead using their dialogue to express their creativity. Such variation in how teams have approached the problem is fascinating, however it is highly problematic for analysis. As such, the data gathered from this activity was excluded from further analysis in this thesis. Future versions of these activities will need to have more specific instructions so that teams approach the activity consistently.

6. Internal threat: Maturation effect. There is a risk that teams could be affected by either learning or fatigue effects. That is, if all teams completed tests in the same order then teams may become more familiar with the type of activity or tool and consequently perform better in later activities. Teams may encounter team fatigue due to the length of the test and perform worse in later activities. Either would skew results. This risk is negated by presenting teams with the tests in a random order. As such, no two teams out of our sample of 37 completed the activities in the same order.

7.3.2 The Study

The study itself introduces a number of possible threats to validity, with several pertaining to participant selection and team formation, and others relating to the scoring of outputs.

1. External threat: Generalisability. The decision to use teams of three participants is a limitation of these findings. However, such small teams had to be used for pragmatic reasons, namely increasing the likelihood of being able to recruit enough participants to produce a sufficiently large sample size of teams. Ideally future studies would use a variety of team sizes to explore the relationship between creativity and team size.

2. External threat: Selection bias. Recruiting from the student population. Student participants are far less experienced at working in teams and therefore may not be representative of the majority of established professional teams. It is for this reason that I decided to concentrate on newly formed teams, actively forming teams where participants did not know each other. This has the added benefit of enabling this research to focus entirely on the creative processes of teams without established Transactive Memory Systems [174].

3. External threat: Selection bias. Limitation of participant experience. Recruiting from the student population introduced problems during prototyping. Student teams were unable to complete more realistic scenario based activities. I would hypothesise that this is because students generally have little work experience. This factor motivated the move from the search for a realistic scenario-driven creativity activity for teams to complete towards the more abstract Torrance Tests of Creative Thinking [8]. However, this in turn has the benefit of making the CreativeTeams tool suitable for studying almost any group of interest, regardless of background or experience.

4. Internal threat: Selection bias. The Torrance Tests of Creative Thinking [8] are heavily reliant on participant drawing. As such, it is possible, and even likely, that participants with a greater propensity for drawing may produce more artistically accurate responses, thus potentially skewing their teams scores. In order to take this into account participants were asked to evaluate their own artistic experience on a scale. These values were then compared with their team's scores to see if artistic experience introduced any bias to the scoring. The results in section 6.4 suggest not.

5. Internal threat: Experimenter bias. The scoring of the Picture Construction, Picture Completion, Parallel Lines and Alternative Uses activities is also problematic. Not only is there the problem that the test is 40 years old as previously highlighted, but there is a risk that outputs are not scored consistently, without Torrance's [8] extensive experience. Multiple markers were therefore used in order to negate the risk of inconsistent marking. The markers demonstrated a high level of inter-rater agreement when using Torrance's [8] scoring guides.

6. Internal threat: Confounding. The majority of the analysis indicates no difference in the performance of co-located and virtual teams. However, there is a difference in the performance observed during the Parallel Lines activity in the elaboration scores and related drawing meta data. This finding is contrary to the majority of other trends identified across a wider range of activities and data. In order to explore this threat further the dialogue of the teams themselves was analysed and contrasted with that of teams completing the most similar activity - Picture Completion. No significant differences were found in the quantity of dialogue that teams used in either activity, nor was there any difference in the level of verbal interactions used by the co-located and virtual teams. As it stands this threat must be treated as an anomaly. It is possible that the Parallel Lines activity is not suitable for completion by teams. Further research will need to be completed to understand this difference.

7. Internal threat: Compensation rivalry. There is a risk that the virtual teams actively work harder because they feel they are at a disadvantage in comparison to their co-located counterparts. However, this is not something that I have witnessed during the study. Furthermore, there is no difference in the number of utterances used by co-located and virtual teams during both the Parallel Lines and Picture Completion activities. As such, it seems unlikely that the virtual teams actively work harder.

7.4 Reflections on the study

This thesis has asked teams of students to complete the same series of creativity activities within either a co-located of virtual environment. The outputs of these activities are then assessed to provide an indication of the creative performance the teams exhibited. Both the nature of the study, the scoring of outputs and the method of analysis rely on interpretation and co-creation of information.

The testing procedure asks teams of strangers to work together on a deliberately abstract series of activities. These are specifically chosen because participants will not have encountered them before and so all participants should have an equal footing in starting them. However, this assumes that all teams get along as well as others. This is a potential weakness in this approach with some teams readily bonding and sharing a lot of dialogue whilst others failed to participate to the same extent. This variation in the extent to which teams bond ultimately affects the way that they complete the activities.

My own involvement in the study process will also have had an impact on the data gathered. At the beginning of each session I spent around ten minutes with each team explaining ethics paperwork to them and introducing the core concepts of the game. I sat around as they completed the practice area activity and answered any questions they had. I was also available to answer any questions during the game although this rarely happened. It is possible that my interactions with the teams may have given some teams an advantage or insight into the test.

The use of multiple markers represents another key point where understanding is co-created and where limitations to this research may arise. It became apparent as the markers completed their test scoring that they had very different views of the what constituted creativity despite being able to follow Torrance's scoring criteria relatively consistently. This motivated the inclusion of the additional marker creativity scoring. Could the three of us ever score creativity consistently using our own definitions of creativity? Ultimately the answer was no, but it served as a valuable confirmation of the overarching complexity of creativity, that it is almost impossible to define, even when we (the markers) had worked together specifically to discuss what constituted creativity.

The designing of the tool itself has also been heavily influenced by social interactions. The initial conceptual idea is the result of discussions with supervisors and the development of the tool itself and much of the emergent functionality stems from interactions with developers and testers. In this way, the core mechanism in this research is socially constructed.

Ultimately this research studies a phenomena that is socially constructed, as is the study, and tool developed for the study. It is important to understand this because it means that all of the aforementioned findings are ultimately applicable within the context in which they were situated.

7.5 Summary

This chapter has highlighted the key contributions that stem from this thesis:

1. The adaptation of The Torrance Tests of Creative Thinking from a test for individuals into a test for teams.

2. The creation of the CreativeTeams platform including the adapted TTCT that enables completion of these activities by teams collaborating from any location.

3. The first study to compare co-located and virtual team creativity, indicating no difference in creative performance.

These represent important contributions to the area of psychology concerned with the measurement of creativity and the wider emergent field of creativity science. They are also important prompts for a wider discussion about the adaptation of virtual working practises within organisations and the practitioner community. This chapter also discusses key threats to validity pertaining to the tool itself and study, including discussion of how these threats were mitigated or how they should be addressed in future work. Finally, I have reflected on the overall study and the extent to which findings and the CreativeTeams tool itself are socially constructed.

Chapter 8

Conclusion and Future Research

In this thesis I have discussed the need to understand the differences between the way that co-located and virtual teams are creative. In particular there is a shortcoming in the existing Psychology, Management and Computer Science literature pertaining to the way that virtual teams handle complex activies. This work has been motivated by the continuing confusion and reluctance of many organisations to adopt virtual working practises, despite the numerous benefits that they afford. Key to this hesitation is the widely held belief that virtual teams cannot complete complex socio-cognitive processes such as designing and problem identification as well as traditional co-located teams. This thesis therefore sets out to compare as objectively as possible the performance of virtual and co-located teams as they complete a number of creativity activities. Creativity is chosen because of its inherent complexity - there is no clear definition and no established methods of best practice. Teams completing creative tasks are therefore entirely reliant on their sensemaking skills in order to share information and collaborate toward their goals.

I have therefore worked first to adapt an established method of measuring creativity (the Torrance Tests of Creative Thinking [8]) from a test for individuals into a team format. I have then worked to specify, design and test the creation of the CreativeTeams tool. This is a testing platform that enables teams to complete a series of shared creativity activities in a synchronous digital environment. This platform means that team members can collaborate to complete the test from any

location. This in turn means that I am able to ask both co-located and virtual teams alike to complete the same series of activities. The only variation in these instances is the means of communication.

I have run a study in which 37 teams of three participants each completed the CreativeTeams activities. Teams consisted of students recruited from the student populace and placed purposely into teams that did not know each other. This was to study newly formed teams in particular. Teams completed the activity in either a controlled co-located environment - that is, a meeting room, or in a virtual team environment, where each team member was placed in a different meeting room and provided with video conferencing in order to collaborate with the rest of the team. A comparison of both the different teams' activity outputs and verbal interactions was then completed.

The outcome of this study enables me to answer research question 1: "Do virtual or co-located teams perform creative tasks better?" by stating that (within the context of this study) co-located and virtual teams perform equally according to the majority of metrics generated. It has to be noted that there is one anomaly that I have not been able to explain, that teams put different levels of detail into their drawings during one particular activity (Parallel Lines). However, despite this, the majority of the data supports the finding that there is no difference between co-located and virtual team creativity. To the best of my knowledge this represents the first time that such a comparison has occurred.

This finding builds on previous work by Girotra et al. [174] who demonstrated that virtual teams can establish Transactive Memory Systems in the same way as co-located teams by demonstrating that virtual teams are as creative as co-located teams. This finding is important because it has practical implications for organisations, i.e., everyone understands what creativity is and why it is important.

Furthermore this thesis represents a key contribution to the area of Psychology concerned with studying creativity. Building both on Torrance's established work, whilst taking into account the suggestions raised by Kim [9] results in a platform that can be developed further into a research tool for future studies.

8.1 Future Research

Future research will need to address a number of weaknesses and opportunities raised in this thesis.

- The adaptation of the TTCT needs to be verified to confirm that both individuals and teams produce results that adhere to Torrance's [8] research. Closely related to this is the need to develop a scoring rubric that reflects modern team responses in contrast to Torrance's [8] 40 year old rubric for individual responses. This could be done by gathering data from a large number of teams and then identifying the most common responses generated, as per Torrance's [8] instructions. This would provide a far more accurate measure of originality in teams.

- The Elaboration scoring anomaly that occurs during the Parallel Lines activity needs to be assessed further. There are two obvious approaches to this: one, run the test with a wider range of teams and see if the trend continues. Two, change the activities instructions or user interface (e.g., remove indicator of screens remaining), rerun the study and see if the trend remains.

- There is a need to include a wider range of creativity metrics and activities within future iterations of the CreativeTeams platform in order to provide information on other aspects of creative performance. The current iteration of the CreativeTeams tool has only produced reliable data from the activities that are derived from the TTCT: Picture Construction, Picture Completion, Parallel Lines and Alternative Uses. The Design Challenge and Design Questions activities in their current form were not found to produce reliable enough data.

- The CreativeTeams platform should be developed so that it can be utilised to study a wider range of teams. In particular a variation of the tool should be adapted for studying the creativity of asynchronous teams. These are teams that collaborate globally but who, often because of time differences,

rarely work at the same time. However, to do so would mean developing new metrics for assessing team creativity. Such research into asynchronous team creativity would be especially valuable as this is a highly under-researched area.

- A variety of team factors could be altered to explored:
  - The size of teams could be varied. Such a study would provide a valuable addition to the ongoing discussion within management research about the ideal team size. It would be fascinating to see if there is a similar decrease in creativity as team size increases to that observed in team productivity [163].
  - Team background could be varied. For example, academic teams could be compared with teams from industry. There is an opportunity here to contrast what are traditionally considered to be highly creative teams, such as artists, with notionally less creative teams such as scientists.
- The CreativeTeams tool has only been used with virtual teams collaborating via video conferencing. Further studies could vary the communication tools used enabling a form of benchmarking of communication tools. Benchmarking in this way would help organisations to identify methods of best practice for running creative virtual teams.
- Finally, the CreativeTeams tool could be re-developed to improve overall usability. There is also the opportunity to re-design the platform to work across a wider range of devices.

8.2 Concluding Remarks

To conclude, this thesis provides both a means (in the form of the CreativeTeams platform) of measuring team creativity and an indication (through the study) that there is no difference in the creative performance of co-located and virtual teams. I recognise that this is only a preliminary step in this field of research. However, I feel that it provides a compelling indication of what virtual teams are capable of. The impact of adopting even partial forms of virtual working (e.g., home working a few days a week) are potentially far-reaching for organisations, employees and the wider environment.

I'd like to close with the observation made by Sternberg (2012) [179] that "creative people are creative largely not as a result of any particular inborn trait, but, rather, through an attitude toward life (Maslow 1967, Schank 1988, Sternberg 2003): They habitually respond to problems in fresh and novel ways, rather than allowing themselves to respond mindlessly and automatically (Sternberg et al. 2002, Sternberg et al., 2004, Sternberg and Lubart 1995)."

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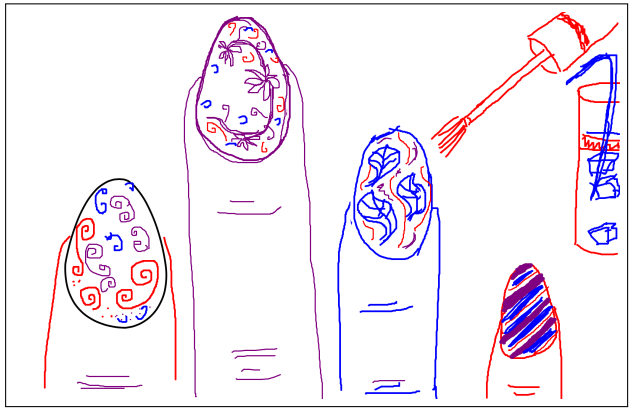
Appendix A

Drawing examples

This section introduces examples of the drawings produced by teams. Examples have been selected from all the activities to demonstrate the most and least original responses produced by the co-located and virtual teams. Examples are also included to demonstrate examples of the highest and lowest levels of elaboration in responses produced by co-located and virtual teams. A number of co-located and virtual team outputs from the Design Challenge are also reproduced to provide an indication of just how much team responses vary during this particular activity.



(a) Co-located - Team No.7

(b) Virtual - Team No.24

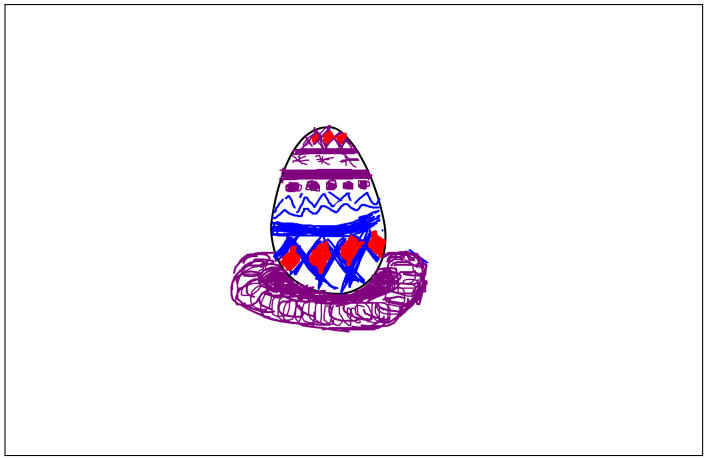
(c) Co-located - Team No.4

(d) Virtual - Team No.21

Figure A.1: Picture construction examples. Figures a & b = most original, figures c & d = least original.

(a) Co-located - Team No.5

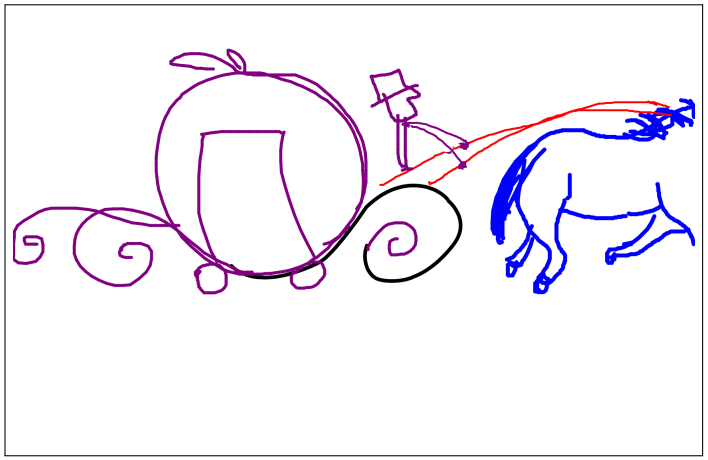
(b) Virtual - Team No.28



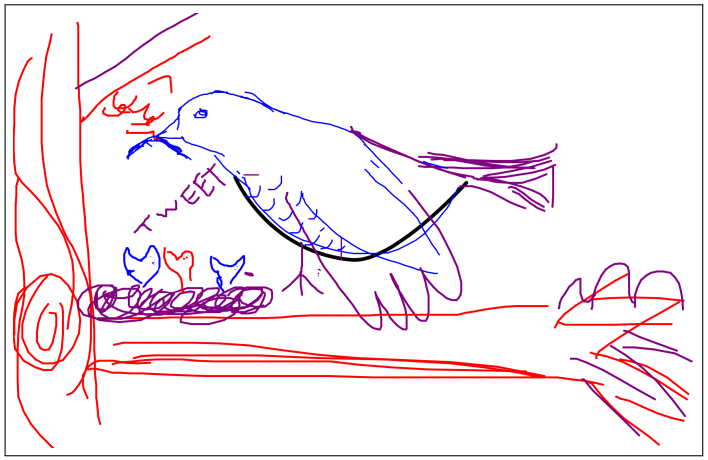
(c) Co-located - Team No.16

(d) Virtual - Team No.30

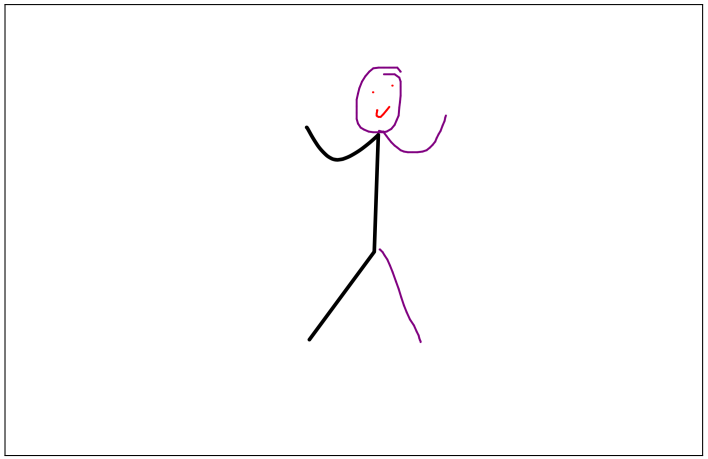
Figure A.2: Picture construction examples. Figures a & b = most elaboration, figures c & d = least elaboration.



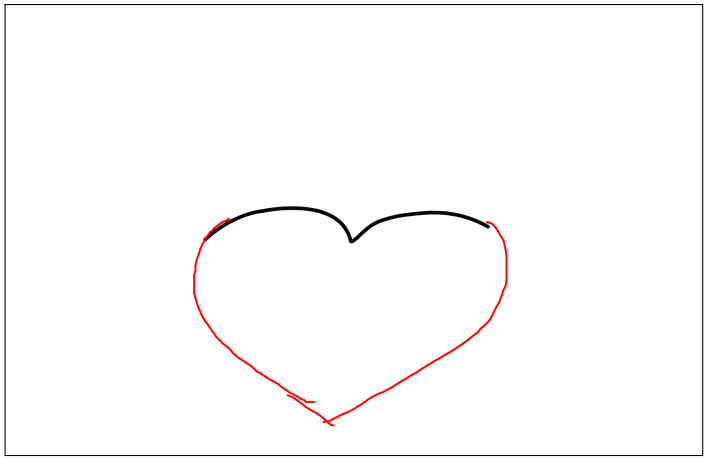
(a) Co-located - Team No.6, Picture No.4



(b) Virtual - Team No.18, Picture No.5



(c) Co-located - Team No.16, Screen No.8

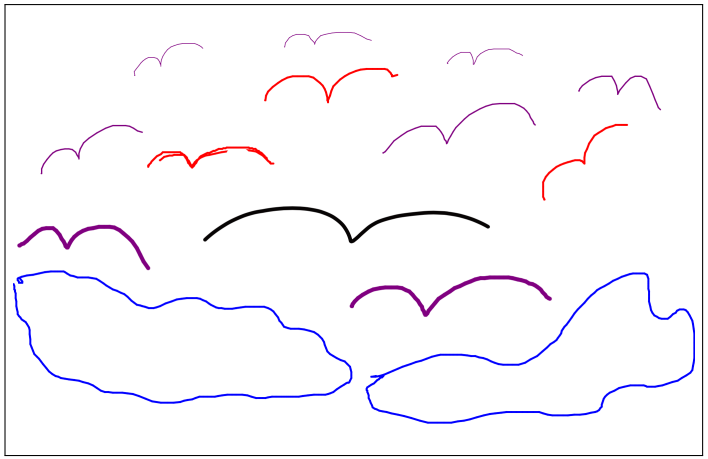


(d) Virtual - Team No.29, Picture No.1

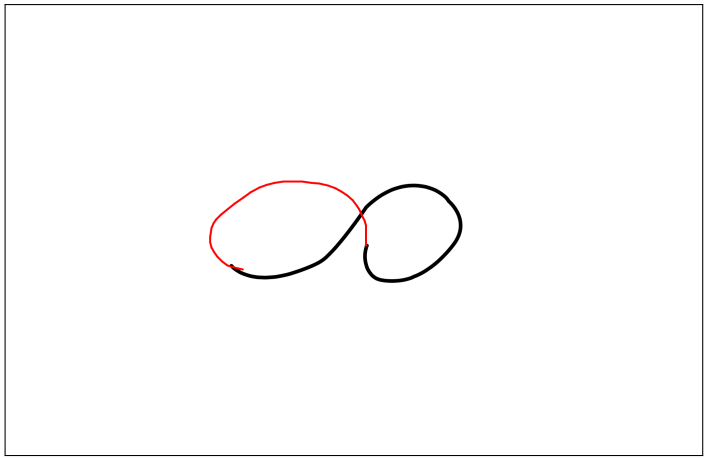
Figure A.3: Picture completion examples. Figures a & b = most original, figures c & d = least original.

(a) Co-located - Team No.13, Picture No.2

(b) Virtual - Team No.22, Picture No.2

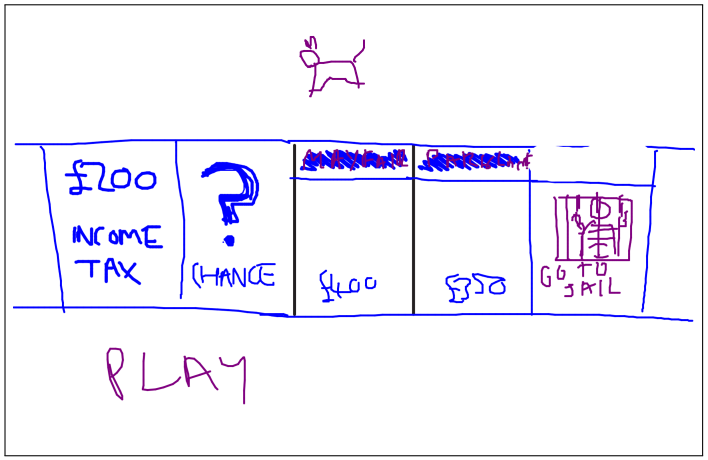


(c) Co-located - Team No.7, Picture No.1

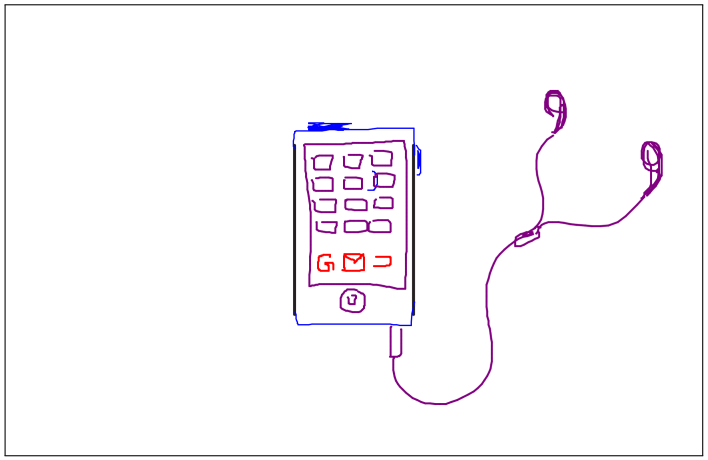


(d) Virtual - Team No.29, Picture No.4

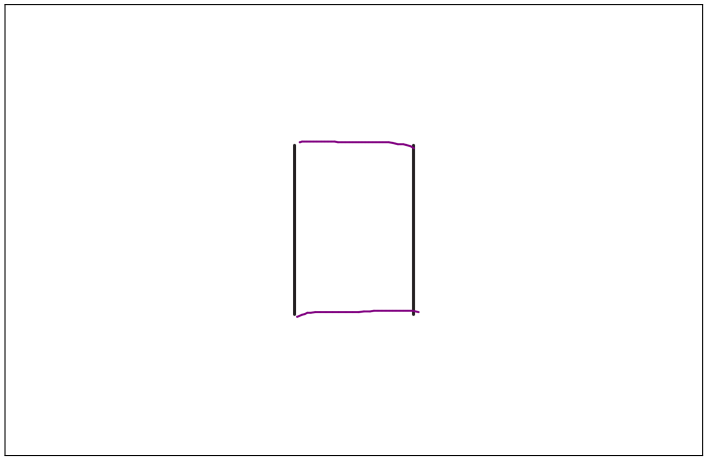
Figure A.4: Picture completion examples. Figures a & b = most elaboration, figures c & d = least elaboration.



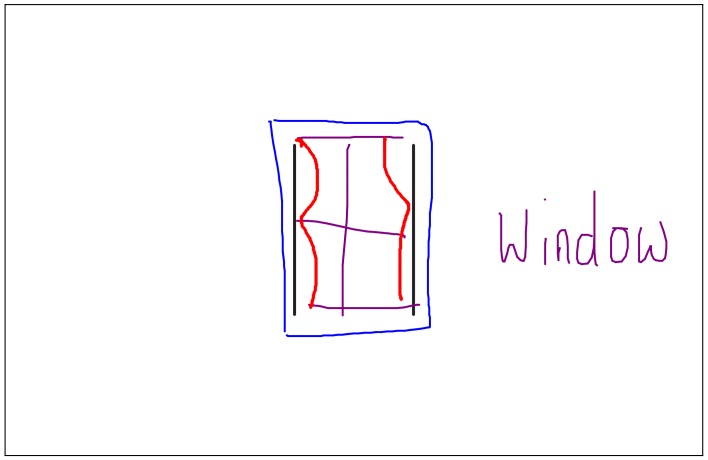
(a) Co-located - Team No.2, Picture No.5



(b) Virtual - Team No.22, Picture No.4

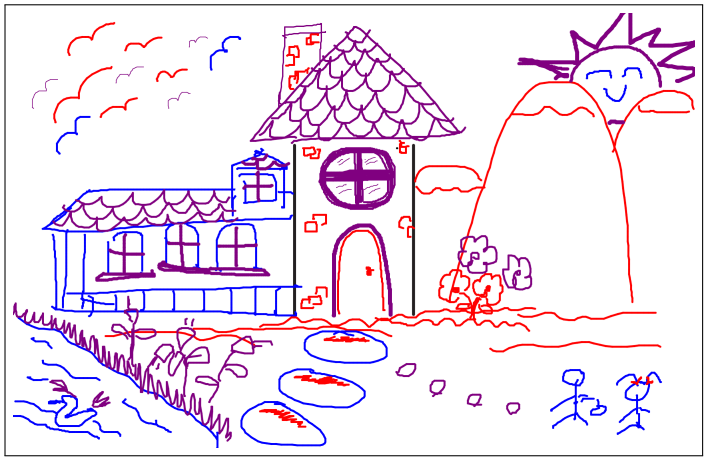


(c) Co-located - Team No.12, Screen No.14

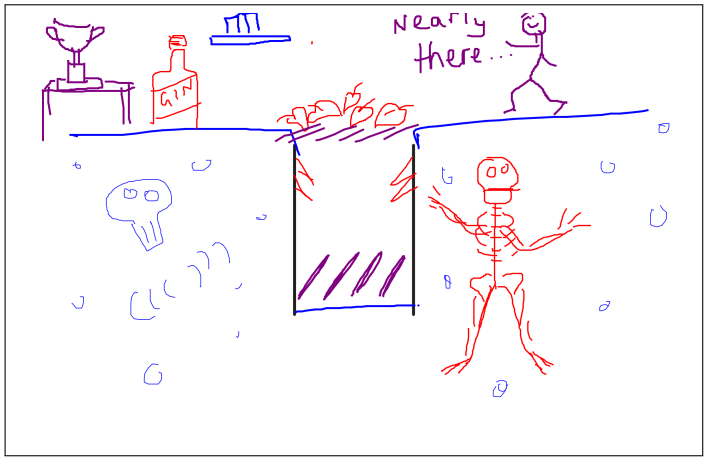


(d) Virtual - Team No.25, Picture No.4

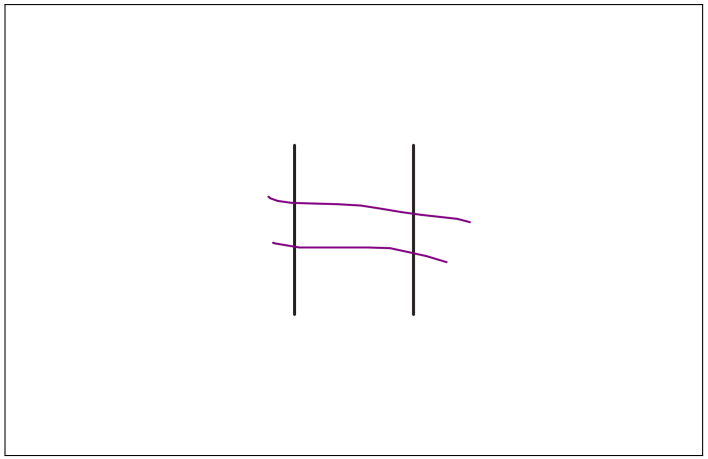
Figure A.5: Parallel lines examples. Figures a & b = most original, figures c & d = least original.



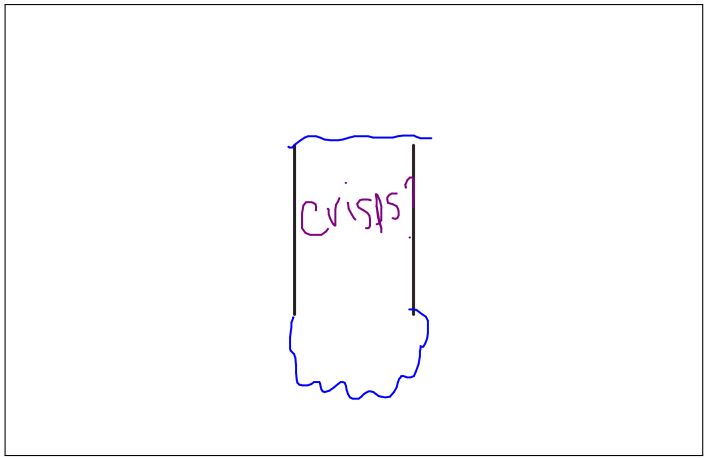
(a) Co-located - Team No.7, Picture No.2



(b) Virtual - Team No.20, Picture No.4

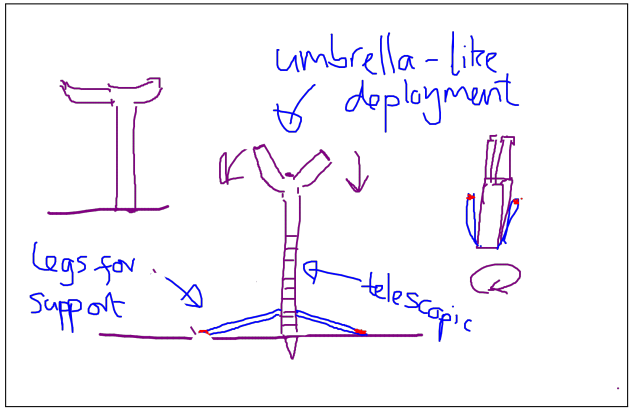


(c) Virtual - Team No.12, Picture No.8

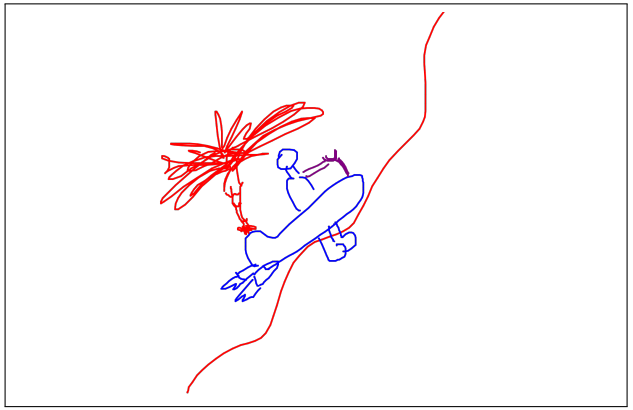


(d) Co-located - Team No.28, Picture No.4

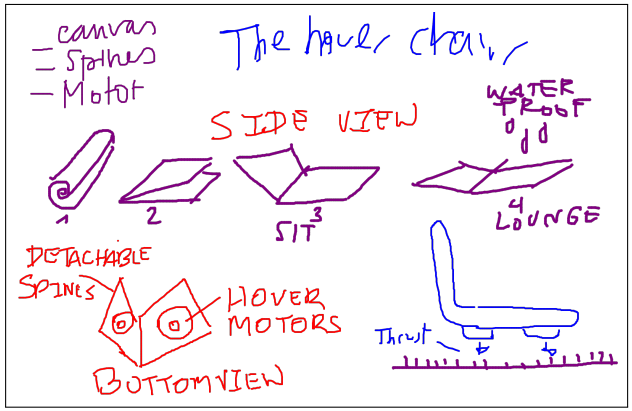
Figure A.6: Picture completion examples. Figures a & b = most elaboration, figures c & d = least elaboration.



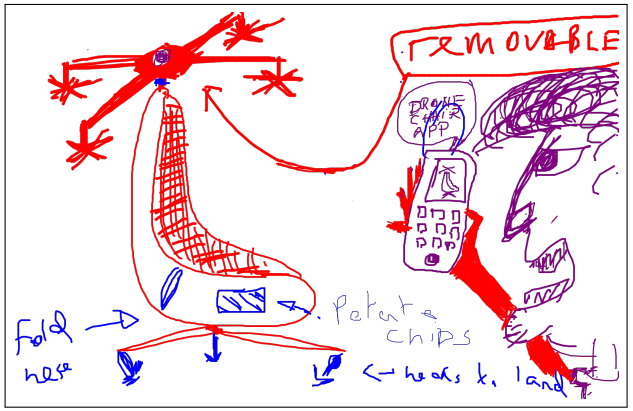
(a) Co-located - Team No.2



(b) Co-located - Team No.5

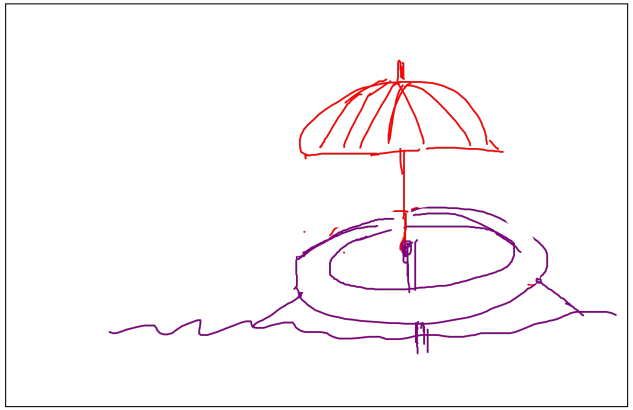


(c) Co-located - Team No.6

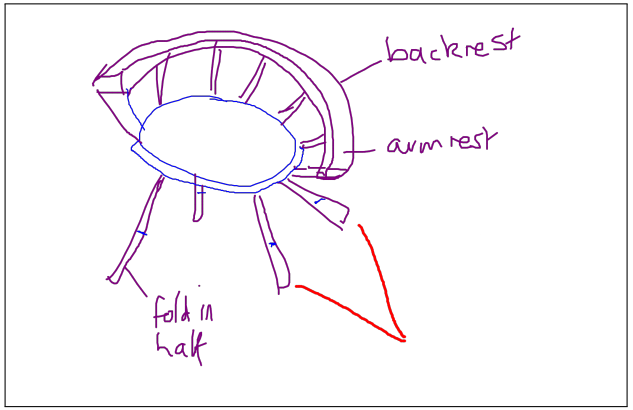


(d) Co-located - Team No.15

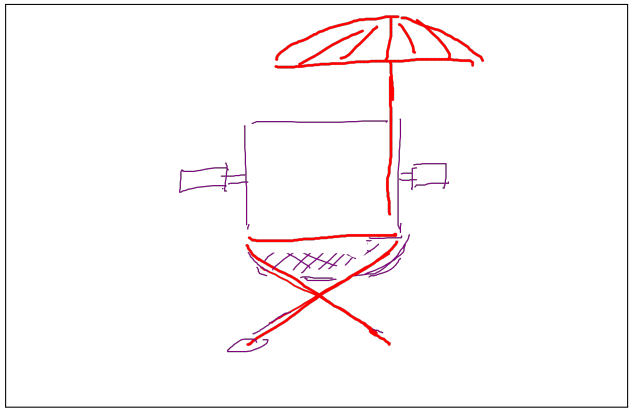
Figure A.7: Design challenge examples illustrating a wide range of variety in responses.



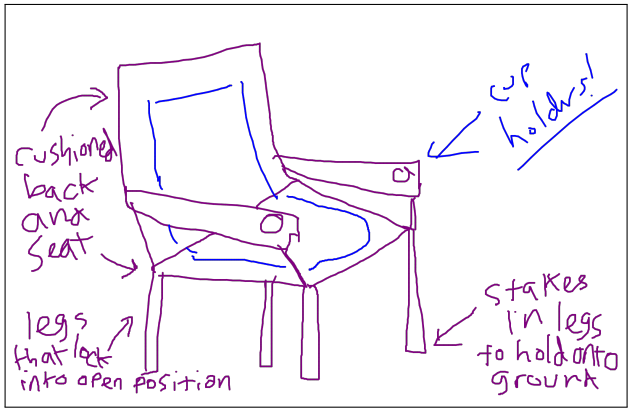
(a) Virtual - Team No.23



(b) Virtual - Team No.25



(c) Virtual - Team No.29



(d) Virtual - Team No.30

Figure A.8: Design challenge examples illustrating a wide range of variety in responses.

Appendix B

Scoring Documentation

This appendix contains the guides used for scoring Originality for the Picture Construction, Picture Completion, Parallel Lines and Alternative Uses outputs. All guides are reproduced verbatim from Torrance's Figural Test A [154] (Picture Construction, Picture Completion and Parallel Lines) and Verbal Test A [155] (Alternative Uses) guides. The Design Questions rubric developed by working with 10 professional designers is also included.

The scoring guides for elaboration, title originality and marker assessed creativity are contained within the main body of the thesis in section 5.1.2 (Elaboration), section 5.1.3 (Title originality) and section 5.1.4 (Marker assessed creativity).

B.1 Originality

B.1.1 Picture Construction

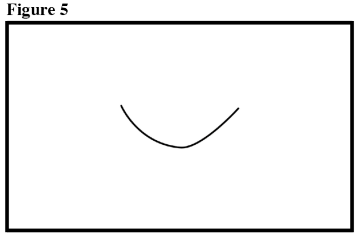
Response	Score	Response	Score
Abstract design without meaningful title	0	Flower	4
Airplane	5	Flying object (UFO)	5
Balloon	4	Girl	1
Bird (s)	3	Golf green	5
Bug	4	Hat	5
Bunny	4	Humpty Dumpty	4
Car	5	Man (all kinds except from outer space)	0
Cat	4	Man (from outer space)	3
Chicken	4	Monster	5
Circle	0	Mouse	4
Cloud	5	Mouth	5
Dinosaur	5	Nose	3
Duck	5	Pond (lake)	5
Ear (human)	4	Rabbit	4
Ear (animal)	5	Rock	5
Egg (Easter)	0	Rocket	5
Egg (not Easter)	0	Spaceship	3
Egg (in basket)	0	Swimming pool	5
Eggman; egghead, etc.	3	Sun	4
Eye	4	Teardrop	0
Face (human)	2	Tree	5
Fish	5	Turtle	5

Table B.1: Picture Construction originality scores, reproduced from Torrance (1972) [154]

B.1.2 Picture Completion

Figure B.1: Picture Completion Scoring Example, Reproduced from Torrance (1972) [154]

Figure 5

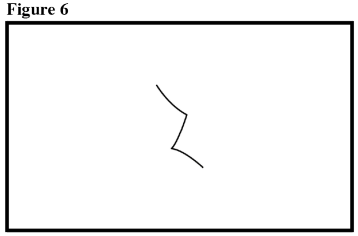


Zero points (5% or more of responses)
- Abstract design without meangingful title
- Boat (or hull)
- Boat (sail)
- Bowl
- Circle
- Face or head

One point (2% to 4.99%)
- Egg (s)
- Hammock
- Mountains
- Mouth
- Smile (lips)
- Valley
- Water (stream, pool, lake, wave, etc.)

Two points (less than 2% or responses)
Other responses showing creative strength.

Figure 6

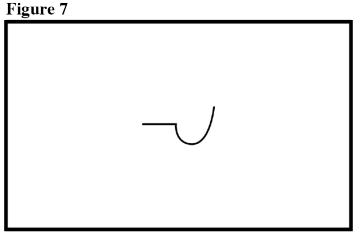


Zero points (5% or more of responses)
- Abstract design without meangingful title
- Face
- Lightning
- Steps (staircase)

One point (2% to 4.99%)
- Chair
- Girl (woman)
- Man (boy)
- Man skating
- Tree

Two points (less than 2% or responses)
Other responses showing creative strength.

Figure 7

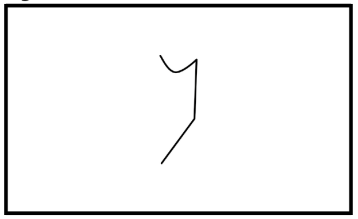


Zero points (5% or more of responses)
- Abstract design without meangingful title
- Carriage (buggy)
- Question mark (s)
- Snake

One point (2% to 4.99%)
- Auto (car)
- Body (human)
- Dipper
- Face
- Hook
- Key
- Pipe (smoker's)
- Sickle
- Spoon, dipper
- Word (letter, symbol, number)

Two points (less than 2% or responses)
Other responses showing creative strength.

Figure 8



Zero points (5% or more of responses)
- Abstract design without meangingful title
- Man (head and body)
- Man, men (stick)

One point (2% to 4.99%)
- Dress
- Face
- Girl
- Monster (ghost)
- Shield (medieval, etc.)
- Tree

Two points (less than 2% or responses)
Other responses showing creative strength.

Figure B.2: Picture Completion Scoring Example, Reproduced from Torrance (1972) [154]

Figure B.3: Picture Completion Scoring Example, Reproduced from Torrance (1972) [154]

B.1.3 Parallel Lines

Response	Score	Response	Score
Abacus	3	Bridge	2
Abstract design	0	Broom	3
Airplane	3	Bucket (paint, water)	2
Apartment (building)	2	Bullet, shell	2
Arrow (s)	2	Butterfly	2
Automobile	2	Cabinet (cupboard)	3
Balloons	3	Cage (for animal)	2
Barn	2	Cake	2
Backet	3	Calendar	2
Bed (s)	2	Camera	3
Bible	0	Can, metal	1
Bird (s)	3	Candle (s)	1
Birdhouse	3	Candy, (peppermint)	2
Blackboard	2	Candy, bar	2
Block (toy)	3	Car, automobile	2
Board	1	Cards, playing	3
Boat (motor, sail, etc.)	1	Castle	3
Book	0	Cat	3
Bookshelf	3	Cave	3
Bottle	1	Chair (s)	1
Bow (tie, ribbon)	2	Chalkboard (black-board)	2
Bread, load	3	Checkerboard	1
Chewing gum, stick	3	Glass (drinking)	1
Chimney (ies)	2	Goalposts, football	1
Church	3	Hammer	3
City skyline, buildings	2	Hat	1
Clock	1	Hexagon	0
Clothesline	3	Highway	1
Coat	3	Horse	3
Columns (building)	3	Hourglass	1
Crayon (s)	2	House	0
Crayon box	2	House (tree)	3
Cross (religious)	2	Hut (no house or tree house)	2
Crown (king)	3	Ice cream cone	2
Cube (square)	1	Jack-in-the-box	2

Response	**Score**	**Response**	**Score**
Cup	2	Jail (not window)	2
Cylinder (geometric)	3	Jar (container, jelly, face cream, etc.)	3
Desk	2	Kite (box)	3
Diving board	3	Knife (ves)	3
Dog	3	Ladder	0
Doghouse	3	Leg (s) (man)	2
Dollar bill	3	Letter (to person)	2
Door	0	Letter (s) (alphabet)	0
Dress	2	Light (lamp)	2
Drum	2	Lighthouse	3
Dynamite	2	Light socket (receptacle)	3
Egg(s)	3	Light switch	3
Envelop	3	Log (tree)	3
Eye (s)	3	Lollipop	2
Eyeglasses	3	Mailbox	2
Face (s)	0	Mailbox	2
Fence	1	Man (figure or stick)	0
Fireplace	2	Map	3
Firecrackers	3	Maze	3
Fish	3	Milk carton	1
Flag (s)	1	Mirror	3
Flower (tulip, rose, etc.)	1	Monster (whole)	2
Flowerpot	3	Mountain peaks	3
Football field	3	Mug (drinking)	3
Fork (to eat with)	3	Mushroom	3
Frame (picture)	0	Musical note (s)	3
Garbage can	2	Number (s) (Arabic and Roman)	0
Geometric design	0	String	3
Gift	1	Suckers (lollipops)	2
Girl, face	0	Swimming Pool	3
Outhouse	3	Swing, swing set (play)	1
Pail	2	Table	1
Pants (man's)	1	Tank (container)	3
Paper, piece of, sheet, typing	1	Telephone poles	2
Pencil (s)	1	Television	1

Response	Score	Response	Score
Picture	1	Tick-tack-toe	1
Picture frame	0	Tombstone	3
Pocketbook	2	Tower (to climb) (watch, water, Pisa, Eiffel)	3
Present	1	Train track	2
Prison building	2	Trash can	2
Privy	3	Trash can	2
Radio	3	Tree (s)	0
Railroad track	1	Tree stump; trunk (not log)	3
Rectangle	0	Truck	2
Road (street)	1	Umbrella (s)	3
Robot	2	Vase (for flowers)	3
Rocket	1	Wagon, covered	3
Room (in building)	3	Wall (s)	3
Ruler	3	Washing machine	3
Sack (bag)	2	Washboard	3
School buildings	2	Wastebasket	2
Shirt	2	Weapon, collection (bor and arrow; bor and gun)	2
Shoe (boot)	3	Window	0
Sign, advertising	2	Window	0
Silo	2	Window, jail	1
Skyscraper (building)	2	Woman (face)	1
Spaceship	2	Spool, spindle	3
Stairs, steps	1	Stilts	2
Stover	3		

Table B.2: Parallel lines originality scores, reproduced from Torrance (1972)[154]

B.1.4 Alternative Uses

Responses	**Originality Weighting**
Airplane, helicopter	1
Alphabet, cut out	1
Animals, toy	0
Animal cage/shelter/house	0
Apparel	0
Ash tray	2
Baby crib	1
Bank	1
Bed	1
Bed, animal	1
Bed or crib, toy	1
Black board, bulletin board	1
Blocks	2
Boat	1
Boat, toy	1
Books/booklets	1
Book cover	2
Building blocks, bricks	1
Buildings, including playhouse, club house, school, church, etc	0
Burn, throw away, etc	0
Cabinet	1
Car, toy	0
Cards	2
Carrier, “carry stuff in”	0
Chair	0
Chair, toy	1
City, town, play or model	1
Clock	1
Closet, clothes	2
Clothing, unspecified	0
Coffin for dead pet	2
Container for junk, jewelry, etc	0
Costume	0

Responses	**Originality Weighting**
Cover for plants, lawn, etc	1
Crayon holder	0
Cupboard	2
Decoration	1
Desk	1
Desk, toy	1
Divider, for drawer/room	1
Doll	1
Doll clothes	2
Doll furniture	1
Doll house	0
Door	1
Drawing paper/board	1
Eating utensils	1
Feeder/waterer, animal/bird	2
Fence/fencing	2
File/filing cabinet	2
Fire starter	1
Flower grower/starter	1
Flowers, make	1
Footstool	2
Fort, play	0
Furniture, unspecified	0
Games, unspecified	0
Garbage can	1
Grocery container/carrier	0
Hat	0
Hide in	1
Insulating material	0
Kick the box game	0
Kite	2
Lamp shade	2
Lunch box	2
Mail box	1
Mask	1
Mobile	1
Musical instrument	2

Responses	**Originality Weighting**
Numerals, cutout	1
Paint on them	1
Pencil holder	0
People, toy/cutout	0
Pictures	1
Picture frame	1
Planter/plant grower/starter	1
PLay house, play in	1
Poster, maps	1
Puppet	1
Purse	2
Robot	1
Rocket weapon, toy	1
Room divider	1
Shelf	1
Shield	2
Shoes	1
Signs, all kinds	1
Sled	1
Slide, slide down hill	0
Space ship	1
Stage, make	1
Steps or ladder	1
Storage	0
Stove, toy	2
Suitcase	1
Table	1
Target	1
Television, toy	1
Tent	2
Toy, unspecified	0
Toy box	0
Toy car	1
Toy desk	1
Train, toy/play	0
Tree, cutout	1
Tree house	2

Responses	**Originality Weighting**
Truck, toy	1
Tunnel	1
Vase	0
Wagon	1
Walls, patch wall, etc	1
Writing material	0

Table B.3: Alternative uses scoring guide
Reproduced from Torrance (1974) [155]

B.1.5 Potential Design Questions

Response
How much do you expect to sell the chair for?
What is the expected production cost of the chair?
Is the chair expected to be used in all seasons or only during the summer?
Do you have a preference for chair materials?
How many people should the chair accommodate?
What colour should the chair be?
Can the chair be mechanical/electrical? I.e., not just a manual chair
Would you like the design to be similar to existing popular chairs? I.e., based on a simple metal frame with canvas bucket seat.
Is longevity a priority? I.e., should the chair be made to last or be disposable?
How much should a 'portable chair' weigh?
Should the chair be washable? I.e., to deal with the mud of festivals/outdoors generally
Is this chair aimed at any particular age group/demographic?
Given it's a 'portable chair', what is the suitable size for this chair?
Would there be any digital technology embedded in the chair?
Should the chair be recyclable?
Would you prefer the chair be made from virgin or recycled materials?
How much weight should the chair support?
Should it be pretty?
Should this be a range of chairs? I.e., Adult chair/Child Chair
Does the chair need to have multiple uses? I.e., Swiss Army Chair?
How many chairs are you intending to produce?
How should chairs be stored?
Should chairs be designed for mass production?
Should chairs be designed to occupy maximum container/trailer space?
What is a reasonable carrying weight for the envisioned user?
What is the expected primary market - hikers, tourists or festival attendees?
Is a cup holder important?
Has the company produced portable chairs in the past? If so, what was successful, what was not?
How will it be carried?
Does it have a carrying bag?
Is there a way of identifying individuals? (label etc)
Are there a range of fabric designs?

Are there patent limitations?
What is the uniqueness/USP in a saturated market?
Are the legs adjustable to accommodate undulating ground?
Are there a variety of feet for different ground?
Are there any manufacturing (i.e., iso standards) or health and safety standards that it has to comply with?
Should the material have any thermal properties?
Should the chair be modular? I.e., can it be modified for different situations
Should the chair have some form of anti-theft / tracking device?
Should this chair be functional? Or is it only a status chair?
Is the chair seamless? I.e., to make cleaning easier
How important is it for the chair to be designed for dis-assembly (both for repairing and end of life)?
What production/manufacturing technologies are already in house or preferred?
Will the chair be sold outside Britain? If so, in which other markets?
Are there brand guidelines to follow (both from the company and the collection that the chair might be part of)?
Is it a chair for sitting temporarily, lounging, relaxing...?
Are there accessories that will be sold or suggested to buy together with the chair (e.g. blanket, cup holder, umbrella...)? (coordinate the aesthetics as well as consider modularity)
Where will the chair be sold (what type of store)?

Table B.4: Possible questions generated by professional designers

Appendix C

Team data

This appendix contains the data used for the calculations discussed in chapter 6. Data is divided by metric.

C.1 Originality

	Team Number	Originality
Co-located teams	1	5
	2	5
	3	0
	4	0
	5	5
	6	0
	7	5
	8	4
	9	3
	10	0
	11	2
	12	5
	13	5
	14	4
	15	3
	16	0
	17	2
Virtual teams	18	0
	19	5
	20	3
	21	0
	22	5
	23	5
	24	5
	25	5
	26	0
	27	5
	28	0
	29	5
	30	4

Table C.1: Picture construction adjusted originality scores

		Screen number										
		1	2	3	4	5	6	7	8	9	10	Total team originality
Co-located teams	1	2	2	2	2	2	2	2	2			16
	2	1	2	1	0	2	2	2				10
	3	2	0	1	2							5
	4	1	2		0		0		1		1	5
	5	2	0	2	2	2	2	1	2	1	1	15
	6	2	2	2	2	2	0	1				11
	7	0	1	1	0	2	2	2				8
	8	2	2	1	0	2						7
	9	2	2	1	2	0						7
	10	1	2	1	1	0	0	1	2	2	0	10
	11	2	1	2	2							7
	12	1	1	2	1	2	1	1	1	1	0	11
	13	1	1	2	0	0	2	1	0			7
	14	0	2	1	0	1	0					4
	15	1	1	1								3
	16	0	0	2	1	0	1	1	0	0	0	5
	17	1	1	1	1	2	2	2	0	1	0	11
	Co-located totals	21	22	23	16	17	14	14	8	5	2	142
Virtual teams	18	2	2	1	2	2	1	1				11
	19	2	2	2								6
	20	2	1	1								4
	21	0	1	1	1	1	2	2	0			8
	22		1	1	1	1						4
	23	0	2	1	1	2						6
	24	2	1	1	0	2	1	1	2			10
	25	1	2	2	0	0	1	1	2	0	1	10
	26	0	2	1	0	0	0		1	1		5
	27	0	0	2	1	1	1	1	0	0	1	7
	28	0	1	1	2	1	0	1	1	0	1	8
	29	0	0	1	2	2	2	2	0	1	1	11
	30	1		1	0	1	2	1	1	2	2	11
	Virtual team totals	10	15	16	10	13	10	10	7	4	6	101
	Grand Total	31	37	39	26	30	24	24	15	9	8	243

Table C.2: Picture completion adjusted originality

		Screen Number																												
	Team Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Grand Total
Co-located teams	1	3	3	1	2	0	1	1	2	3	1	3	3	2																25
	2	1	0	3	1	3	3																							11
	3	0	3	0	1	1	0	3	3	1	3	1	0	0																16
	4	2	3	0	1	3	3																							12
	5	1	1	3	3	0	3	3	0	1	0	3	2	3	1	3														27
	6	3	3	1	0	0	3	3	0	1																				14
	7	3	0	3																										6
	8	3	3	0																										6
	9	1	3	1	2	3	0	3		2																				15
	10	3		0	0	0	3	0	0	3	3	2																		14
	11	0	2	2	3																									7
	12	1	3	3			1	1	3	3	0	3	3	1	0	3	0													25
	13	2	2	0	0	1	3	3	3																					14
	14	1	0	1	1	2	2	1	3	3	2																			16
	15	3	0	2																										5
	16	0	3	0	3																									6
	17	3	3	0	0	0	3	0	3	0	1	3	0	1	1	0														18
	Co-located team total	30	32	20	17	13	25	18	17	17	10	15	8	7	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	237
Virtual teams	18	3	3	0	1																									7
	19	0	1	1	0	0	2																							4
	20	2	0	0	3	3																								8
	21	0	1	0	1	0	3	0		3	2		3																	13
	22	0	2	0	3	3	0																							8
	23	1	3	1	2	0	0	2	0	3	3	0	0	3	3															21
	24	3	3	0	2	3	3	1	1	1	3	0	1	3																24
	25	1	2	0	0	1	3	3	2	2	0	1	3	3	3															24
	26	0	3	3	0	3	3	3																						15
	27	0	0	0	3	1	3	3	0																					10
	28	0	1	0	3		3	3	3	3	3	0	3	0	0	0	0	0	1	3	1	3	3	3	1	1	1	0	0	39
	29	1	3	3	3	0	3	3		1	3		3	2	1	3	1	3	3											36
	30	3	3	2	3	2	3	3	1	3	0	2																		25
	Virtual team total	14	25	10	24	16	26	21	7	16	14	3	13	11	7	3	1	3	4	3	1	3	3	3	1	1	1	0	0	234
	Grand total	44	57	30	41	29	51	39	24	33	24	18	21	18	9	9	1	3	4	3	1	3	3	3	1	1	1	0	0	471

Table C.3: Parallel lines adjusted originality scores

		Alternative use number																																																							
	Team Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	Grand Total
Co-located teams	1		2	0	0	0	0	2	1	1	2	1	0	2	0	2	2	1	1	1	2	2	1	2	1	1	2	0	2	1	1	2																											35
	2		0	0	1	1	1	0	1	2	0	1	1	2	0	1	1	0	0	2	2	1	0	2																																			19
	3	1	0	0	1	0	2	2	0	2	2	2	0	1	1	2	2	0	0	2	2	1																																					23
	4		2	2	1	0	2	2	0	2	2	1	1	1	0	2	2	2	1	2	2	1																																					28
	5	0	0	1	0	1	1	0	2	0	0	0	2	2	2	1	0	2	2	0	2	0	2	0	2	0	0	2																															24
	6		0	0	0	1	2	2	2	0	2	0	1	2	1	2	1	2																																									18
	7		1	0	0	0	0	1	1	1	0	1	0	2	0	0																																											7
	8		2	1	0	1	1	2	0	2	1	0	0	1	0	1	0	1	1	2	1	0	2	2	0	0	2	1	1	1	0	1	0	0	0	0	0	1	2	2																			32
	9	0	0	0	0	0	1	0	1	0	2	0	2	1	0	1	0	0	1	1	1	0	2	0	2	0	1	1	0	0	2	2	0	1	2	0	1																						25
	10	0	0	0	2	0	0	1	1	0	1	2	1	2	0	0	1	1	1	1	0																																						14
	11		0	0	0	0	1	0	2	1	0	0	1	1	0	0	1	0	1	1	2																																						11
	12	0	1	0	1	0	1	0	0	0	2	0	1	2	0	2	2	0	0	0	2	0	0	0	2																																		16
	13	0	0	0	0	2	2	0	0	2	1	2	1	2	0	0	2	0	1	2	0	2	0	2	2	1	0	0	1	0	0	1	2	0	0	0	2	0	1	2	1	0	2	1	0	2	1	0	1	1	0	0	0	2	2	2	0	0	48
	14	0	0	0	0	1	2	1	2	1	0	1	1	0	1	1	1	2	0	0	0	2	0	0	0	1	0	0	1	1																													19
	15	2	0	0	2	0	0	0	1	2	0	1	0	0	0	0	1	0	2	2	2	1	1	1	2	2	1	0	2	1	1	0	2	0																									29
	16	0	1	0	1	2	0	0	2	1	1	2																																															10
	17		0	0	0	1	0	2	1	2	0	0	1	1	1	2	2	2	2	0	0	0	1	2	1	1	2	1	0	1																													26
	Co-located team total	3	9	4	9	10	16	15	17	19	16	14	13	22	6	17	18	13	13	16	18	10	9	11	12	6	8	5	7	5	4	6	4	1	2	0	3	1	3	4	1	0	2	1	0	2	1	0	1	1	0	0	0	2	2	2	0	0	384
Virtual teams	18	1	0	1	0	1	2	1	1	0	1	2	2	2	0	2	2	1	2	2	1	2	2	1	1	2	1	2	1																														36
	19		0	0	0	2	0	2	0	0	2	0	1	0	2	1	0	2	0	1	1	1	2	1	2	0																																	20
	20		0	1	0	0	0	1	0	0	0	1	1	1	1	2	2																																										10
	21		0	0	1	2	1	0	0	1	1	2	1	0	0	0	0	1	0	0	1	1	1	1	1	2	1	1	0	2	0																												21
	22	1	0	1	0	1	0	2	1	0	1	1	2	0	2	1	1	2	2	2	0	2	0	0	1	2	0	1	0	0	2	0	0																										28
	23		2	0	0	0	0	1	2	1	0	2	0	0	2	0	0	0	1	1	0	0	1	2	2	2	1	0	0	1	1	2																											24
	24		2	2	0	0	2	2	0	0	0	1	2	0	0	0	1	0	2	2	0	1	0	1	0	0	1	1	0	0	0	2	0	2	2	1	0	0	1	1	0	0	0	1	0	2	0	0	2										34
	25	0	2	1	1	2	1	1	0	0	1	0	1	1	2	2	2	2	0	1	2	0	2	1	2	1	1	1	0	2	0	2																											34
	26	0	0	1	1	2	2	2	1	2	2	0																																															13
	27	1	1	0	0	2	1	0	1	1	0	1	0	0																																													8
	28		0	0	2	1	1	0	1	2	1	0	1	1	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	2	2	1	1	2	1	2	0											28
	29		0	1	0	0	1	2	1	1	2	1	2	2	0	1	0	2	1	2	1	1	2	1	1	1																																	26
	30		1	0	0	1	1	1	0	2	0	0	1	2	0	0	2	1	0	2	2	0	2																																				18
	Virtual team total	3	8	8	5	14	12	15	8	10	11	11	14	9	9	9	10	11	8	14	10	8	12	8	10	10	5	6	1	6	3	6	0	3	3	1	0	0	1	2	2	2	1	2	2	3	2	0	2	0	0	0	0	0	0	0	0	0	300
	Grand Total	6	17	12	14	24	28	30	25	29	27	25	27	31	15	26	28	24	21	30	28	18	21	19	22	16	13	11	8	11	7	12	4	4	5	1	3	1	4	6	3	2	3	3	2	5	3	0	3	1	0	0	0	2	2	2	0	0	684

Table C.4: Alternative uses adjusted originality scores

		Question number																					
	Team number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Grand Total
Co-located teams	1	1	1	1	1	1	2	2	1	1	2	1	1											15
	2	2	1	1	2	1	1	1	2															11
	3	2	1	1	1	1	1																	7
	4	2	1	1	1	1	1	0	1	0	2	0	1											11
	5	1	2	1	1	1	1	1	1	1	2	2	2	1	2									19
	6	1	2	1	1	1	1	2	1	1														11
	7	2	1	1	1	1	1	1																8
	8	2	2	1	1	2	2	1	1	2	2	2	2	2										22
	9	1	1	1	0	1	1	1	1	2	1	1												11
	10	1	1	1	1	1	1	1	2	2														11
	11	1	1	1	2	1	2																	8
	12	2	1	1	1	1	1	1	1	1	1	2	2	1	1									17
	13	1	2	2	2	1	2	1	1	1	1	1	1	2										18
	14	1	2	1	1	2	0	1	1															9
	15	2	1	2	1	0	2	1	1	1	2	0	1	0	2	1	0	1						18
	16	1	2	1	1	2	1	1	1	1	1													12
	17	1	0	2	1	0	0	0	0	0	0	0	1	1	2	1	0	0	1	1	0	0	0	11
	Co-located team total	24	22	20	19	18	20	15	15	13	14	9	11	7	7	2	0	1	1	1	0	0	0	219
Virtual teams	18	0	0	0	0	0																		0
	19	1	1	1	0	1	0	0	0	0	1	1	1											7
	20	1	1	1	1	1	2	2	1	2	2	1												15
	21	2	1	1	2	1	1	1																9
	22	1	1	0	1	1	1	1	1	1	2	1	1	2	2	0	1	1	1					19
	23	1	2	1	1	1	2	1	1	1	2													13
	24	1	2	1	1	1	2	1	1	1	2	2	1	2	2	1								21
	25	1	2	1	1	2	1	1	1	2	1	1	1	2	2									19
	26	1	1	1	1																			4
	27	1	2	1	1	1	2																	8
	28	1	1	0	0	1	1	2	1	0	1	1												9
	29	1	1	2	1	1	1	2	2	1														12
	30	1	1	1	1	0	1	1	2	1	2	1	1	1										14
	Virtual team total	13	16	11	11	11	14	12	10	9	13	8	5	7	6	1	1	1	1					150
	Grand Total	37	38	31	30	29	34	27	25	22	27	17	16	14	13	3	1	2	2	1	0	0	0	369

Table C.5: Design questions adjusted originality

C.2 Elaboration

	Team Number	Elaboration score
Co-located teams	1	46
	2	31
	3	40.5
	4	41
	5	86.5
	6	68.5
	7	20
	8	54
	9	71
	10	20.5
	11	50.5
	12	34
	13	15
	14	45
	15	16.5
	16	6
	17	37.5
	Co-located team total	683.5
Virtual teams	18	53.5
	19	46.5
	20	38.5
	21	37
	22	46.5
	23	12.5
	24	29
	25	49.5
	26	20.5
	27	22
	28	59.5
	29	30
	30	11.5
	Virtual team total	456.5
	Grand total	1140

Table C.6: Picture construction averaged elaboration scores

		Screen Number										
	Team Number	1	2	3	4	5	6	7	8	9	10	Total
Co-located teams	1	2	8	16	13	5.5	9.5	11.5	2.5			68
	2	6.5	29	9.5	9.5	14.5	7.5	0.5				77
	3	27.5	28	17.5	12.5							85.5
	4	14	11		12		14.5		14.5		11	77
	5	13.5	17.5	9.5	7	14.5	9.5	8	4.5	8	13.5	105.5
	6	6.5	9	13.5	15	14	8	11				77
	7	2	5.5	14.5	16.5	19.5	18.5	6.5				83
	8	16.5	4.5	22	11.5	15						69.5
	9	19.5	21	24	27.5	4.5						96.5
	10	9.5	4	5	4	10.5	9	3	5	10	4.5	64.5
	11	21	19.5	27.5	19							87
	12	7.5	12.5	8.5	5.5	10	5.5	4	12	10.5	14.5	90.5
	13	15	36	29	18	26	17.5	28	0			169.5
	14	10	22.5	16	12.5	21	6					88
	15	16.5	12	15.5								44
	16	5.5	5	4	2.5	8	6.5	2	5	5	7.5	51
	17	6.5	10	8.5	9.5	11.5	15	18.5	16.5	12	14.5	122.5
	Co-located team total	199.5	255	240.5	195.5	174.5	127	93	60	45.5	65.5	1456
Virtual teams	18	16.5	26.5	28	26.5	21.5	9	18				146
	19	19	9.5	13								41.5
	20	26.5	32	2								60.5
	21	4	12	6.5	13.5	9.5	12	16.5	4.5			78.5
	22		34	28.5	18	16.5						97
	23	4	5	9	3	7.5						28.5
	24	6	2	4.5	9	18.5	23	4	4.5			71.5
	25	11	14.5	8.5	10.5	11	9.5	11.5	4	10.5	7	98
	26	2	7	5.5	6.5	6.5	3		19.5	12		62
	27	0.5	2	4	7.5	10	11	10.5	16.5	11	9.5	82.5
	28	0.5	5.5	9.5	12	9.5	11	22.5	22.5	20	14.5	127.5
	29	0.5	7.5	7	1	5	10	8.5	18.5	20.5	14	92.5
	30	9		4.5	8.5	14.5	7	16	15	6	9	89.5
	Virtual team total	99.5	157.5	130.5	116	130	95.5	107.5	105	80	54	1075.5
	Grand total	299	412.5	371	311.5	304.5	222.5	200.5	165	125.5	119.5	2531.5

Table C.7: Picture completion averaged elaboration scores

		Screen Number																												
	Team Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Grand Total
Co-located teams	1	12	12.5	4	14	11.5	12	16.5	18	16.5	7	10.5	13	3.5																151
	2	16	11.5	9.5	23.5	19	12.5																							92
	3	4.5	23	2	1	9.5	1	13.5	5.5	8.5	3.5	3.5	1	2																78.5
	4	9	12.5	22.5	26.5	13	6																							89.5
	5	6	13	7.5	10	3.5	19	6.5	5.5	2.5	3.5	7	8	6	10.5	7.5														116
	6	12.5	18.5	3.5	13.5	7	10.5	5	3	6																				79.5
	7	3	40	8																										51
	8	20	13.5	35																										68.5
	9	16.5	24	12.5	15	12	1	10		13																				104
	10	19.5		17	5.5	16.5	1.5	2	4	7	5	3.5																		81.5
	11	11.5	26	7	28.5																									73
	12	9.5	16.5	10.5	0	3	19	4.5	1	2	4.5	3.5	3.5	8	1	10	7													103.5
	13	21.5	15	34.5	22	23	28	22	27																					193
	14	15	3.5	7	4.5	10.5	16	14.5	11.5	13.5	15																			111
	15	13	14.5	11																										38.5
	16	15	5.5	16	12.5																									49
	17	21	22	8.5	7.5	12.5	6	13.5	7.5	2	6	8.5	3.5	3.5	5	1														128
	Co-located team total	225.5	271.5	216	184	141	132.5	108	83	71	44.5	36.5	29	23	16.5	18.5	7	0	0	0	0	0	0	0	0	0	0	0	0	1607.5
Virtual teams	18	10.5	17.5	25.5	27.5																									81
	19	30.5	21.5	11	12.5	3	18.5																							97
	20	11	8	19.5	36	8.5																								83
	21	11.5	9.5	7	8	1	12.5	17		3.5	18.5	0	1.5																	90
	22	12	24	3	13	20.5	14.5	2																						89
	23	3	1	3	1	5	9.5	2	4.5	3	2.5	1	1	1	3.5															41
	24	3	7	6	9	6.5	4	2.5	5.5	4.5	11.5	2	12	6																79.5
	25	6.5	5	14	3.5	6	8.5	10.5	2.5	8.5	9.5	4	4	6	3.5															92
	26	8.5	6	7.5	14	1	12.5	2																						51.5
	27	13	12.5	10.5	10	5.5	21.5	4.5	3																					80.5
	28	12	3	3	1		6	1	7	1	3	3	6	2	4	2	2	6	9	5	3.5	4.5	3.5	2	8	6	10.5	3.5	2	119.5
	29	3.5	7.5	6	2	13	5.5	4		4.5	3	0	2	4.5	3.5	3.5	5	7	9.5											84
	30	4	3.5	11.5	4	4	10	4	13.5	8	12	1																		75.5
	Virtual team total	129	126	127.5	141.5	74	123	49.5	36	33	60	11	26.5	19.5	14.5	5.5	7	13	18.5	5	3.5	4.5	3.5	2	8	6	10.5	3.5	2	1063.5
	Grand total	354.5	397.5	343.5	325.5	215	255.5	157.5	119	104	104.5	47.5	55.5	42.5	31	24	14	13	18.5	5	3.5	4.5	3.5	2	8	6	10.5	3.5	2	2671

Table C.8: Parallel lines averaged elaboration scores

		Alternative use number																																																							
	Team Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	Grand Total
Co-located teams	1		1	0.5	1.5	1	0	1.5	0	1	0.5	1	0.5	0	1.5	1	0.5	0	0	0	0.5	3	1	0.5	0	0	1	0.5	0	0	0	0																											18
	2		0	0	0	2	0	0	0	0.5	0.5	0.5	0	3	0	0	0	0	0	0.5	0	0.5	0	1																																			8.5
	3	0.5	0	0.5	0	0	0	0	0	0	0	0	0.5	1	0	1	0	0.5	0	0	0.5	0.5																																					5
	4		1	0.5	1	0	0	0	0	2.5	1	0.5	0	0.5	0	0	0	0	0.5	1	0	0																																					8.5
	5	0.5	0.5	0	0.5	4	0	0	1.5	0.5	1	0.5	3	1.5	1.5	1	0	1.5	1.5	1	1	1	1	1.5	2	0.5	1	1																															29
	6		0.5	0.5	0	0	2.5	0	0	0	0	0.5	0.5	1.5	0.5	0.5	0	0																																									7
	7		0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0																																											1
	8		0.5	0.5	0.5	0.5	1	1.5	0	0.5	0	0.5	0	1	0	0.5	0	0.5	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0.5	0	1	0	0		0	0	0	0	0	0	0.5																			12
	9	0	0	0.5	0	0	0	0	0	0.5	0	0.5	0	0	0	1	0	0	0	0	0	0	0		0	4.5	0	1.5	1		0	0	0	0.5	0	0.5	0																						10.5
	10	0	1.5	0	0	0	0	0	0.5	0	0	0.5	0	0		1	0.5	0.5	0	0	0																																						4.5
	11		0	0	0.5	0.5	2	0	0.5	0.5		0	1	0	1	0	0.5	0.5	2	0.5	0																																						9.5
	12				0	0	0.5		0		0	1.5	0	0.5	0.5	0	0			1	0	0		0.5	0																																		4.5
	13	0	0	0	0	0	0.5	0	0	0.5	0	1.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	1.5	1.5	0	1	0.5	0	3	1	0	0.5	0.5	0.5	0.5			0	0.5	0	1	0	0	1.5	1.5	0.5	0.5	0.5	0.5	0.5	0.5	1		0	0.5	0.5	2	2.5		0.5	32
	14	0	0	0	0	0	0	0	1.5	0	0	0	0		0	0.5	0	1	0.5			1	0	0.5	0.5	0			0	0																													5.5
	15	0	0.5	1	0.5	0	0.5	0	0.5	0.5	0.5	0.5		0.5	0		0		0.5	0	0.5	1	0	0		0.5	1		1	0.5	0	0.5	0																										10.5
	16	0.5	0	0	0.5	0	1	0.5	0	0	0.5	0																																															3
	17		0	0	0.5	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0																													2
	Co-located team total	1.5	5.5	4.5	6	8	8	3.5	5	7	4.5	8	6	10	5.5	7	2	5	6	5	4.5	8.5	2.5	5	3.5	5.5	6.5	5	2	2	0.5	1	0.5	0.5	0	0.5	0.5	0	1	0.5	0	1.5	1.5	0.5	0.5	0.5	0.5	0.5	0.5	1	0	0	0.5	0.5	2	2.5	0	0.5	171
Virtual teams	18	0	0	0	0	1	0.5	1	1	0.5	0	0.5	1.5	0	0.5	0	0.5	0.5	1	1	0	0		0	1	0	0	0	1																														11.5
	19		0	0.5	0	0	1	0	0.5	0.5	1	0	0.5	0	1	0	0	0.5	0	0	0	0	0	0	0.5	0																																	6
	20		0	1	1	1	0	0.5	0	0.5	0	1.5	0	0	0	1.5	1																																										8
	21		0	0	0	2	0.5	0	0	1	1	1	0			0	1.5	0	0.5	0	0	2	0	0.5	0.5	2	1.5	0	0	0	0.5																												14.5
	22	0	0	0	0.5	0	0	0	0	0.5	0.5	0.5	0	0	0	0.5	0	0	0			0			0	0	0	0.5	0	0	0.5		0																										3.5
	23		0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																											1
	24		0.5	0	1	0.5	0	0.5	0.5	0	0	0.5	0	0	0	2.5	0	0	0	0.5	0	0		0	0	0	0	1				1		0	0	0	1		0	0.5	1.5		0	0		0	0.5	0	1										13
	25	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0.5	0.5	0.5																											3
	26	0	0.5	0	0		0	1.5	0	0	0.5	1																																															3.5
	27	0	0	0.5	0	0	0	0.5	0	0	0	0	0																																														1
	28		0	0	0.5	0	0	0.5	0.5	0	0	0	0	0	2.5	0.5	0	0	0.5	0	0	0.5	1	0	0.5	0	0		0.5	0	0	0	0	0	0	0.5	0	0.5		0.5	0	0	0.5	0	0	0	0												9.5
	29		0.5	0.5	0	0	0	0.5	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0.5	0	0	0																																	3
	30		0	1	1	0	0	1	0	2	0	0	0	1	0.5	0	0.5	0.5		0	0.5	0.5	1																																				9.5
	Virtual team total	0	1.5	3.5	4	4.5	2	6.5	3	5	3	5	3	1	5	5	4	1.5	2	1.5	0.5	3	2.5	1	2.5	2	1.5	1.5	1.5	0.5	1.5	1.5	0	0	0	0.5	1	0.5	0	1	1.5	0	0.5	0	0	0	0.5	0	1	0	0	0	0	0	0	0	0	0	87
	Grand total	1.5	7	8	10	12.5	10	10	8	12	7.5	13	9	11	10.5	12	6	6.5	8	6.5	5	11.5	5	6	6	7.5	8	6.5	3.5	2.5	2	2.5	0.5	0.5	0	1	1.5	0.5	1	1.5	1.5	1.5	2	0.5	0.5	0.5	1	0.5	1.5	1	0	0	0.5	0.5	2	2.5	0	0.5	258

Table C.9: Alternative uses averaged elaboration scores

C.3 Title originality

	Team Number	Marker A Title Originality	Marker B Title Originality
Co-located teams	1	3	3
	2	3	3
	3	2	2
	4	3	3
	5	3	2
	6	2	3
	7	0	0
	8	3	3
	9	3	3
	10	2	1
	11	2	1
	12	2	3
	13	0	1
	14	1	3
	15	2	3
	16	0	0
	17	2	3
	Co-located team total	33	37
Virtual teams	18	2	2
	19	2	3
	20	2	3
	21	3	3
	22	0	0
	23	0	0
	24	2	1
	25	2	2
	26	3	3
	27	1	1
	28	2	2
	29	1	3
	30	3	3
	Virtual team total	23	26
	Grand total	56	63

Table C.10: Picture construction title originality scores

		Screen Number																					
	Team Number	1		2		3		4		5		6		7		8		9		10		Total A	Total B
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B		
Co-located teams	1	0	2	2	2	0	0	3	3	0	0	1	1	2	2	1	1					9	11
	2	2	2	1	1	1	2	1	1	0	0	2	3	0	1							7	10
	3	2	3	1	2	1	1	2	3													6	9
	4	2	2	2	2			2	1			2	3			0	0			2	1	10	9
	5	2	2	1	1	3	3	3	2	1	1	1	1	2	2	2	2	2	3	2	2	19	19
	6	0	0	0	0	1	1	2	2	0	0	0	1	0	0	0	0					3	4
	7	0	0	0	0	0	0	1	1	0	0	0	0	2	0							3	1
	8	2	3	0	0	1	3	1	1	0	0											4	7
	9	2	2	2	3	2	3	1	1	1	3											8	12
	10	1	1	0	0	1	1	1	1	1	1	2	1	1	1	0	0	1	1	0	0	8	7
	11	2	2	0	0	0	0	0	0													2	2
	12	2	3	1	1	1	3	1	3	1	1	0	0	0	1	0	0	0	0	1	1	7	13
	13	1	1	1	1	2	3	2	3	2	3	2	3	2	3	2	3					14	20
	14	0	0	2	2	0	2	0	1	1	2	1	1									4	8
	15	2	3	1	2	3	3															6	8
	16	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	17	1	1	2	3	1	1	1	2	1	1	2	2	2	1	2	1	1	1	15	2	28	15
	Co-located team total	21	27	16	21	17	26	21	25	8	12	13	16	11	11	7	7	4	5	20	6	138	156
Virtual teams	18	1	1	1	3	2	2	2	3	2	1	1	3	2	2							11	15
	19	2	1	1	1	2	2															5	4
	20	3	3	2	2	0	1															5	6
	21	1	1	1	1	1	1	2	3	1	2	2	3	1	2	0	2					9	15
	22	0	0	1	2	1	2	0	0	1	1											3	5
	23	0	0	1	1	0	0	0	0	0	0											1	1
	24	0	0	1	3	1	1	1	2	2	3	1	3	0	1	0	0					6	13
	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	1	0	0	2	1	0	1			0	0	0	0	0	0	2	3
	27	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2
	28	0	0	0	0	0	0	3	3	0	0	0	1	0	1	2	3	0	0	2	1	7	9
	29	0	0	0	0	1	1	0	0	1	0	1	1	1	1	1	0	1	0	1	0	7	3
	30	0	3			2	3	1	1	2	2	1	3	1	1	1	2	2	3	2	3	12	21
	Virtual team total	7	9	8	13	10	14	9	12	11	11	6	15	5	8	4	7	3	4	5	4	68	97
	Grand Total	28	36	24	34	27	40	30	37	19	23	19	31	16	19	11	14	7	9	25	10	206	253

Table C.11: Picture completion title originality scores

C.4 Marker assessed creativity

	Team Number	Marker A Creativity	Marker B Creativity
Co-located teams	1	2	2
	2	2	1
	3	0	0
	4	0	0
	5	2	2
	6	2	0
	7	2	1
	8	0	0
	9	0	0
	10	0	0
	11	0	0
	12	1	1
	13	2	2
	14	2	1
	15	1	2
	16	0	0
	17	2	1
	Co-located team total	18	13
Virtual teams	18	1	0
	19	2	0
	20	1	2
	21	0	0
	22	2	2
	23	2	2
	24	2	2
	25	2	1
	26	0	0
	27	2	2
	28	0	0
	29	0	0
	30	2	0
	Virtual team total	16	11
	Grand total	34	24

Table C.12: Picture construction marker assessed creativity scores

		Screen number																					
	Team Number	1		2		3		4		5		6		7		8		9		10		Total A	Total B
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B		
Co-located teams	1	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2	2					15	14
	2	0	1	2	2	2	1	1	1	1	0	2	2	2	2							10	9
	3	1	0	2	1	0	0	1	1													4	2
	4	2	1	2	1			2	1			2	1			1	0			1	0	10	4
	5	2	2	2	0	2	2	2	2	1	1	1	1	0	1	2	1	2	1	2	0	16	11
	6	2	2	2	1	2	2	2	2	1	0	2	0	1	0							12	7
	7	0	0	2	1	0	0	0	0	2	0	2	1	2	0							8	2
	8	2	2	2	1	1	1	2	1	0	0											7	5
	9	1	0	2	0	1	0	2	1	2	0											8	1
	10	0	1	2	2	2	1	1	0	1	0	2	0	2	1	2	2	1	2	1	0	14	9
	11	1	0	1	0	2	2	2	2													6	4
	12	2	0	2	2	2	2	1	1	1	0	2	1	2	0	1	0	2	1	2	1	17	8
	13	0	0	2	1	2	2	0	0	1	0	2	2	0	0	0	0					7	5
	14	2	2	2	0	2	2	0	0	2	1	2	0									10	5
	15	2	1	2	2	0	0															4	3
	16	0	0	0	0	2	2	1	1	1	0	2	0	0	0	2	0	0	0	1	0	9	3
	17	0	1	1	0	2	1	2	1	2	2	2	2	2	2	1	0	0	1	2	0	14	10
	Co-located teams total	19	14	30	16	23	19	21	16	17	6	23	12	13	8	11	5	5	5	9	1	171	102
Virtual teams	18	2	2	1	0	2	0	2	1	2	1	2	2	0	0							11	6
	19	2	2	2	2	2	2															6	6
	20	2	2	2	2	0	0															4	4
	21	0	0	0	0	1	0	2	1	2	0	2	2	2	2	1	0					10	5
	22			2	2	2	0	2	2	0	0											6	4
	23	1	0	2	1	1	0	2	1	1	0											7	2
	24	1	0	2	2	0	0	0	0	2	1	2	1	0	0	1	0					8	4
	25	2	0	2	2	1	0	0	0	1	0	1	0	2	0	1	0	0	0	2	0	12	2
	26	0	0	2	1	2	1	0	0	1	0	0	0			0	0	0	1			5	3
	27	1	0	0	0	1	0	1	1	0	0	2	2	2	0	2	0	0	0	1	0	10	3
	28	1	0	2	2	0	0	2	1	0	0	2	0	2	0	2	0	0	0	2	1	13	4
	29	1	0	0	0	1	0	2	1	2	2	1	0	2	2	2	0	2	2	2	1	15	8
	30	2	2			0	0	2	2	2	1	1	0	2	2	0	0	1	1	2	2	12	10
	Virtual teams total	15	8	17	14	13	3	15	10	13	5	13	7	12	6	9	0	3	4	9	4	119	61
	Grand Total	34	22	47	30	36	22	36	26	30	11	36	19	25	14	20	5	8	9	18	5	290	163

Table C.13: Picture completion marker assessed creativity scores

		Screen number																																																						Total A	Total B
	Team Number	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25		26		27		28			
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B		
Co-located teams	1	1	1	2	2	0	0	2	2	2	1	2	1	0	1	1	0	1	2	2	2	2	0	2	2	1	1																															18	15
	2	0	0	0	0	2	2	1	1	2	2	1	0																																													6	5
	3	0	0	2	2	0	0	2	0	1	1	1	0	0	2	2	1	2	0	1	0	0	0	0	0	0	0																															11	6
	4	1	2	1	1	0	0	1	2	1	1	2	0																																													6	6
	5	0	0	2	1	2	2	2	2	0	1	2	2	2	1	0	0	1	2	1	0	2	1	1	1	1	2	2	1	2	2																											20	18
	6	1	1	2	2	2	2	1	1	0	1	1	1	2	2	0	2	1	1																																							10	13
	7	2	2	0	0	2	2																																																			4	4
	8	2	2	1	1	2	0																																																			5	3
	9	0	0	2	2	1	1	2	2	0	0	0	1	2	1			0	0																																							7	7
	10	1	2			0	0	0	0	0	0	2	2	0	0	0	0	2	2	1	0	2	2																																			8	8
	11	0	0	2	2	0	1	2	2																																																	4	5
	12	2	2	2	1	2	2					0	0	0	0	1	2	2	2	0	0	2	0	0	1	1	1	0	0	2	2	0	0																									14	13
	13	2	1	2	1	0	0	1	1	0	1	2	2	2	1	2	2																																									11	9
	14	1	1	0	0	1	2	2	2	2	1	2	1	0	0	1	2	1	1	1	1																																					11	11
	15	0	1	1	1	0	1																																																			1	3
	16	0	0	0	0	0	0	2	1																																																	2	1
	17	2	2	2	1	0	0	2	2	0	0	2	2	1	1	2	1	0	0	1	0	2	1	1	0	1	1	0	1	0	1																											16	13
	Co-located teams total	15	17	21	17	14	15	20	18	8	9	17	12	9	9	9	10	10	10	7	3	10	4	4	4	4	5	2	2	4	5	0	0																									154	140
Virtual teams	18	2	2	1	2	1	0	1	0																																																	5	4
	19	0	0	1	1	0	0	2	0	0	1	2	0																																													5	2
	20	1	1	1	0	0	0	2	2	2	1																																															6	4
	21	0	0	1	1	0	0	1	1	0	1	2	2	0	0			2	2	1	2	0	0	0	1																																	7	10
	22	2	1	0	0	0	2	0	0	2	2	1	1	0	0																																											5	6
	23	0	0	2	1	0	0	2	1	1	0	0	0	2	2	0	0	2	2	2	2	0	1	0	1	2	2	2	1																													15	13
	24	2	1	2	1	0	0	1	1	2	1	2	1	2	2	2	2	1	1	2	2	0	0	2	1	0	0																															18	13
	25	1	1	0	1	0	0	0	0	1	1	2	2	2	2	1	1	2	1	2	2	1	1	1	2	2	1	2	2																													17	17
	26	0	0	2	2	2	2	0	0	0	2	2	1	2	1																																											8	8
	27	1	1	0	0	0	0	0	0	1	0	0	0	1	1	0	0																																									3	2
	28	0	0	1	1	1	1	2	1			2	2	2	1	2	2	1	2	0	0	1	0	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	1	1	1	1	2	1	1	0	1	1	1	1	1	31	29
	29	2	2	2	1	1	1	1	0	1	1	2	1	1	2			1	1	2	2			1	1	2	1	0	0	2	2	1	0	1	1	2	2																					22	18
	30	2	2	2	2	1	1	1	2	1	1	2	2	2	2	2	1	2	2	0	0	2	2																																			17	17
	Virtual teams total	13	11	15	13	6	7	13	8	11	11	17	12	14	13	7	6	11	11	9	10	4	4	6	8	7	5	5	4	3	3	2	1	2	2	3	3	1	1	1	1	2	1	2	1	1	1	1	2	1	1	0	1	1	1	1	1	159	143
	Grand Total	28	28	36	30	20	22	33	26	19	20	34	24	23	22	16	16	21	21	16	13	14	8	10	12	11	10	7	6	7	8	2	1	2	2	3	3	1	1	1	1	2	1	2	1	1	1	1	2	1	1	0	1	1	1	1	1	313	283

Table C.14: Parallel lines marker assessed creativity

C.5 Fluency

	Team	Picture Completion	Parallel Lines	Alternative Uses	Team Total
Co-located teams	1	8	13	31	52
	2	7	6	23	36
	3	4	13	21	38
	4	10	6	21	37
	5	10	15	27	52
	6	8	9	17	34
	7	7	3	15	25
	8	5	3	39	47
	9	5	9	36	50
	10	10	11	20	41
	11	4	4	20	28
	12	10	16	24	50
	13	8	9	57	74
	14	6	10	29	45
	15	3	4	33	40
	16	10	4	11	25
	17	10	16	29	55
	Total	125	151	453	729
Virtual teams	18	7	4	28	39
	19	3	6	25	34
	20	3	5	16	24
	21	8	12	30	50
	22	5	7	32	44
	23	5	14	31	50
	24	8	13	48	69
	25	10	14	31	55
	26	10	7	11	28
	27	10	9	13	32
	28	10	28	47	85
	29	10	19	25	54
	30	10	11	22	43
	Total	99	149	359	607

Table C.15: Fluency scores per team, activity and treatment

C.6 Team Meta Data

	Team	Picture Construction	Picture Completion	Parallel Lines	Total
Co-located teams	1	15,847	10,551	12,961	39,359
	2	8,173	11,129	10,417	29,719
	3	8,392	13,812	9,589	31,793
	4	14,020	14,162	19,104	47,286
	5	10,524	10,190	9,340	30,054
	6	14,021	9,959	10,051	34,031
	7	13,871	22,226	20,846	56,943
	8	13,500	11,944	21,066	46,510
	9	19,355	19,280	18,836	57,471
	10	10,470	11,075	9,034	30,579
	11	13,565	12,802	13,022	39,389
	12	8,954	8,403	14,945	32,302
	13	16,768	18,394	18,243	53,405
	14	9,527	13,694	14,135	37,356
	15	20,075	16,237	16,041	52,353
	16	8,069	5,829	9,327	23,225
	17	18,910	19,355	19,255	57,520
	Total	224,041	229,042	246,212	699,295
Virtual teams	18	8,705	21,815	11,495	42,015
	19	13,056	11,723	14,912	39,691
	20	10,975	13,593	11,382	35,950
	21	21,368	14,294	16,293	51,955
	22	16,792	18,444	22,840	58,076
	23	8,773	5,901	7,030	21,704
	24	16,115	5,543	7,423	29,081
	25	14,522	14,769	15,914	45,205
	26	7,608	6,941	7,914	22,463
	27	8,069	14,666	14,228	36,963
	28	13,438	18,337	11,266	43,041
	29	8,526	12,212	9,774	30,512
	30	14,412	12,462	9,900	36,774
	Total	162,359	170,700	160,371	493,430

Table C.16: Summary of total actions performed per team, per activity

	Team	Picture Construction	Picture Completion	Parallel Lines	Total
Co-located teams	1	00:23:14	00:07:49	00:10:27	0:41:30
	2	00:14:25	00:10:23	00:10:33	0:35:21
	3	00:19:33	00:15:44	00:10:28	0:45:45
	4	00:23:38	00:16:44	00:16:14	0:56:36
	5	00:23:01	00:10:39	00:09:43	0:43:23
	6	00:20:32	00:11:06	00:12:12	0:43:50
	7	00:20:15	00:16:02	00:20:44	0:57:01
	8	00:18:52	00:15:06	00:21:34	0:55:32
	9	00:23:16	00:16:17	00:17:31	0:57:04
	10	00:18:22	00:09:47	00:10:02	0:38:11
	11	00:20:43	00:13:50	00:14:20	0:48:53
	12	00:19:37	00:12:25	00:12:20	0:44:22
	13	00:23:25	00:14:11	00:15:51	0:53:27
	14	00:19:49	00:12:44	00:13:16	0:45:49
	15	00:22:46	00:20:07	00:20:51	1:03:44
	16	00:17:15	00:05:55	00:10:34	0:33:44
	17	00:17:28	00:11:47	00:12:18	0:41:33
	Total	5:46:11	3:40:36	3:58:58	13:25:45
Virtual teams	18	00:14:51	00:35:13	00:14:20	1:04:24
	19	00:20:08	00:14:12	00:14:50	0:49:10
	20	00:22:53	00:19:47	00:15:05	0:57:45
	21	00:22:25	00:14:02	00:12:55	0:49:22
	22	00:23:12	00:19:31	00:17:56	1:00:39
	23	00:21:44	00:09:19	00:07:02	0:38:05
	24	00:15:45	00:08:24	00:07:14	0:31:23
	25	00:18:43	00:14:09	00:12:05	0:44:57
	26	00:20:54	00:06:24	00:08:24	0:35:42
	27	00:12:00	00:13:02	00:12:37	0:37:39
	28	00:23:37	00:17:18	00:06:27	0:47:22
	29	00:10:34	00:10:33	00:07:36	0:28:43
	30	00:20:47	00:11:23	00:08:36	0:40:46
	Total	4:07:33	3:13:17	2:25:07	9:45:57

Table C.17: Summary of total time spent drawing per team, per activity.
N.B. This may well appear larger than the total time per activity because this is the total time per team and therefore includes each participants time spent drawing.

C.7 Number of utterances

	Team Number	Speaker 1	Speaker 2	Speaker 3	Test Admin	Total Utterances
Co-located teams	6	57	55	49	0	161
	7	36	8	39	3	86
	8	44	33	40	0	117
	10	60	69	67	13	209
	11	20	1	18	0	39
	12	12	33	30	0	75
	14	82	80	43	4	209
	15	105	122	73	2	302
	16	7	4	0	0	11
	17	36	80	46	5	167
Virtual teams	18	83	87	36	11	217
	19	30	23	4	10	67
	21	60	40	63	3	166
	22	23	39	36	7	105
	23	68	52	54	15	189
	24	45	25	37	6	113
	26	15	17	29	0	61
	27	33	39	6	1	79
	29	47	40	31	0	118
	30	42	22	25	0	89

Table C.18: Picture completion number of utterances

		Speaker 1	Speaker 2	Speaker 3	Test Admin	Total
Co-located teams	6	62	62	55	4	183
	7	23	10	23	4	60
	8	39	35	31	15	120
	10	61	49	70	27	207
	11	23	12	16	9	60
	12	41	27	37	4	109
	14	35	77	59	4	175
	15	89	60	99	5	253
	16	6	6	2	0	14
	17	64	27	47	0	138
Virtual teams	18	78	64	19	2	163
	19	32	39	6	3	80
	21	52	61	45	0	158
	22	33	19	23	0	75
	23	54	45	34	3	136
	24	39	23	30	1	93
	26	45	39	38	4	126
	27	57	49	30	6	142
	29	45	59	39	3	146
	30	19	35	24	5	83

Table C.19: Parallel lines number of utterances

Appendix D

Findings Charts

D.1 Originality

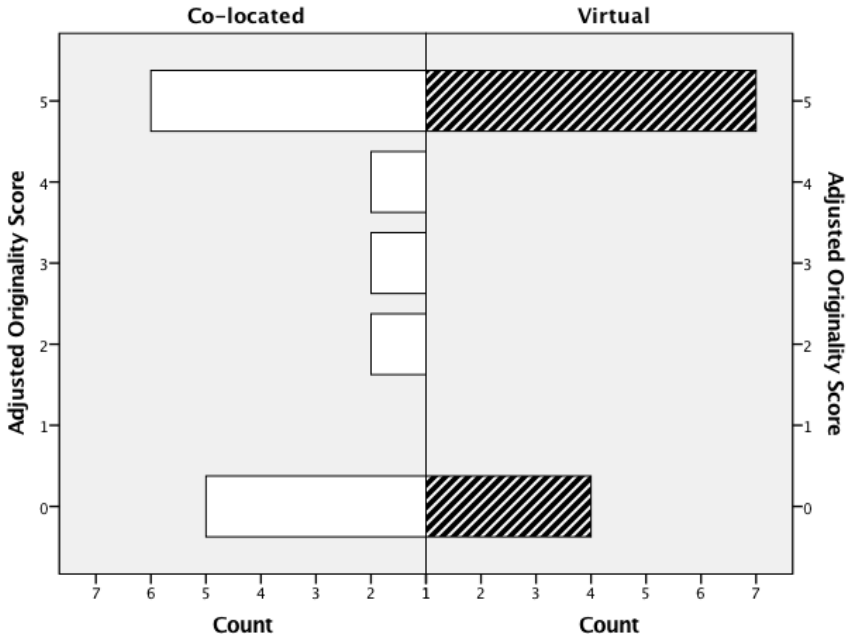


Figure D.1: Picture Construction originality scores

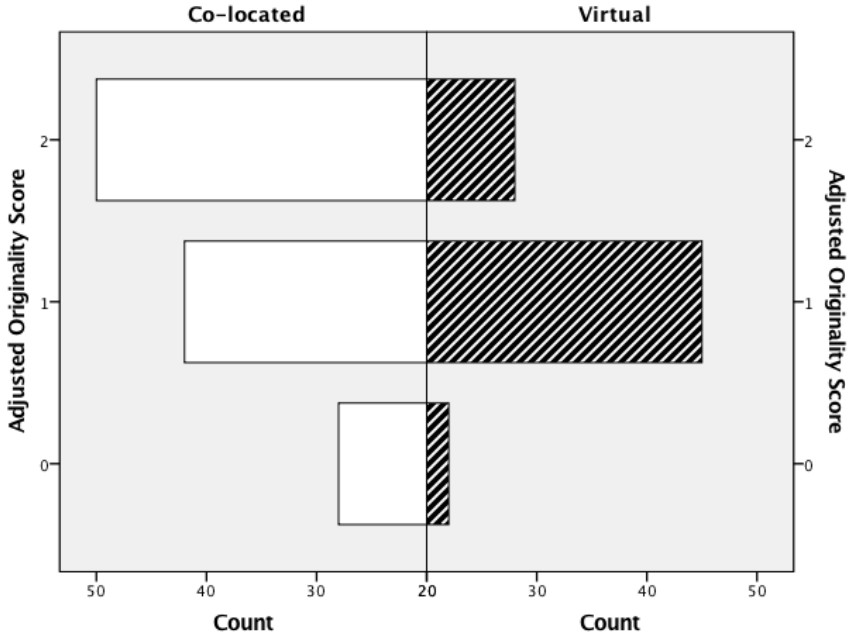


Figure D.2: Picture Completion originality scores

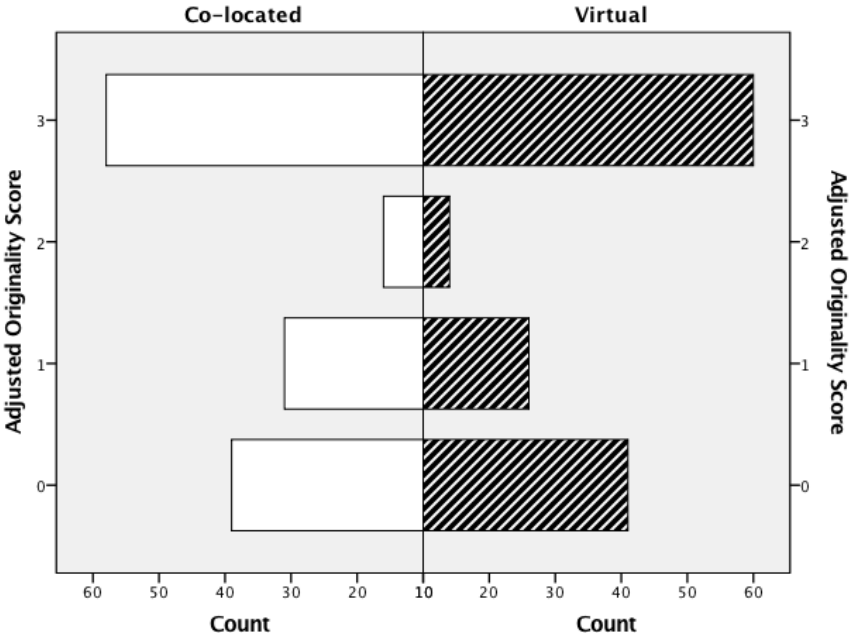


Figure D.3: Parallel Lines originality scores

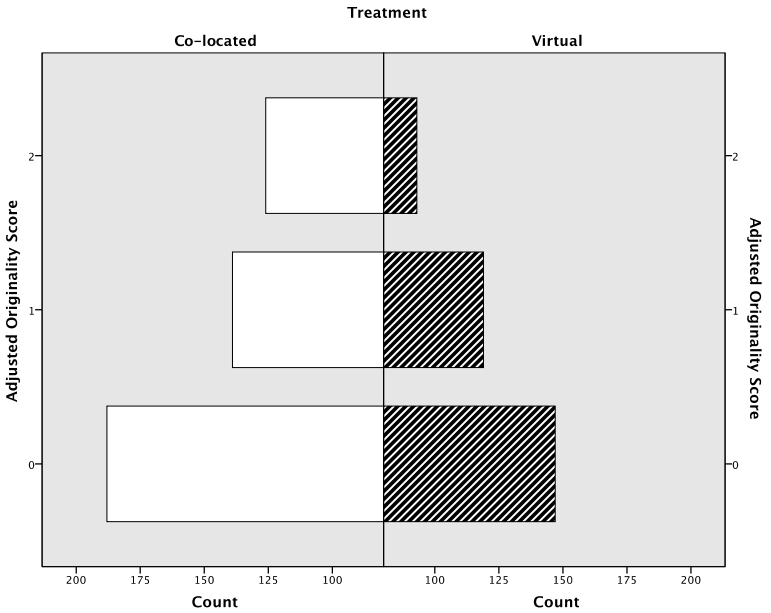


Figure D.4: Alternative Uses originality scores

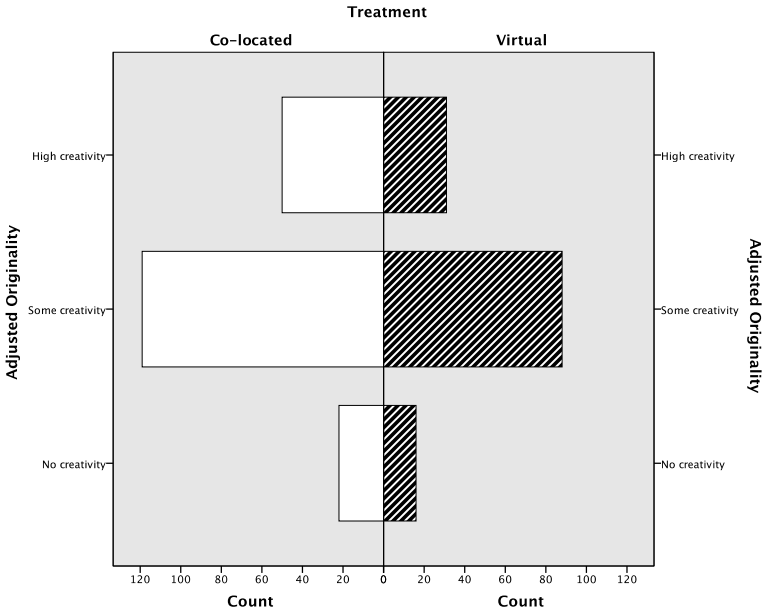


Figure D.5: Design Questions originality scores

D.2 Elaboration

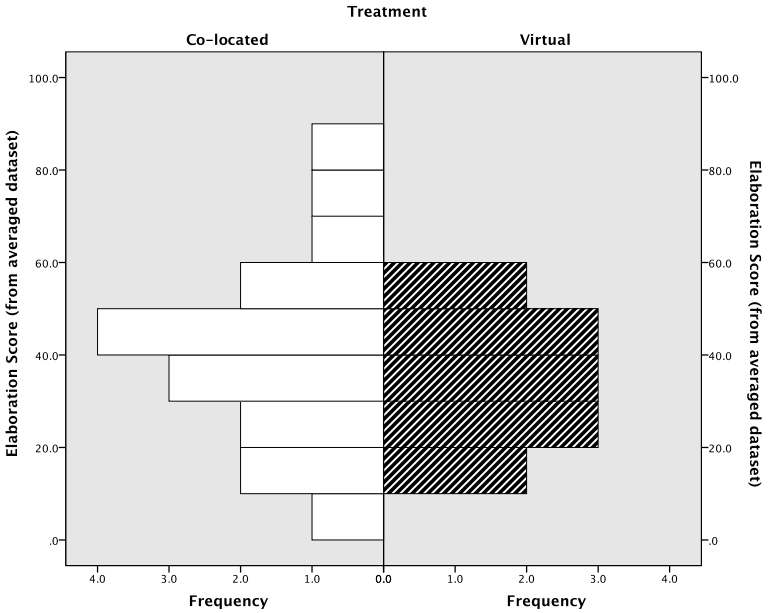


Figure D.6: Picture Construction elaboration scores

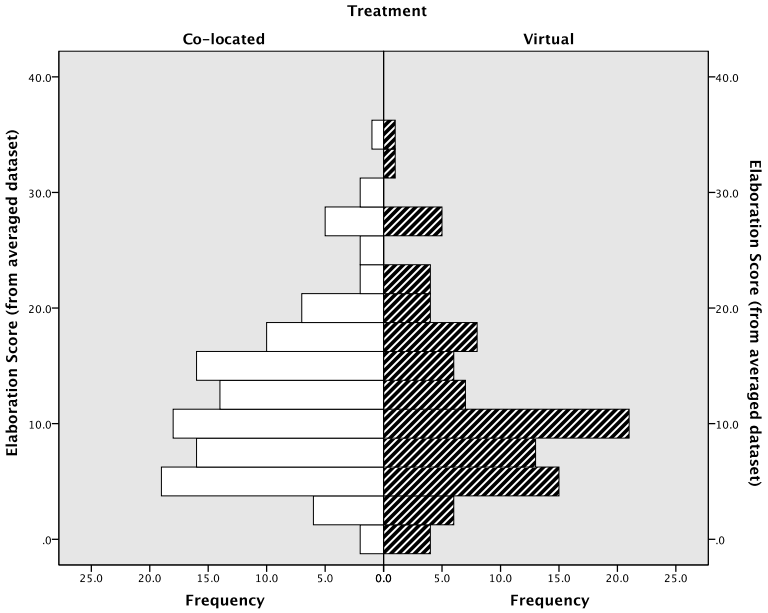


Figure D.7: Picture Completion elaboration scores

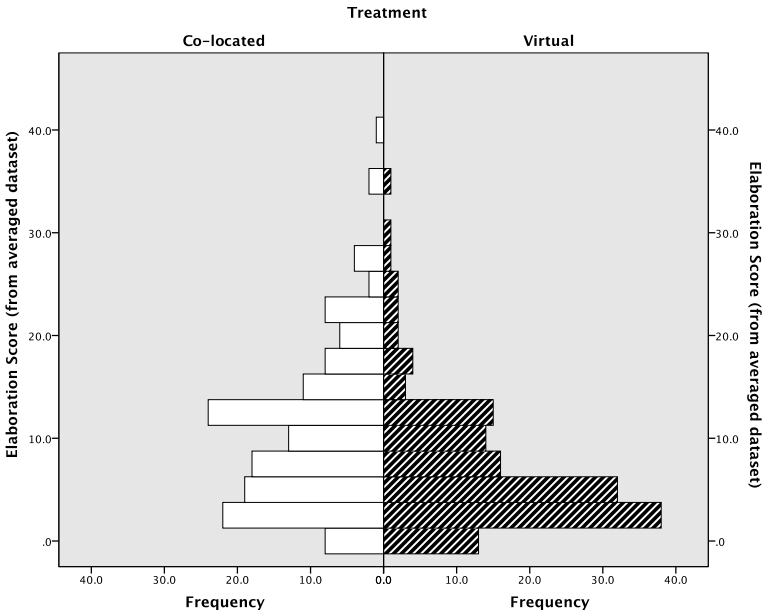


Figure D.8: Parallel Lines elaboration scores

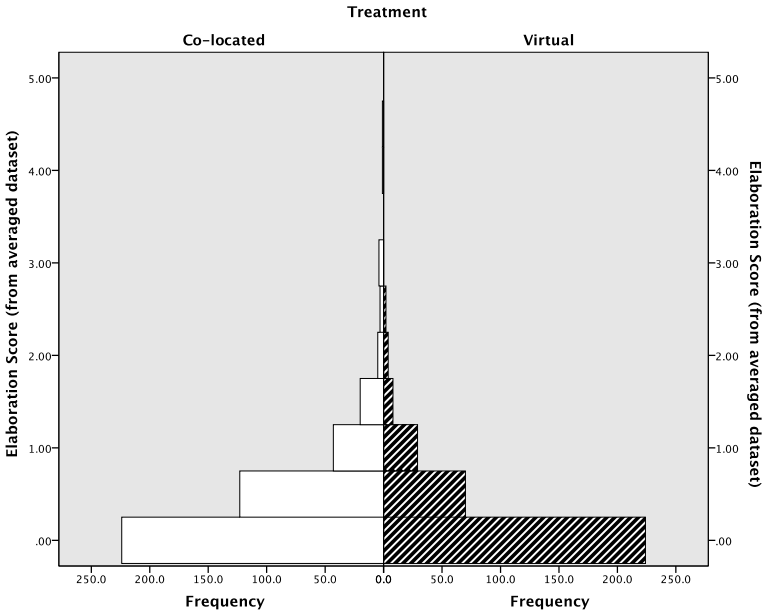


Figure D.9: Alternative Uses elaboration scores

D.3 Fluency

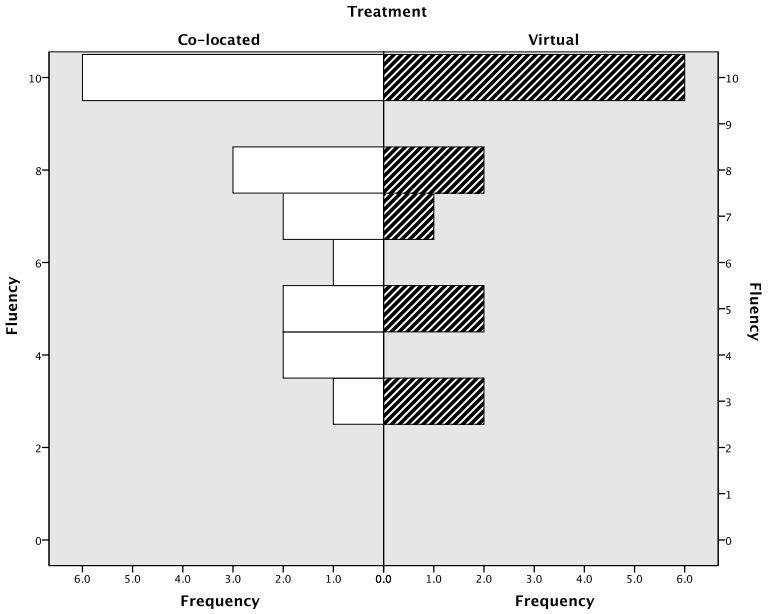


Figure D.10: Picture Completion fluency

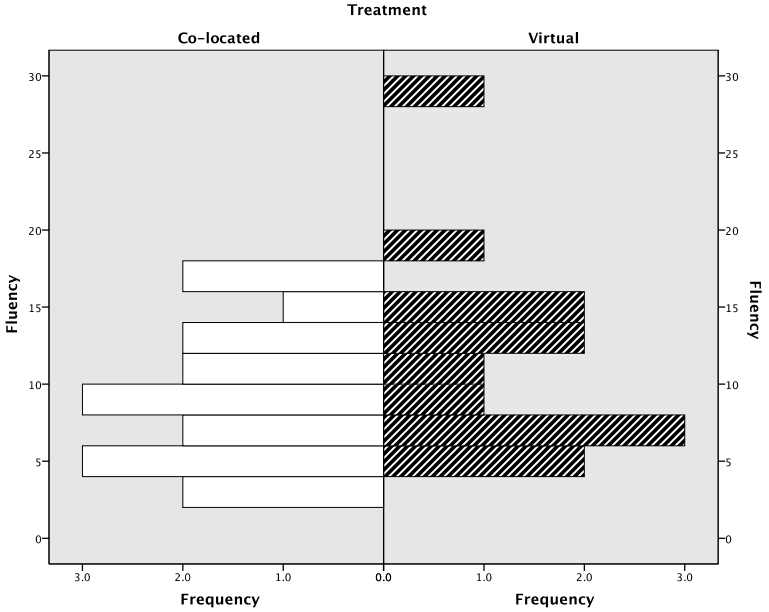


Figure D.11: Parallel Lines fluency

D.4 Total drawing actions per activity

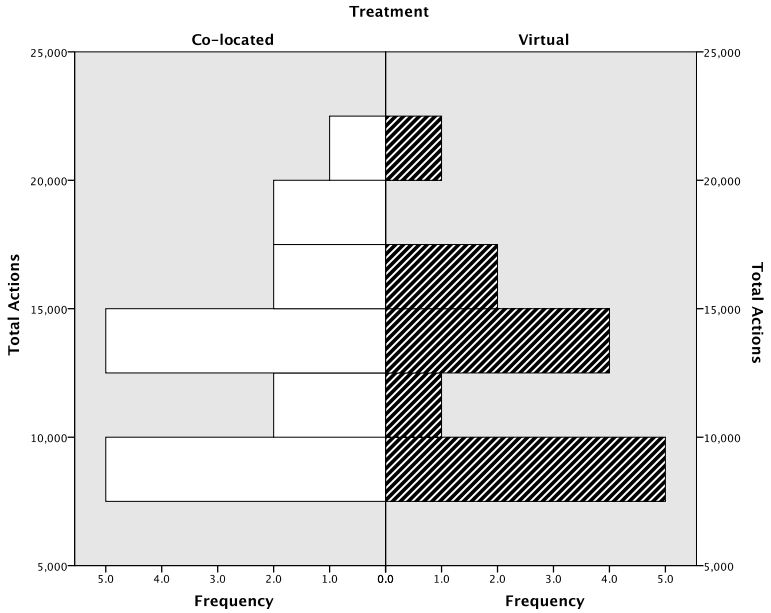


Figure D.12: Picture Construction total drawing actions

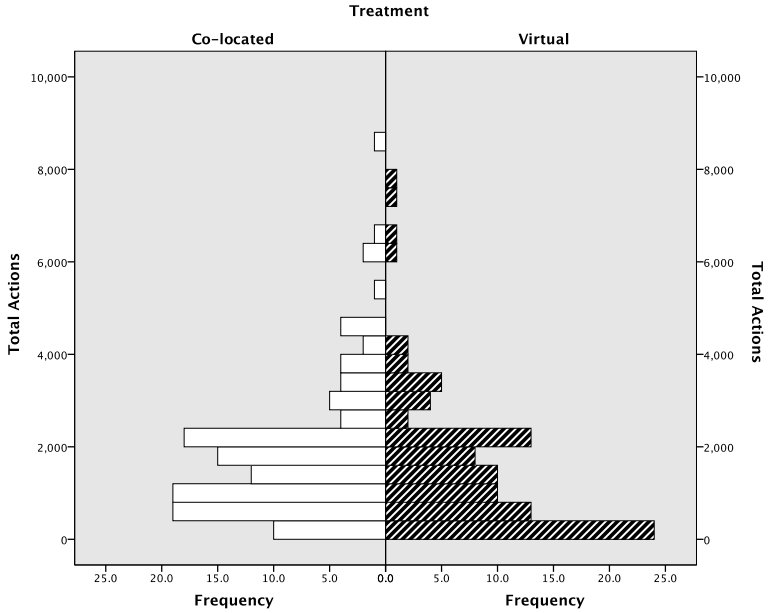


Figure D.13: Picture Completion total actions per drawing

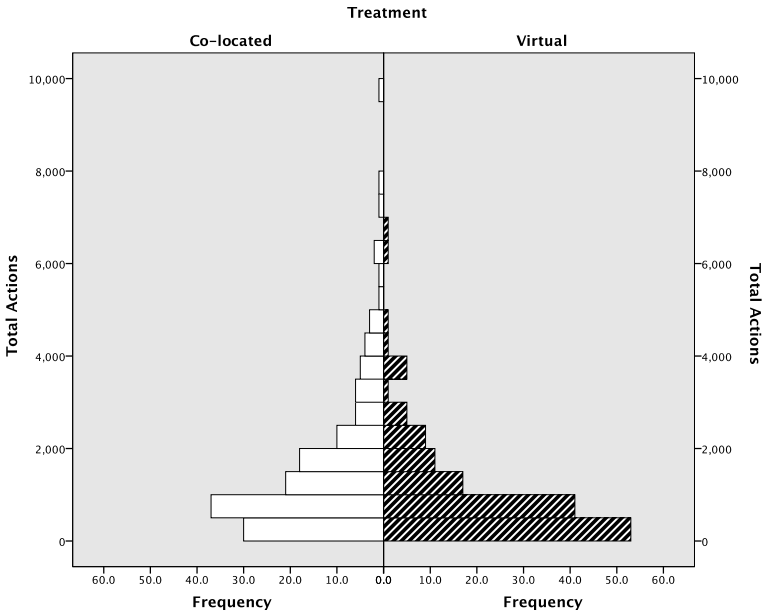


Figure D.14: Parallel Lines total actions per drawing

D.5 Total Time Spent Drawing per activity

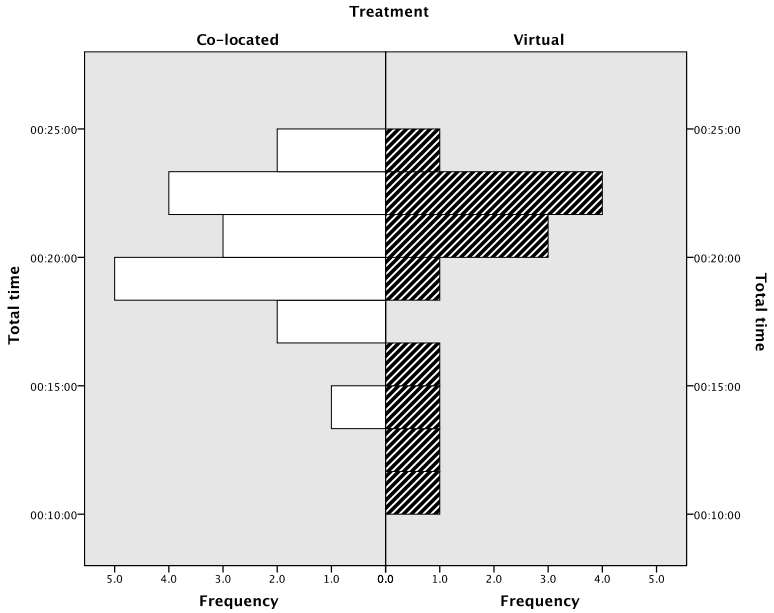


Figure D.15: Picture Construction total drawing time

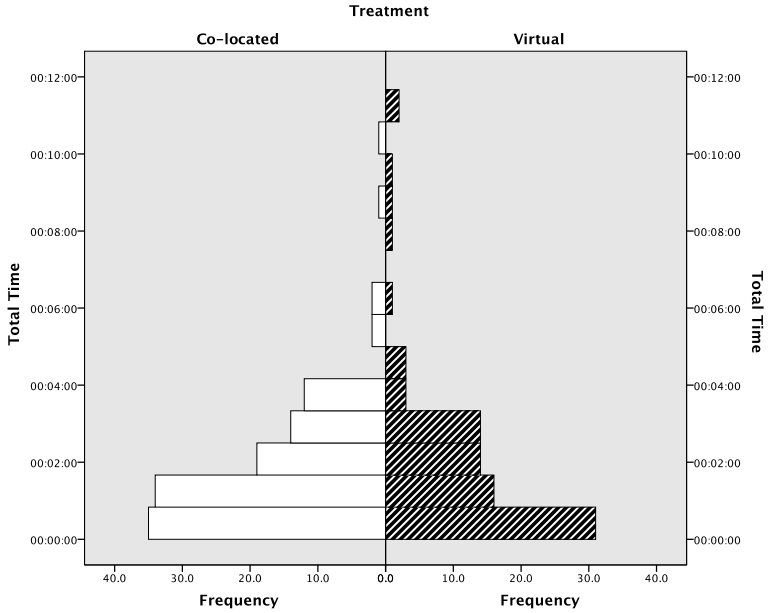


Figure D.16: Picture Completion total time per drawing

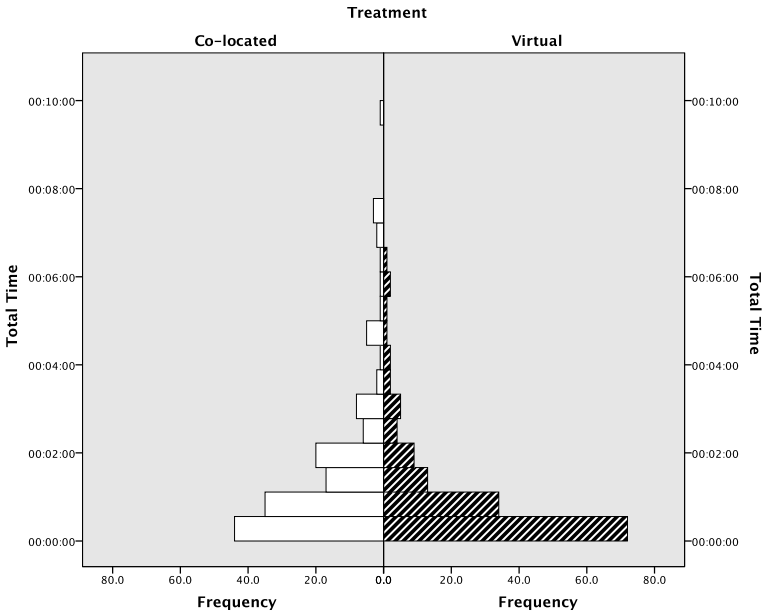


Figure D.17: Parallel Lines total time per drawing

Appendix E

Participant Questionnaire

This is the final questionnaire that teams encountered reproduced verbatim:

> Please can you complete the following 60 second questionnaire to finish (there are only 13 questions). The data gathered is only used to help with the analysis, we won't share it with anyone.
>
> 1. First Name
> 2. Surname
> 3. Test Access Code Please enter the access code you used at the start of the test
> 4. Lancaster University Email Address This is to allow us to arrange a short follow up interview (if needed), your email address will not be shared.
> 5. What is your current role at the University?
>   (a) Undergraduate Student
>   (b) Masters Student
>   (c) PhD Student
>   (d) Post-Doc Student
>   (e) Lecturer / Professor

(f) Administrator / Support Staff

6. What is your main area of study? E.g. Studying for a degree in Business Studies Bsc = Business / Management. You can choose multiple if necessary.

   (a) Accounting and Finance
   (b) Art / Design
   (c) Biology
   (d) Business / Management
   (e) Chemistry
   (f) Computer Science
   (g) Engineering
   (h) English
   (i) Geography
   (j) History
   (k) Law
   (l) Linguistics
   (m) Maths
   (n) Physics
   (o) Psychology
   (p) Sociology
   (q) Economics
   (r) Not applicable (Work in a Support or Administrative Function)

7. To what extent have you studied art or design before? Please select the level of previous experience you have.

   (a) No formal training - finger painting as a kid
   (b) Enthusiastic amateur - I keep drawing, doodling and painting as a hobby
   (c) I studied art to GCSE or Equivalent (Age 16)

(d) I studied art to A-level or Equivalent (Age 18)

(e) I'm doing / I've done a degree in art

(f) I'm doing / I've done a related art degree (I will get / have got a BA in a related field)

(g) I'm studying for / have got a masters in art

(h) I've worked in a professional capacity as an artist, illustrator or similar

8. Have you ever heard of the Torrance Tests of Creative Thinking?

   (a) Yes

   (b) No

9. At the start of this test, how well did you know your team mates?

   (a) 0 - I'd never met them before

   (b) 1 - I know at least one of them well enough to say hello

   (c) 2 - We know each other fairly well, we'd stop to chat to one another

   (d) 3 - We know each other fairly well, we go for lunch, coffee, beer together occasionally

   (e) 4 - We know each other well - we're good friends

10. Please select the option that best describes your Gender This is just to explore the distribution of participants - to check we are being representative

    (a) Male

    (b) Female

    (c) Other

    (d) Prefer not to answer

11. Age

    (a) 18 - 21

    (b) 22 - 25

    (c) 26 - 35

(d) 36 - 50

(e) 51 - 65

(f) 65+

12. Is English your Native Language?

    (a) Yes

    (b) No

13. What is your home country?

Thank you once again for participating in this study - please see the test convener for your hard earned reimbursement.