THE DYNAMIC COGNITIVE PROCESSES UNDERLYING CREATIVITY

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Abstract

Despite the growing importance of creativity and innovation at work, the abilities that allow people to develop new and useful ideas in the workplace remain unclear. Advances in research suggest that several core cognitive processes underlie creative thought, such as problem finding, information gathering, incubation, idea generation, evaluation, and implementation. Although multiple studies have investigated these processes individually, few researchers have observed the joint impact of these processes on creativity or its dynamism.

Current process models suggest that we go through these processes in a linear and logical sequence, from finding a problem to the implementation of an idea. However, some scholars have posited that multiple iterations or feedback loops may exist throughout the creative problem-solving effort. To the author's knowledge, this study is the first to empirically investigate the feedback loops or transitions between processes and how they are related to creative output.

The first study employed a mixed-method approach to investigate the core cognitive processes underlying creativity by presenting 24 participants with an ill-defined problem to solve by thinking out loud. The frequencies of and time spent engaging in each cognitive process, as well as the transitions from one process to another, were investigated quantitatively. A deductive thematic analysis was then conducted on the high and low creative output individuals to further explore these cognitive processes and to understand whether there was a difference in how the participants engaged in them. Results revealed that the frequencies, time spent, and number of transitions between idea generation, evaluation and implementation were positively correlated with creative output. The total number of transitions was also found to be positively related to creativity scores. These findings were also supported by the qualitative analysis conducted.

Following the findings from the first study, Study 2 involved the same 24 participants in an online experiment designed to capture the dynamic cognitive processes underlying creativity in an objective and automated manner. The results from this study cross-validated adequately with the results obtained in Study 1, and the frequencies and time spent engaging in idea generation and implementation were found to be positively related to creative output. No significant correlations were found between the transitions between processes and creative output; however, this outcome might have been due to the small sample size. Nevertheless, the total number of transitions engaged was significantly positively related to creative output.

The online experiment was then tested on a larger sample size (N = 146). A series of correlational and regression analyses confirmed the findings from Studies 1 and 2. The frequencies of idea generation, evaluation and implementation and time spent engaging in evaluation and implementation were found to be positively related to creative output, supporting the previous findings. Two subsequent multiple regression analyses revealed that the frequencies and time spent engaging in the processes had a combined effect on creative output, but only implementation was found to have a significant independent effect on creativity in both models.

Additionally, significant differences were found between high and low creative output individuals when exploring the percentage of time spent engaging in certain processes compared to the other processes. Furthermore, an inverted-U relationship was also observed between information gathering and creative output as well as between overall time taken and creativity. The number of transitions made during the task were also predictive of creative output, regardless of time spent engaging in the task. Mediation analyses were then conducted to test the causal relationship between idea generation and creative output. The results revealed a full mediation effect of idea generation on creative output through the transitions from idea generation to implementation.

The results were largely consistent across all three studies. The frequency and time spent in idea generation, evaluation and implementation were more or less found to be positively correlated with creative output in all three studies, including the frequent shifts between them. The creative process appears to consist of multiple feedback loops up to the point where a solution to an ill-defined problem is fully formed. Indeed, the total number of transitions engaged were positively correlated with creativity output across all three studies. Investigating these loops revealed that certain transitions from one process to another were predictive of creative output in Study 3. The process of generating a solution through a form of a generate-and-refine method appeared to be the most effective thought sequence or strategy in predicting creativity.

This thesis provides new insights into the cognitive processes underlying creativity, how they function independently and holistically and, most importantly, how frequent shifts between the processes can predict creative output. This research also addresses the need to develop an instrument that captures the creative process and its dynamism in an objective, valid and cost-effective manner. Furthermore, the research findings also have several implications for creativity research and practice, such as creativity interventions. Lastly, this research puts forward alternative strategies that could be useful in both organisational and educational settings.

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Related Publications and Conference Presentations

Chapter 1 and 5:

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Study 1:

Palermo, G. M., & Moneta, G. B. (2022, January 11–14). *On your marks, get set, create! Impact of time pressure on the creative process* [Oral presentation paper to be presented]. The 20th Congress of the European Association of Work and Organizational Psychology, Glasgow, United Kingdom.

Study 3:

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Chapter 1: Introduction

1.1. What Is Individual Creativity?

In today's ever-changing and turbulent world, coupled up with the consequences of the ongoing COVID-19 pandemic, many organisations around the world are under pressure to remain competitive and survive. Creativity and innovation in the workplace are considered crucial to organisational sustainability (Amabile, 1988; Gallate et al., 2012; Ko & Butler, 2007) as well as survival (Nystrom, 1990). Indeed, the competitiveness and survival of any organisation is contingent on the generation of new business strategies, processes, or products. In these desperate times of uncertainty, the need for organisational innovation could not be more crucial. Research suggests that employee creativity plays a key role in organisational innovation (Amabile, 1996; Nonaka, 1991). Despite the growing importance of creativity and innovation at work, understanding how people develop new and useful concepts remains an enigma.

Creativity is considered a multifaceted complex phenomenon, which can be researched in terms of behaviour (Barron & Harrington, 1981; Runco, 2005), motivation (Hennessey, 2010; Runco, 2005), cognition (Finke et al., 1992; Mobley et al., 1992; Wallas, 1926), and environment (Amabile, 1996; Mumford, Whetzel et al., 1997). Consequently, numerous definitions of creativity have emerged. Nevertheless, scholars generally believe that creativity involves an amalgamation of originality, quality, and usefulness (Amabile 1996; Mumford et al., 2012). Plucker et al. (2004) have more broadly and inclusively defined creativity as "the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" (p. 90). However, questions remain as to the particular abilities people hold that allow them to produce novel, high-quality, and useful ideas, as defined in their social group.

Research has extensively examined creativity in the workplace via the psychometric approach. Guilford (1950) proposed that divergent thinking – the ability to produce numerous solutions to a problem – represents a key capability underlying creative thought. This notion of divergent thinking led to a proliferation of standardised tests, such as the Torrance Tests of Creative Thinking (TTCT). Although many studies have used the TTCT or similar tests to assess creativity in individuals, some researchers have argued that divergent thinking tests have poor predictive validity in relation to creative performance (Baer, 1993; Mumford & Gustafson, 1988), and others have asserted that these tests are inadequate measures of creativity (Amabile, 1996; Sternberg & Lubart, 1999).

In recent years, there has been calls to integrate approaches in order to understand and assess creativity in real-life work settings (e.g. Mumford et al., 2009; Sternberg, 2006a). Many researchers agree that cognition plays a key role in creativity (Finke et al., 1992; Lubart, 2001; Mumford, Supinski et al., 1997). Work on discerning the core mental operations involved in creativity began just over a century ago (Dewey, 1910; Wallas, 1926). Notable progress has been made since then, with researchers proposing an array of process models (e.g. Isaksen et al., 2000; Mumford et al., 1991; Sternberg, 2006a). Although these models differ in terms of the number of processes involved, the nomenclature applied to each process, and how the processes interact with each other, they share common fundamental mental operations.

Recently, Sawyer (2012) organised the various process models to form an integrated framework that encapsulates the core stages of the creative process. This integrated model consists of eight phases: (a) find the problem, (b) acquire the knowledge, (c) gather related information, (d) incubation, (e) generate ideas, (f) combine ideas, (g) select the best ideas, and (h) externalise ideas. This model, like many others (e.g. Isaksen et al., 2000; Mumford et al., 1991; Sternberg, 2006b), assumes that the first mental operation of creative thinking is to identify and define the problem. This process leads to gathering information relevant to the problem, mastering the domain, and then absorbing new information from a wide array of sources. Once the problem has been defined and all relevant knowledge has been acquired, time is required to allow the mind to process all the information to allow for idea generation. Although ideas are generated consciously throughout these stages, they can also emerge spontaneously by unconsciously integrating the accumulated knowledge into new concepts. This unconscious process is known as incubation. These concepts are then organised and reshaped to form new ideas, typically resulting in the generation of more ideas. Thus, this stage is followed by the selection of the best ideas and, finally, their implementation, where ideas are fully formed and executed.

Although research that has observed these processes holistically is lacking, an overwhelming amount of research has examined each of them independently. Using Sawyer's (2012) integrated framework as a guide, this chapter examines the core cognitive processes underlying creative thought and considers the prior research that has observed these processes and their effects in the workplace.

1.2. Cognitive Processes Underlying Creativity

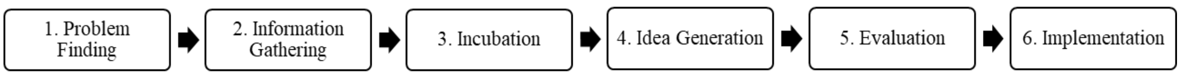
Taxonomy of Cognitive Processes

Figure 1 provides a summary of the various cognitive processes that this dissertation investigates. Sawyer's (2012) *acquire the knowledge* and *gather related information* stages have been combined into *information gathering*, and the *combine ideas* stage will be examined under *idea generation*. *Select the best ideas* has been renamed *evaluation*, and *externalise ideas* has changed to *implementation*. *Idea evaluation* and *evaluation* will be used interchangeably in this thesis, as will *idea implementation* and *implementation*.

1.2.1. Problem Finding

Many scholars have asserted that creativity is fundamentally a type of problem-solving (Guilford, 1967; Kaufmann, 1988; Klahr, 2000). However, researchers claim that creativity occurs when individuals are confronted with an *ill-defined problem* rather than well-defined problem (e.g. Mumford & Gustafson, 1988). The key differences between an ill-defined problem and a well-defined one include the way the problem situation and goal are specified and the number of possible solutions (Mumford et al., 1991; Sawyer, 2012). The problem situation and goals of an ill-defined problem are not clearly specified, and there are multiple solutions to the problem. In contrast, well-defined problems have clearly specified problem situations and goals as well as a single solution (e.g. algebraic problems). In a similar vein, Amabile (1996) specified in her conceptual definition of creativity that the task of developing an idea or product that is both novel and appropriate must be heuristic (where the path to a solution is neither provided nor easily identifiable) rather than algorithmic (where the path to a solution is either provided or easily identifiable). As heuristic tasks do not have clearly specified solutions, it is up to the problem-solver to identify them. This phenomenon has led many researchers to believe that creativity involves problem finding (Amabile, 1996).

Figure 1: *The Cognitive Processes Underlying Creativity*



Problem finding, also described as problem construction (Mumford, Baughman, Threlfall et al., 1996) or problem definition (Csikszentmihalyi, 1999), is the process of outlining the goals and objectives of the problem-solving effort and constructing a plan to structure and guide problem-solving (Mumford et al., 1994). Put more simply, this process involves the ability to identify and construct the problem before trying to solve it. For clarity, the term problem finding will be used in this chapter. In many process models, problem finding is the first stage in the creative process and is believed to be the prerequisite for all other cognitive processes underlying creativity (Finke et al., 1992; Lubart, 2001; Mumford et al., 1991).

Empirical evidence suggests that how a problem is constructed will have a noticeable impact on the generation of creative products and solutions (Getzels, 1979; Mumford et al., 1991; Runco & Okuda, 1988). One of the first studies to observe problem finding in art students found that spending more time and effort formulating and solving a visual problem was strongly related to originality and aesthetic value in the resulting painting (Getzels & Csikszentmihalyi, 1975, 1976). Getzels and Csikszentmihalyi (1976) identified individual differences in problem finding, and that a propensity toward problem finding has long-term implications for artists' career achievement. Students enrolled in a fine arts programme at the Art Institute of Chicago were assigned the task of painting a canvas of three-dimensional objects that were placed on a table. The students' problem finding propensity was assessed using a checklist of exploratory behaviours that they engaged in before and over the course of painting the objects, such as walking around the objects, handling and lifting the objects, and observing the objects from different perspectives. In the end, the art students' problem finding scores predicted their career success, measured as yearly income derived from their artwork at midlife.

In another study where problem finding, divergent thinking tests and creative problem-solving for real-world problems were evaluated, problem finding was found to be the best predictor of accomplishments in children's creative activities (Okuda et al., 1991). Other studies demonstrated that problem construction ability was found to predict high-quality and original creative solutions, some yielding correlations in the .40s (Mumford, Baughman, Threlfall et al., 1996; Redmond et al., 1993; Reiter-Palmon et al., 1997). This finding suggests that problem construction accounts for roughly one sixth of the variance of creativity in terms of the quality and originality of solutions generated.

Research has shown that certain core cognitive functions – such as memory, attention, and perception – help facilitate problem identification and construction. Regarding Mumford and colleagues' (1994) model of problem construction operations, the authors claimed that problem construction processes function on a type of knowledge called problem representations, which involve categorical knowledge structures or schemas that have come from previous problem-solving efforts (Holyoak, 1984; Mumford, Baughman, Threlfall et al., 1996). Holyoak (1984) posited that problem representations include information about (a) goals related to the problem-solving effort, (b) key diagnostic facts needed to frame and solve the problem, (c) procedures required to solve the problem, and (d) constraints or limitations in problem-solving. When faced with a novel problem, multiple problem representations are triggered through attention to cues in environmental events and past experiences (Holyoak, 1984; Mumford et al., 1994).

Initial support for Mumford and colleagues' (1994) model of problem construction operations came from studies that manipulated active engagement in problem finding. For example, Redmond and colleagues (1993) found that participants who were forced to engage in the problem construction process prior to solving a marketing problem produced higher quality and more original solutions compared to those who were asked to solve the problem straightaway. Results from these studies indicate that more original and higher quality solutions to ill-defined problems occur when problem finding is carried out in an effortful manner.

As organisations are consistently faced with global competition and technological change, employees are increasingly confronted with more ill-defined problems (Dess & Picken, 2000; Reiter-Palmon & Illies, 2004). Thus, understanding how problem finding can help employees to produce more creative solutions to problems in the work setting is paramount. Indeed, one study found that successful scientists spent more time structuring and defining problems before commencing their work when compared to their less successful counterparts (Rostan, 1994). Other studies have investigated the impact of leader behaviours on subordinate creativity. For example, Redmond and his colleagues (1993) demonstrated that subordinates were more creative when their leaders instructed them to engage in problem finding prior to being asked to solve the problem. The findings from these studies suggest that employees might benefit from actively engaging in problem finding before working on a heuristic task, as identifying and defining a problem has strong influences later on processes.

1.2.2. Information Gathering

Once the goals of a heuristic task have been identified and constructed, the mental synthesis of existing knowledge structures is required to aid further information gathering and subsequent idea generation. Thus, acquiring knowledge in a specific field or particular domain is essential to the generation and combination of existing ideas (Sawyer, 2012; Ward et al., 1999). Amabile's (1996) componential framework of creativity posited that domain-relevant skills – factual knowledge (e.g. facts or opinions), special talents (e.g. natural aptitude), and technical skills (e.g. laboratory techniques) in a domain – play a key role in the production of creative work. Many researchers have suggested that domain expertise helps individuals identify and organise relevant information to solve problems (Amabile, 1996; Mumford, Baughman, Supinski et al., 1996).

Numerous terms have been used to describe this process; for example, Wallas (1926) used the word preparation, while Mumford and colleagues (1991) defined it as information gathering, and Sternberg (2006b) characterised it as "know the domain". In a more recent model, Sawyer (2012) separated the process into two steps: *acquire the knowledge* and *gather related information*. However, acquiring information and gathering related information arguably involve the same mental operations, as both encompass the ability to acquire information that will aid idea generation. Indeed, experts tend to search for information in a more systematic and efficient manner, ignoring task-irrelevant data (Charness et al., 2001; Ericsson, 1999).

Scholars have frequently reported that individuals tend to make significant discoveries after about 10 years of being heavily involved in a domain. This 10-year rule was found in a study that examined biographies of extraordinary creators (Gardner, 1993) and in an investigation of classical composers (Hayes, 1989). This finding highlights the importance of gaining knowledge in the domain or field in order to generate a creative solution to an ill-defined problem. However, the link between expertise and creativity is not straightforward. For example, several studies have reported that creative production only increases at the start of the career, tending to decline after reaching the career peak output (e.g. Dennis, 1966; Simonton 1984). Another study that investigated opera composers identified an inverted-J relationship between the creativity of a composer's operas and the cumulative number of operas produced (Simonton, 2000). Other researchers have countered that the relationship between creativity and expertise conforms to an inverted-U curve, where an optimal level of knowledge is required to produce a creative idea or solution (Sawyer, 2012; Weisberg, 1999). Indeed, an inverted-U relationship was discovered between ranked eminence for creators and formal education (Simonton, 1983). This finding suggests that too much knowledge could have a detrimental effect on creativity. Similarly, researchers who have focused on problem finding have asserted that too much knowledge or expertise can lead to tunnel vision for problem construction (Basadur, 1994).

Individual differences in information acquisition and the associated search strategies for creative problem-solving tasks have also been reported. For example, Mumford, Baughman, Supinski et al. (1996) assessed the type of information attended to during encoding in ill-defined problem-solving tasks in college students. In this study, prior to being asked to write a solution to an ill-defined problem, students were asked to read out a range of cards that provided information on the problem. The researchers manipulated the information presented to the students to assess their inclination to focus on certain types of information (e.g. irrelevant facts, inconsistent findings, or goals of the problem). Those who focused on relevant and inconsistent findings or facts and disregarded irrelevant information produced more original and higher quality problem solutions.

In a similar vein, Dunbar (1995) discovered that creative achievement in microbiology laboratories was related to the inclination to focus on discrepant information, that is, information that was inconsistent with initial expectations. Furthermore, extensive search strategies during information acquisition have been linked to creative achievement. For example, one study reported that individuals who attended to and used a wider range of information in their search strategy generated more creative products (Alissa, 1972). This process of gathering related information from an extensive array of sources can also feed into later processes, such as conceptual combination, where initial acquisition of a diverse and wide range of relevant information leads to a greater number of ideas that can be combined and reorganised into new concepts (Illies & Reiter-Palmon, 2004; Mumford, Baughman et al., 1997). Cumulatively, these studies suggest that the way that individuals encode information when confronted with novel and ill-defined problems influences their ability to produce original and high-quality solutions.

Information gathering is thought to play a key role in the development of novel ideas at a team and organisational level as well as an individual level. In fact, various studies have highlighted the importance of knowledge or information sharing between employees within and across the organisation in boosting innovation capability in organisations (Carmeli et al., 2013; Daellenbach & Davenport, 2004; Weisberg, 1999). One research endeavour, for example, investigated team innovation among 48 teams in primary and secondary schools (Drach-Zahavy & Somech, 2001). The investigators reported that increased information sharing positively related to team innovation. Meanwhile, in a longitudinal study of five firms, Monge et al. (1992) determined that the amount of information exchanged and level of group communication within the organisations were the greatest predictors of innovation over time.

The relationship between information sharing and team innovation comes as no surprise, as each team member can act as a unique knowledge bank, helping other team members to search and use relevant information necessary to generate a creative solution to a problem (Reiter-Palmon et al., 2008). Other studies have examined how a leader might influence subordinates' creative problem-solving. For example, Carmeli and colleagues (2013) investigated the role leaders might play in enabling both internal (e.g. memories and experiences) and external (e.g. books and the Internet) knowledge sharing and whether the leaders' efforts would enhance creative problem-solving. They found that leaders who facilitated both internal and external knowledge sharing enhanced employee creative capacity; moreover, internal knowledge sharing, in particular, was an important contributor to creative problem-solving.

In summary, the mental synthesis of existing knowledge structures plays a key role in the production of creative solutions. Although expertise in a domain helps in organising and identifying relevant information to aid idea generation, increased expertise does not necessarily lead to more creative solutions. This finding has important implications for organisations. On the one hand, employing experts in a domain could help organisations to develop more creative solutions to problems on account of their past experiences and acquired knowledge. On the other hand, too much knowledge could have an adverse effect on their ability to produce more creative solutions. Nevertheless, the positive effects of knowledge sharing found in teams suggest that having a team of experts who share their knowledge and ideas with each other can enhance creative problem-solving in organisations, as it allows them to gain a diverse and wide range of relevant information.

1.2.3. Incubation

Incubation refers to the unconscious process that occurs when an individual experiences improved problem-solving ability after taking a pause in their work (Dodds et al., 2002; Sawyer, 2012). This phenomenon has gained widespread attention in the field of creativity research due to its association with insight – the "aha" moment when a problem-solver unexpectedly reaches a solution to a problem. Over the years, various process models have included incubation as a necessary stage in the creative thought process. For example, Wallas (1926) named the incubation period as the second phase in the process, while Sternberg (2006b) outlined "take time off" in his model, implying incubation, and Sawyer (2012) incorporated incubation within his integrated creative process framework.

Although many researchers have described incubation as an unconscious process (e.g. Smith, 1995; Woodworth & Schlosberg, 1954; Yaniv & Meyer, 1987), most scholars have attempted to induce incubation and assess its effects in experimental settings. For example, Beeftink et al. (2008) divided participants among three conditions and asked them to solve three crossword puzzles. In the first condition, the researchers asked the participants to work continuously on one puzzle at a time. Meanwhile, in the second condition, the participants had to switch between the puzzles after 3 minutes. In the last condition, participants could decide when to switch between the puzzles. Interestingly, those in the third condition solved more insight problems and experienced less impasses compared to those in the other conditions. In another study, participants who were given an unrelated task for a break while they completed an idea generation test produced more ideas compared to those who were either asked to work on the test continuously or given a related task for a break (Ellwood et al., 2009).

Researchers have put forward several theories in an attempt to explain how this unconscious process occurs. Woodworth and Schlosberg (1954) proposed one of the earliest of these, suggesting that the impasse occurs when an individual becomes mentally exhausted from the attempt to solve a problem. Because the incubation period allows individuals to relax and recover, rest helps in finding a solution. Another theory proposes that incubation effects are due to selective forgetting (Smith, 1995). According to Smith’s view, the incubation effect occurs because an individual becomes fixated on an incorrect solution path. Hence, the incubation period allows their mind to forget the incorrect solution, which liberates the mind to discover more effective solutions to the problem.

Yaniv and Meyer’s (1987) spreading activation theory provides an alternative explanation of incubation, claiming that existing related ideas in memory are progressively activated through the mind’s semantic network. Empirical evidence supports this hypothesis (e.g. Sio & Rudowicz, 2007; Yaniv & Meyer, 1987). So do the results of a recent neuroimaging study in which Cai et al. (2009) reported that rapid eye movement (REM) sleep enhances creative problem-solving via the formation of associative networks and the combination of unrelated information.

Although researchers may disagree about what actually happens during the incubation period, the phenomenon is believed to play a key process in creative thought (Sawyer, 2012). However, as noted in Dorfman et al.’s (1996) review of incubation research, studies attempting to observe this phenomenon under laboratory conditions have produced mixed results. For example, while numerous experimental studies have demonstrated positive incubation effects (e.g. Dreistadt, 1969; Ellwood et al., 2009; Segal, 2004), other studies have failed to reproduce such positive findings (e.g. Olton, 1979; Olton & Johnson, 1976). Moreover, in a study conducted in a natural setting where the researchers observed artists and non-artists who were illustrating a poem, Eindhoven and Vinacke (1952) found no evidence of the incubation effect. These inconsistent results have led some scholars to question whether the incubation effect actually exists (Olton & Johnson, 1976; Smith & Blankenship, 1991). Reasons for the conflicting findings may include the various lengths of incubation period implemented, the type of problem presented, and the nature of the intervening task given during the incubation period (Dorfman et al., 1996; Sio & Ormerod, 2009).

Nevertheless, a meta-analytic review of studies that have explored the incubation effect on problem-solving in general supported the existence of the incubation effect (Sio & Ormerod, 2009). The meta-analysis also identified potential moderators of the effect, such as the nature of the problem presented, the length of the preparation period, and the interpolated task given during the incubation period. Interestingly, one of the conclusions that the researchers drew was that individuals will benefit from an incubation period if they are attempting to solve a creative problem that requires an extensive search of knowledge.

Despite efforts to explain how and why the incubation effect can foster creativity in individuals, the process remains poorly understood. Comprehending how incubation can enhance creativity could allow us to implement strategies to facilitate creativity in work environments. Investigations of this topic in other areas, such as education, have produced promising results. For example, some studies that introduced incubation periods in classroom activities reported positive incubation effects (Medd & Houtz, 2002; Webster et al., 2006). However, no similar study has yet been conducted in a work setting.

Notwithstanding the ongoing debate about what actually happens in individual’s brains during the incubation period, incubation is a key process in creativity. The positive incubation effects that have been reported in previous studies suggest that organisations might benefit from allowing their employees to take a break or turn to an unrelated task for a break while they are attempting to solve an ill-defined problem. On a related note, sleeping has been found to enhance creative problem-solving (e.g. Cai et al., 2009). Consequently, employees might benefit from taking a nap during a stint of creative problem-solving or by spreading the creative problem-solving effort over the course of a few days.

1.2.4. Idea Generation

The process of idea generation involves the concepts of insight and conceptual combination. Insight is the “aha” or “eureka” moment when a solution unexpectedly emerges following an attempt to solve a problem. Scholars have described insight in varying ways. For example, Wallas’ (1926) classic process model calls insight the illumination phase, while Sawyer’s (2012) integrated framework refers to this phenomenon as the idea generation stage. Building on the concepts outlined by Wallas, Osborn (1953) developed a process model to include analysis, hypothesis generation, and synthesis of ideas. Conceptual combination, where ideas are generated through the amalgamation and reorganisation of existing knowledge structures, emerged from the notion of synthesis. Accordingly, this section will briefly explore the various ways that ideas are generated.

1.2.4.1. Insight

Cognitive psychologists and neuroscientists have attempted to investigate how people generate ideas by presenting participants with insight problems, such as Karl Duncker's (1945) radiation problem. Insight problems require restructuring to reach a solution. In contrast, non-insight problems, which are often referred to as standard and algorithmic, do not require restructuring; examples include algebraic problems (Chu & MacGregor, 2011; Sawyer, 2012).

Initial research into this area assumed that ideas spontaneously emerge. Metcalfe (1986), for example, presented subjects with insight problems. The participants were asked to report their perceptions of how close they were to solving a problem every 15 seconds in temperature-related terms: "cold" meant they did not feel close at all and "warm" meant they felt closer to solving the problem. Participants presented with insight problems characterised their perceptions as "cold" until they suddenly found the solution. In contrast, those who were presented with non-insight problems reported feeling "warmer" to solving the problem every 15 seconds until they came up with the solution. Although it may appear as though one generates ideas out of thin air, recent research developments have shown that insight does not occur in an unforeseen manner.

Research into how restructuring occurs during insight problem-solving has led to the emergence of several theories of insight. For example, the representational change theory (RCT) suggests that individuals begin to problem-solve with a false representation of the problem, resulting in failure to find a solution (Knoblich et al., 1999). After a problem-solver is able to view the problem from a different perspective or with a new representation, the individual will be able to generate a solution. The RCT proposes that initial erroneous representations of a problem arise due to past experiences that prompt the problem-solver to take an incorrect route that worked in the past to solve the problem. This results in an impasse, which can only be unblocked by altering the faulty representation. Knoblich and colleagues (1999) identified two specific mechanisms of representational change: constraint relaxation (e.g. the liberation of unnecessarily constrained assumptions) and chunk decomposition (e.g. the decomposition of perceptual chunks into smaller segments so that they can be recombined into more constructive representations).

Although compelling evidence supports the classic theories, including RCT (e.g. Knoblich et al., 1999; Knoblich et al., 2001), scholars have questioned whether a restructuring is necessary to reach an insight, or whether an impasse is a fundamental element of insight (Bowden et al., 2005). Furthermore, Knoblich and colleagues (1999) posited that knowledge plays a role in decomposing chunks into smaller components because the problem-solver must be aware of the chunks in order to decompose them. This suggests that experts might have an advantage over novices in decomposing chunks when faced with an algorithmic problem. Nevertheless, as mentioned previously, too much knowledge can have a detrimental effect on creativity. Despite discrepancies in insight research investigating the precise mental processes that are involved in insight, there is a widespread agreement that previous experience and acquired knowledge are involved in the ability to generate ideas (Hunter et al., 2008; Sawyer, 2012).

Taken together, research into how people reach insights suggests that individuals who are confronted with an ill-defined problem may develop false representations of the problem. Only when they are able to view the problem in a different light can they generate a solution. Understanding how people could alter their false representations of a problem may have significant organisational implications, as such knowledge could reduce the number of impasses that an employee might encounter during creative problem-solving and, therefore, the time needed to generate a solution.

1.2.4.2. Conceptual Combination

Acknowledging that it is impossible to generate an idea from nothing, researchers have steered towards the idea that the combination and reorganisation of existing knowledge structures or schemas may play a crucial role in the generation of novel concepts (Baughman & Mumford, 1995; Mumford, Baughman et al., 1997; Sawyer, 2012).

Early theories of conceptual combination proposed that novel insights occur due to mental cross-fertilisation between different domains (Koestler, 1964; Simonton, 1988). They claimed that combinations result when individuals change domains or work on multiple projects, allowing them to gain a larger pool of ideas and increasing the chance to develop innovative combinations.

Developments in creativity research have led investigators to identify numerous mental processes that are involved in the mental synthesis of ideas, such as conceptual combination and metaphorical or analogical thinking (Mumford & Gustafson, 1988; Ward, 2004). Combining ideas, also called conceptual combination, describes the process of mentally synthesising previously dispersed ideas, concepts, or other forms (Ward, 2004). Metaphorical or analogical thinking, also known as conceptual transfer, is another process that involves applying knowledge from a familiar domain to a unique or unfamiliar one (e.g. Gentner et al., 2001).

Although the origins of the conceptual combination process are unknown, numerous studies have demonstrated the importance of mental synthesis in creativity (e.g. Middleton et al., 2011; Mobley et al., 1992; Scott et al., 2005). In one study, the researchers presented students with three concepts defined by four exemplars (e.g. birds: hawks, owls, robins, sparrows). They were asked to combine these concepts to form an idea, and then create a new set of exemplars. Upon completing this process, they were then asked to generate a story involving the new concept (Mobley et al., 1992). Those who were asked to work with more diverse concepts produced more original, high-quality stories. Another study that used the same method found that the participants' performance on this type of conceptual combination tasks predicted the originality and quality of advertising campaigns (Mumford, Baughman et al., 1997).

These findings suggest that the integration of diverse information or ideas fosters more creative solutions. Despite the importance of conceptual combination in the creative process, this process has not been examined in the workplace per se. Nevertheless, some studies have noted the importance of idea sharing and combination in firms, a process that resembles the concept of conceptual combination. For example, a study involving 136 technology companies reported that knowledge/idea sharing and combination predicted revenue from new products and services as well as sales growth (Collins & Smith, 2006). Paulus and Yang (2000) also found that groups that exchanged ideas generated a greater number of novel ideas. These findings demonstrate the importance of synthesising ideas in collective creative processes and suggest that synthesis is equally important in individual creative processes.

1.2.5. Evaluation

Once ideas have been generated, the next stage involves evaluating them and choosing the best one to implement. The evaluation of ideas represents a significant aspect of creative thought, and scholars believe this process to be just as important as idea generation (Lonergan et al., 2004; Runco & Smith, 1992). Studies have consistently found that creative individuals are particularly good at evaluating their multiple ideas and selecting the best one (e.g. Basadur et al., 2000; Lonergan et al., 2004; Runco, 2003). In one study, participants who were more accurate in the evaluation of their own ideas generated more original ideas (Runco & Chand, 1994). Similarly, Runco (2003) found a positive relationship between divergent thinking scores and accuracy of idea evaluation in terms of originality. It is believed that evaluation may function to remediate flaws in ideas and to increase the likelihood of their success in the situation at hand (Lonergan et al., 2004). This has led some researchers to argue that creativity involves both idea creation and critical evaluation abilities (e.g. Runco, 2003; Runco & Dow, 2004).

Indeed, most process models of creative problem-solving include an evaluative element (Mumford et al., 1991). Wallas (1926) described this evaluative activity as verification, while Runco and Smith (1992) defined it as evaluative skill. Although different mental operations have been claimed to be involved in evaluation, most researchers agree that the evaluative process initiates after an idea has been formulated (e.g. Mumford et al., 1991; Wallas, 1926). This led Vincent et al. (2002)

to argue that evaluation is an aspect of implementation as ideas are tested and revised following idea generation.

However, other scholars have countered that the evaluation process is evident throughout the creative process, not just when an idea has been formulated (Sawyer, 2012). For example, an element of evaluation is required in problem finding, reflecting the need to judge whether a problem generated is viable and worth exploring. Also, as demonstrated in Mumford, Baughman, Supinski et al's study (1996), an element of evaluation is also required when gathering information, as one would need to assess what kind of information is required and worth focusing on for the task at hand. Furthermore, research has shown that idea evaluation can occur during the idea generation phase and may lead to more creative ideas being generated. For example, in a study investigating creative story writing and drawing, Lubart (1994, 2001) found that early evaluation during the idea generation stage led to the production of more creative products. Overall, idea evaluation, whether it occurs before or after idea generation, is a key component of the creative thought process.

However, little is known about the origins of idea selection and evaluation (Basadur, 1995; Lonergan et al., 2004; Runco & Chand, 1994). In an attempt to understand how the idea evaluation process functions, Mumford et al. (2002) proposed that evaluation involves forecasting – the ability to identify possible consequences and outcomes of an idea that is a typical strength of chess players and military strategists – followed by the appraisal and revision of that idea, where the consequences or outcomes are assessed against a series of performance standards or goals that are applicable to the context at hand.

Initial support for Mumford and colleagues' (2002) model has come from studies where students were asked to evaluate or forecast the execution of their idea before developing a marketing campaign (Byrne et al., 2010; Lonergan et al., 2004). In these studies, extensive forecasting was related to the originality, quality, and elegance of their solutions; however, forecasting was dependent on the criteria or the set of performance standards presented to the participants. In an organisational setting, idea evaluation is paramount because employees must consider the possible consequences of their solutions and identify potential obstacles they might encounter. These findings suggest that the ability to effectively forecast the consequences or outcomes of a creative solution might be contingent on the criteria set as well as the goals (e.g. budget, resources, timing restrictions) presented to employees.

Moreover, some research evidence has suggested that the idea evaluation process could be domain-specific. For example, Bink and Marsh (2000) proposed that quick evaluations of original and appropriate ideas are based on an individual's internalised model of the domain or field. In this light, a study investigating the factors that affect the evaluations of improvised music demonstrated that overall evaluations were based on perceived complexity, creativity, and technical goodness (Eisenberg & Thompson, 2003). Along the same lines, multiple factors were found to be involved in evaluating culinary dishes, such as professional technique, flavour, and aroma (Horng & Lin, 2009). The findings from these studies highlight the importance of having domain-relevant skills when evaluating ideas. Without these skills, distinguishing a good idea from a bad one would be difficult.

Altogether, the research into idea selection and evaluation suggests that the ability to evaluate ideas critically might be as important as idea generation, considering the evidence that the evaluative process leads to the reshaping of ideas and subsequent implementation of the idea (Lonergan et al., 2004). Although research evidence has suggested that extensive idea evaluation or forecasting is related to more creative solutions, understanding how employees evaluate ideas under challenging work conditions (e.g. time pressure, resource limitations) could have important implications for organisations, leading to a difference in the way employees approach idea evaluation. For example, would frequent engagement in loops of idea generation and evaluation lead to higher creative performance?

1.2.6. Implementation

Once a good idea has been selected and critically evaluated, the next step involves the execution of the idea. After all, an idea is of little use if it is not brought to fruition. However, as in the case of research into evaluation, few studies have explored how people use or implement their ideas at an individual level (Baer, 2012; Reiter-Palmon & Illies, 2004). Most of the existing research has focused on factors influencing implementation, such as communication skills, motivation and climate, and from an organisational point of view, it is believed to be a social-political process (Baer, 2012; Van de Ven, 1986).

Although the implementation of an idea might be influenced by external factors, an individual still needs to plan and actively monitor the outcomes of their idea, an activity that is considered to be cognitive in nature (Reiter-Palmon & Illies, 2004). Accordingly, many process models have included a planning, execution and monitoring element. For example, Wallas (1926) described this process as elaboration of ideas; meanwhile, Mumford and colleagues (1991) defined it as implementation planning and solution monitoring, while Sawyer (2012) coined the term externalise ideas. Although this activity is typically considered the final stage of the creative process, idea implementation can occur throughout the creative process, from problem construction to selecting the best idea (Sawyer, 2012).

While research looking into this process is scarce, some studies have found that idea evaluation, along implementation planning, is a key predictor of creative performance (Berger & Dibattista, 1992; Lonergan et al., 2004; Osburn & Mumford, 2006). For example, in one study, penetration (e.g. the identification of key causes) and forecasting – the two core strategies believed to be involved in implementation planning strategies – were associated with the generation of high-quality and novel plans (Osburn & Mumford, 2006). Other cognitive processes have also been found to influence idea implementation. For example, Berger and Dibattista (1992) discovered that the amount and diversity of information collected during the information gathering stage was related to the elaboration of plans implemented.

Furthermore, research has suggested that idea planning and implementation can result in other ideas and follow-on ideas. For example, Getzels and Csikszentmihalyi (1975, 1976) reported that creative students continuously changed their minds on the overall composition of objects after having sketched their initial composition. In some cases, the final painting was completely different from the one they had initially sketched. This finding suggests that the creative students were testing and elaborating on their ideas before their final idea was fully formed. In another study, individuals who sketched out their ideas during a task discovered and solved more problems than those who did not make a preliminary sketch (Verstijnen, 1997). Along similar lines, a study investigating the communication patterns of R&D groups reported that innovative individuals were more likely to engage in discussion with their leaders in the initial stages of the problem-solving effort (Farris, 1972). Thus, they were articulating their ideas before fully formulating them.

All this evidence shows that implementing an idea, whether verbally or physically, is a key process in creativity. Arguably, although many factors may influence idea implementation, a good idea is easier to sell than a bad one in an organisational context.

1.3. Measurement of Creativity

To this point, this chapter has examined the key cognitive processes underlying creative thought and the ways they are related to creative performance. Despite the surge of research that has emphasised the importance of the mental operations involved in creative thought, most of the research that has been set in the workplace has been based on Guilford’s (1950) early work on divergent thinking. The notion of divergent thinking has led to a proliferation of standardised tests, such as the TTCT, which attempts to quantify the creative process and identify creative potential. The TTCT measures four components of creativity: fluency (number of ideas generated), flexibility (range of perspectives represented in the ideas), elaboration (development or enhancement of ideas), and originality (statistical infrequency of ideas). This approach has proved popular, as evidenced by divergent thinking (DT) batteries, such as the TTCT, remaining the most widely used tools in assessing creativity (Sternberg, 2006a).

Although the DT batteries have demonstrated satisfactory reliability (e.g. Eisen, 1989; Torrance et al., 1973), studies investigating their predictive validity in relation to creative achievement as well as job performance have produced mixed results (e.g. Clapham, 1996; Gough, 1979). For example, research studies have reported that indices of DT skills can predict real-world job performance in organisational leaders (Mumford et al., 1998) as well as high school creative achievement (Kim, 2006). However, many researchers have criticised DT tests for failing to produce sizeable, stable predictive validity coefficients (Baer, 1993; Mumford & Gustafson, 1988). For example, in a longitudinal study, research scientists' divergent thinking scores were found to be strongly correlated, $r = .62$, with supervisor ratings of creative performance; however, the correlation decreased progressively, from $r = .41$ to .17, in the latter phases of the research study (Taylor et al., 1963).

Reasons for a lack of predictive validity vary broadly. In particular, the conditions under which tests are administered can greatly affect responses. For example, test takers' results have been shown to improve if they are simply instructed that they are going to take a creative test (e.g. Manske & Davies, 1968; Speller & Schumacher, 1975). Furthermore, DT batteries are particularly susceptible to coaching and practice effects (Plucker & Renzulli, 1999). These and other contextual factors could lead to inaccurate DT scores, contributing to the observed lack of predictive validity in relation to job performance.

Moreover, although DT batteries have attempted to measure creativity objectively, they have been heavily criticised for being inadequate measures of creativity (Amabile, 1996; Sternberg & Lubart, 1999). Going even further, Weisberg (1993) criticised DT batteries for not measuring creative thinking or capability at all (see also Plucker & Renzulli, 1999). Also, critics have noted that DT batteries at best only measure one narrow aspect of creative thought, failing to capture equally essential dimensions such as problem identification and evaluation (Plucker & Renzulli, 1999; Runco, 1991). Despite these worrying limitations, most creativity research studies, including neuroimaging studies, have used divergent thinking as the sole measure of creativity (e.g. Abraham et al., 2012). The use of this single measure in creativity research may have contributed to the inconsistent and conflicting findings that exist, clouding scholars' understanding of creativity even further.

The importance placed on the cognitive processes underlying creative thought highlights the need to develop measures that explicitly capture the fundamental mental operations. The cognitive approach into creativity has proved successful in terms of increasing researchers understanding of how people produce creative solutions to ill-defined problems; however, there now needs to be a shift in attention towards refining the existing measures of each of the cognitive processes underlying creativity to make them more objective, reliable, and valid.

1.4. Holistic Approach to Cognitive Processes

Over the past century, notable progress has been made in discerning the core mental operations underlying creative thought. Although many process models currently exist, they all share common fundamental mental operations. Although each process underlying creative thought has been studied extensively, most empirical studies have examined these processes in isolation. Only a handful of studies have explored the joint impact of these creative cognitive processes on creativity. The results from these rare studies have uncovered the importance of observing these processes as a whole.

For example, Mumford (2002) examined the joint impact of various processes such as problem construction, information gathering, idea generation, and conceptual combination. He found that each mental operation made a unique contribution to the prediction of overall creative problem-solving performance. Problem construction, conceptual combination, and idea generation, in particular, were good predictors of creative solutions. Together, these cognitive operations were strongly related to the generation of original, high-quality, and elegant solutions, yielding multiple correlations in the .50–.60 range. Although this study did not observe certain key processes, such as idea evaluation, the results obtained demonstrate the importance of examining these processes together.

1.5. Dynamism in Creativity

Although most cognitive process models concerning creativity might appear to propose a linear process in creative thinking, the processes can operate in a dynamic manner, for example, going back to previous processing activities in order to generate a final concept (Sawyer, 2012). In fact, numerous researchers have supported the dynamic interpretation of the model (e.g. Amabile & Pratt, 2016; Botella et al., 2011; Eindhoven & Vinacke, 1952; Lubart, 2001; Mumford, Supinski et al., 1997).

In recent years, scholars have begun to recognise the contemporary need for more dynamic interpretations of creativity (e.g. Beghetto & Corazza, 2019). For example, the oldest known and widely cited componential model of creativity and innovation (Amabile, 1988) was revised in 2016 to incorporate the notion of dynamism (Amabile & Pratt, 2016). This model details the components that influence innovation and creativity in organisations. The individual component of the model consists of intrinsic motivation to do the task, skills in the domain, and creativity-relevant processes. These individual components influence the individual (or small group) creative process, which includes stages similar to the cognitive models of creativity. For example, identifying the goal or problem (task presentation) is the first stage, which is followed by information gathering (preparation) and then idea generation. Idea validation is the fourth stage, which is similar to idea evaluation, where ideas are checked against criteria to determine feasibility and appropriateness. The fifth and concluding stage is outcome assessment. In this stage, decisions are made based on the results of the fourth stage, which is similar to implementation. Amabile and Pratt (2016) postulated that multiple iterations or “loops” are likely to be involved throughout the entire creative process and that many variations of these sequences are probable. However, to my knowledge, these loops within the individual creative process have never been investigated empirically.

Nevertheless, attempts have been made to empirically examine the dynamics of the artistic creative process. For example, Botella et al. (2011) conducted two studies with art students to investigate the dynamics of the creative art process, including affect, by examining the transitions between stages in the morning and afternoon over the course of 5 days. The researchers used a booklet of items that encapsulated nine processes (preparation, concentration, incubation, ideation, insight, verification, planning, production, and validation), which were based on a range of creative process models. The students were asked to tick which processes they had engaged in since the last evaluation. The researchers reported that the artistic creative process was non-sequential and that it was possible to return to a previous stage in the creative process. They also explored the progression of the creative phases by calculating the percentage of the number of transitions between phases by total creation time. For example, all stages were followed by production (from 18.3% to 49.5%) in Study 1.

However, Botella et al. (2011) did not investigate the transitions that were most predictive of creative output. Also, comparing the transitions of the stage between morning and afternoon provided a simplistic, fixed view of the creative processes. Moreover, the authors also noted that multiple stages could occur at the same time (e.g. 100% of students reported engaging in more than one process on Day 1 in their second study). Thus, despite the growing consensus that the cognitive processes underlying creativity operate in a dynamic manner, no study to my knowledge has examined the transitions and how they might be related to creative output. Furthermore, as creativity is commonly an improvisational process that involves frequent shifts in response to changing conditions and new information (Fisher & Amabile, 2008), no known study has tested whether more creative individuals go through these processes in a more dynamic fashion.

1.6. Focus on Time

Some studies have demonstrated that participants who spent more time framing and constructing problems produced more original and higher quality solutions to problems (Redmond et al., 1993; Reiter-Palmon et al., 1997). On a related note, time spent gathering information was found to be related to more creative solutions (Berger & Dibattista, 1992).

In an organisational context, some studies have examined the relationship between time pressure and creativity in the workplace. For example, Amabile et al. (2002) obtained daily questionnaires from 177 employees who were working on projects that required creativity. The employees provided narrative reports of events that occurred while they were working on those projects over periods of up to 30 weeks. The researchers found that high levels of time pressure had a detrimental effect on the employees' creative thought processes. Interestingly, the participants engaged in little or no creative thinking under low levels of time pressure, suggesting that the relationship between creativity and time pressure is likely to be an inverted-U curvilinear. Similarly, another study involving 170 employees from a manufacturing company found a curvilinear relationship between creativity and time pressure, and managerial support for creativity moderated the relationship (Baer & Oldham, 2006).

The results of these studies suggest that an optimal level of time pressure is necessary in order to engage in creative thinking. However, the effects of time pressure on specific cognitive processes, such as problem finding, information gathering, and idea evaluation, were not investigated. Employees are under constant time pressure to generate solutions to problems; however, no known study has examined how time constraints can influence how individuals engage in each of the creative processes. For example, it might be interesting to investigate whether a curvilinear relationship between time pressure and creativity applies to all cognitive processes underlying creative thought.

1.7. Scope and Aim of PhD Dissertation

Although many organisations emphasise the importance of creativity and innovation in the workplace, the abilities that allow individuals to generate novel and useful ideas remain an enigma. Despite advancements in research that have identified the core mental operations that underlie creative thought, several gaps in the literature need to be addressed: specifically, understanding how the cognitive processes behave individually as well as holistically and whether their dynamism is linked to creative output. As such, this dissertation contains two broad goals, listed below.

Research Aims and Questions

This dissertation aims to contribute to the literature on the cognitive processes underlying creativity by investigating the following two broad research objectives:

1. **Examine the independent and combined effects of the cognitive processes underlying creativity on creative output.**
2. **Explore how individuals go through the cognitive processes underlying creativity.**

Additionally, the subsequent chapters will also explore more specific research questions and hypotheses.

The first aim of the thesis was to examine the cognitive processes underlying creativity individually and holistically. In contrast to previous studies that have examined the processes by forcing participants to engage with them (e.g. Byrne et al., 2010; Lonergan et al., 2004; Mumford, Baughman et al., 1997; Reiter-Palmon & Robinson, 2009), this dissertation aimed to examine these cognitive processes by observing how frequently and for how much time individuals would engage in these mental operations while solving an ill-defined problem. This approach facilitated the empirical investigation of the role that each mental operation plays in the creative process, how these processes compare to each other and how they function together as a whole. This approach also led to an understanding of what might differentiate high creative output individuals from the low creative output individuals in terms of how they engaged in each process.

The second broad aim of the dissertation was to investigate how individuals would go through the cognitive processes underlying creativity. As theorised in Amabile and Pratt's (2016) dynamic componential model, multiple feedback loops between the creative processes are likely to be involved throughout the creative process. However, if individuals do go through these processes dynamically, is there common sequence or transition from one process to another? Could these transitions be related to creative output? This thesis aimed to advance the knowledge of the dynamism of the creative process by addressing these questions.

Understanding how the cognitive processes behave independently, holistically, and dynamically and how they are related to creative output would have great theoretical and practical implications. For example, in light of the heavy criticism of divergent thinking tests as being inadequate measures of creativity (Amabile, 1996; Sternberg & Lubart, 1999; Weisberg, 1993), this study could help guide researchers to focus their efforts on other key creative cognitive processes that may have been overlooked. Furthermore, the findings from this research would also have implications on creativity training programmes and interventions. For example, although brainstorming is a common technique used in organisations to help generate ideas, the effectiveness of this intervention remains to be proved. This research introduces alternative strategies that could be useful in organisational as well as educational settings. It is important to note that whilst theoretical and empirical studies have demonstrated the importance of other factors such as mood and motivation on creative performance, this thesis focuses solely on the cognitive aspect of creativity.

1.8. Overview of Chapters

Addressing these research aims took the form of three experiments that were conducted for this investigation. As such, this dissertation comprises five chapters, including this introduction (Chapter 1). Chapters 2–4 describe the interlinked research studies conducted. Each of these chapters includes a brief introduction to the chapter followed by an explanation of each study's aims, a description of the method employed, a presentation of the study results, and a discussion.

Chapter 2 details the initial quantitative and qualitative study (Study 1), which involved analysing transcripts and footage taken of individuals as they solved an ill-defined problem. The results from this study revealed the core processes underlying individual creativity and how they might interact. This study formed the basis of the development of an online experiment, which aimed to capture the dynamism of the creative thought process.

Chapter 3 presents details about Study 2, which tested the online experiment with the same individuals who took part in Study 1. The experiment demonstrated adequate validity and was next tested on a larger sample size (Study 3).

Chapter 4 describes Study 3, which was conducted to confirm the results obtained in Studies 1 and 2. The findings revealed that the creative process is indeed dynamic, and certain transitions are predictive of creative output.

Lastly, Chapter 5 summarises the main findings of the dissertation and contextualises the results within the literature. The chapter then concludes with a discussion of the strengths and limitations of the dissertation, the theoretical as well as the practical implications of the research conducted, and an outlook on future research opportunities.

Chapters 1 and 5 were based on a published book chapter by Palermo and Moneta (2016):

Palermo, G. M., & Moneta, G. B. (2016). Cognitive processes underlying creativity at work. In G. B. Moneta & J. Rogaten (Eds.), *Psychology of creativity: Cognitive, emotional, and social processes* (pp. 49–66). Nova Science.

Study 1 was based on a peer-reviewed conference paper written by Palermo and Moneta (2022):

Palermo, G. M., & Moneta, G. B. (2022, January 11–14). *On your marks, get set, create! Impact of time pressure on the creative process* [Oral presentation paper to be presented]. The 20th Congress of the European Association of Work and Organizational Psychology, Glasgow, United Kingdom.

Study 3 was based on a peer-reviewed conference paper written by Palermo and Moneta (2022):

Palermo, G. M., & Moneta, G. B. (2022, January 11–14). *Does brainstorming really lead to innovation?* [Oral presentation paper to be presented]. The 20th Congress of the European Association of Work and Organizational Psychology, Glasgow, United Kingdom.

1.9. Unique Contribution

This research project is the first known study to have investigated the dynamics of the cognitive processes underlying creativity at an individual level and how they might relate to creative output. Frequencies of and time spent in idea generation, evaluation and implementation were found to be consistently related to creativity. However, when investigating the transitions between the processes, mediation modelling revealed a full mediation effect of the transitions from idea generation to implementation on the relationship between idea generation and creativity. Furthermore, the total number of transitions exhibited was found to be predictive of creative output. This outcome indicates that those who go through the cognitive processes in a more dynamic fashion produce more creative solutions. This newly gained understanding advances our knowledge of the cognitive processes underlying creativity and how their dynamism is predictive of creativity. This research also advances the practical applications of the dynamic creative process in the work context and offers insight into how training interventions could foster individual creativity, facilitating organisational innovation.

Chapter 2: Study 1

Study 1 – Quantitative Study

2.1. Introduction

The study aim presented in this chapter was to explore the cognitive processes in individuals that underpin creativity and how they might relate to creativity via a mixed-method approach. Although each of these creative thought processes have been studied extensively, most have been examined in isolation. The one study known to have investigated the joint impact of some of these processes produced promising findings (see Mumford et al., 2012). However, no known study has investigated whether all processes are equally important in creative performance or whether their dynamism is related to creative achievement.

Based on the literature, this research focused on six key cognitive processes: problem finding, information gathering, incubation, idea generation, evaluation, and implementation. Figure 1 in Chapter 1 provides a summary of the various cognitive processes that Study 1 examined. The cognitive processes under investigation were drawn from Sawyer's (2012) integrated framework, which encapsulates the core stages of the creative process. In this endeavour, it was necessary to create a level playing field to examine the independent and joint influence of these creative cognitive processes. Therefore, this study investigated the frequencies of and time spent engaging in each of the processes. Moreover, this investigation assessed creativity using versions of Amabile's (1982) Consensual Assessment Technique, which has been extensively used in creativity research and is considered the "gold standard" in assessing creativity (Kaufman et al., 2008).

Given that fluency (number of ideas generated) has been found to be positively correlated with creativity (e.g. Wallach & Kogan, 1965; see also Torrance, 2008), many researchers have relied on fluency scores to assess divergent thinking (Silvia et al., 2013). However, investigations have not examined the "fluency" or the frequencies of other processes. The previous reports of positive correlations between fluency and creativity might lead to expectations that the frequencies of other processes are also positively related to creativity. Therefore, the first hypothesis is as follows:

> *H1*: The occurrences of each cognitive process – (a) problem finding, (b) gathering information, (c) incubation, (d) idea generation, (e) idea evaluation, and (f) idea implementation – will be positively related to creative output.

Studies have demonstrated that individuals who spend more time engaging in some of the processes (e.g. problem finding and gathering information) produce more creative solutions. As in the case of the frequencies, the link between time spent in each of these processes and how they are related to creative output are yet to be examined. In light of the studies that have demonstrated that individuals who spend more time engaging in some of the processes generate more creative solutions, the second hypothesis is as follows:

> *H2*: Time spent engaging in each cognitive process – (a) problem finding, (b) gathering information, (c) incubation, (d) idea generation, (e) idea evaluation, and (f) idea implementation – will be positively related to creative output.

As mentioned in the general introduction to the dissertation, no known study has explored potential differences in how creative individuals might engage in each cognitive process. Based on empirical evidence suggesting that creative individuals are highly effective at engaging in some processes (e.g. idea generation, evaluation), the following exploratory research question was postulated:

> *H3*: There will be a difference in how high and low creative output scorers engage in their cognitive processes.

As another consideration in this line of investigation, Sawyer's (2012) process model, like many others, appears to propose a linear process in creative thinking. However, the processes can operate in a dynamic manner, for example, going back to previous processing activities to generate a final concept (Eindhoven & Vinacke, 1952). Indeed, numerous researchers have supported the dynamic interpretation of the model (e.g. Amabile & Pratt, 2016; Botella et al., 2011; Lubart, 2001; Mumford, Supinski et al., 1997). However, no known research has explored how creative individuals might go through these processes at a micro level while trying to solve a creative problem. Given that the thought processes can operate in a dynamic manner and scholars' claims that creative individuals tend to return to the previous stages of creative thought more often than those who are not creative, the fourth and fifth hypotheses are as follows:

> *H4*: The cognitive creative process will not follow a linear sequence.

> *H5*: Individuals who engage in more transitions from one process to another will produce more creative solutions.

Given that some studies have found a curvilinear relationship between creativity and time pressure (e.g. Amabile et al., 2002; Baer & Oldham, 2006), while others have reported a linear relationship between time spent engaging in the processes and creativity (e.g. Getzels & Csikszentmihalyi, 1975, 1976), overall time taken and creativity will be explored. Therefore, the sixth and final exploratory research question was hypothesised as follows:

> *H6*: There will a positive relationship between time taken and creativity scores.

Accordingly, the aim of this quantitative and qualitative study (Study 1), as presented in this chapter, was to provide initial evidence to address the two overarching research questions posed in Chapter 1. The cognitive processes underlying creativity were investigated by analysing the participants' verbal responses as they solved an ill-defined problem – more specifically, the number of observations and time spent in each cognitive process. The transitions from one process to another were also explored. A deductive thematic analysis was then conducted on the top five and bottom five creative output scorers to further explore these cognitive processes and identify any difference in how the participants engaged in them.

2.2. Method

2.2.1. Study Design

Study 1 employed a mixed-method approach. Participants were presented with a dilemma on a computer and asked to generate a solution. As they worked out a solution, the participants thought out loud, as instructed before the experiment began, from start to finish. The participants' verbal thoughts and on-screen actions throughout the experiment were recorded.

The study's independent variables were the frequency of and time spent engaging in each cognitive process, along with the transitions from one process to another throughout the problem-solving effort. The creative output (the final solution that each participant generated) was the dependent variable.

2.2.2. Participants

The present study included 24 participants, which were obtained via opportunity sampling. The average participant age was 30 (SD = 4.5; range = 26–49), and 50% of participants were female. All participants were highly educated; 71% of participants indicated a master's degree or doctorate as their highest level of education achieved, and the remainder had undergraduate degrees. No incentives were provided to the participants for their participation.

2.2.3. Materials and Measures

Experimental task

Each participant was presented with a dilemma and asked to generate a solution. The dilemma was designed to be heuristic (an ambiguous and ill-defined problem to allow multiple plausible solutions to exist), as prior research has suggested that creativity only occurs when individuals are confronted with a heuristic or ill-defined problem. Figure 2 illustrates an example of the dilemma that was presented to participants.

Figure 2: *The Task Dilemma Presented to Participants*

Techappboratory

Techappboratory is a software mobile application company that specialise in the development of a diverse range of mobile apps that appeal to a wide audience. They are considered to be one of the key global players in developing unique mobile apps. However, in the past 6 months, they noticed a sharp decline in app sales. For this task, you will need to come up with a new mobile app idea to restore Techappboratory's place in the market.

Please write your idea below:

Before the dilemma was presented to the participants, they were instructed to come up with a solution by articulating aloud what they were thinking from the moment they saw the dilemma until they were ready to put their final solution forward. Amended versions of Ericsson and Simon's (1993) *Protocol Analysis* instructions and two practice questions were used (see Appendix A). The participants were also informed that they were free to use the computer provided (e.g. use the Internet) or their phones as they wished to help them solve the problem, if necessary.

Apparatus

The participants used a MacBook Air (OS X Version 10.9.5; Apple Inc.), and their responses (spoken words) and on-screen actions were recorded via QuickTime Player (Version 10.3; Apple Inc.) throughout the experiment. The recording was then used to code the participants' cognitive processes using iMovie (Version 10.1.9, Apple Inc.). The dilemma was presented on Microsoft® Word (Version 16.43; Microsoft® Word for Mac), and participants were instructed to write their final solution below the dilemma.

Evaluation of the cognitive processes

In order to assess which cognitive processes the participants were engaging in, how much time they spent engaging in these, as well as the sequence in which they went through them, a checklist of the cognitive processes was created based on the six key cognitive processes using Sawyer's (2012) process model as a guide.

Whenever a participant engaged in one of these cognitive processes or behaviours, a code was assigned, and time spent engaging in the process was captured. Any pauses or silences were assigned an "uncoded" code. For example, during the task, one of the participants said, "The app is going to [pause] find out your personal information. . . . It would be cool if it could weigh you", which was coded as "idea generation"; they spent 4.7s (seconds) engaging in it, and the pause, which lasted 1.2s, was coded "uncoded". The individual then said, "I guess you could just weigh yourself and input that detail . . . erm . . . and that social media bit". Since the participant was evaluating their idea, the "idea evaluation" code was assigned, and the time spent engaging in it (5.2s) was captured.

Each time the participant typed in an idea, the code "implementation" was assigned, and time spent was recorded.

A more detailed coding scheme was introduced following the initial analysis of the data. The aim was to observe the various facets of each cognitive process and how they are related to creative output. Table 1 displays the coding schemes used in this study. For example, participants who re-read or evaluated their written solution and evaluated their ideas were coded "5" in the analysis, which meant that they were engaging in idea evaluation or Sawyer's (2012) cognitive process: Select the best ideas. In the detailed coding scheme, however, these activities were coded separately (5.1 when participants evaluated their ideas; 5.2 when they re-read/evaluated their written solution). Problem finding, the ability to identify and construct a problem before trying to solve it, was also split into three sub-processes (1.1, 1.2, and 1.3) to make a distinction between coming up with and evaluating ideas or strategies in an effort to frame the problem.

Additional codes were assigned to actions and processes not specified in the coding sheet. These codes are listed as "Other" codes in Table 1. Some participants made a conscious effort to retrieve information or ideas from memory to help them reach to a solution; therefore, another code was assigned and coined "Retrieve information from memory". It was also observed that some participants jotted notes that were not ideas or the solution. This behaviour was captured and coded as "writing notes". Lastly, another code was assigned when participants spent time formatting their output and deleting words or sentences.

In some instances, individuals generated an idea while evaluating it. These occurrences were assigned a different code (4&5.1). For example, one participant came up with a well-being app as a solution, and as they were evaluating it, they were generating more ideas for it/elaborating it (i.e. [the app will] "help . . . reduce stress by, I think . . . um . . . if it's sort of one if you're not feeling great if, if you know it will"). After coming up with a final solution, the participant reflected on their solution: "I think it's in line with the current market of er" and then realised that it was a good idea/addition to the solution and implemented it. Because these processes were a mixture of idea generation and evaluation, they went into both of the overarching cognitive processes idea generation and idea evaluation.

Similarly, in cases where participants' activities involved two codes at the same time (e.g. coming up with an idea as they were implementing it), the codes went into both overarching cognitive processes. For example, for those who came up with ideas while typing/implementing ideas without having thought of the idea before, the code 4&6 was assigned and went into the overarching processes "idea generation" and "implementation" separately. Similarly, if participants evaluated

Table 1: *Detailed Coding Scheme of Cognitive Processes*

Overarching cognitive processes		Code	Detailed breakdown of cognitive processes
1	Problem finding	1.1	Problem finding without coming up with an idea/strategy, nor evaluating it
		1.2	Coming up with ideas or strategies for generating a solution
		1.3	Evaluating strategies for generating a solution
2	Information gathering	2.1	Using the Internet to acquire new information not related to an idea
		2.2	Evaluating new information acquired for solution while on the Internet
		2.3	Re-reading dilemma/searching relevant information for an idea
		2.4	Using the Internet to gather relevant information for an idea
3	Incubation	3	Taking a break
4	Generation	4	Generating an idea
		4&5.1*	Generating an idea while evaluating it at the same time
5	Evaluation	5.1	Evaluating an idea
		5.2	Re-reading/evaluating output
6	Implementation	6	Implementing/writing up the solution
7	Other	7.1	Retrieve information from memory
		7.2	Writing notes, not related to solution
		7.3	Editing and formatting solution, including deleting sentences, words, and letters

*Note. *This process fed into both overarching processes Idea Generation and Idea Evaluation.*

their ideas while deleting their output, the code 5.1&7.3 was used, and the occurrence and time spent were coded as both went into both “idea evaluation” and “other” processes.

Using the detailed coding scheme, the sample yielded 9,874 occurrences of the cognitive processes in total. The average frequency of cognitive processes identified per participant was 411.42 codes (*SD* = 278.76; min = 24, max = 1,398, range = 1,374 cognitive processes), and the average time spent engaging in each process, including uncoded time, was 4.05s with a standard deviation of 6.99s.

Pauses of over one third of a second were assigned an “uncoded” code, as it was not possible to infer which cognitive process the participants were engaging in. Overall time spent on the task was timed from the moment the dilemma was presented to the participants until the participants confirmed that they were happy to submit their final idea.

Evaluation of Creativity

Participants’ solutions were assessed for creativity using two different creativity measures, both based on Amabile’s (1982) Consensual Assessment Technique. One of the measures, used in Reiter-Palmon et al.’s (1997) study into problem finding and creativity, was employed to assess the quality and originality of the generated solutions (see Appendix B). The rating scale for quality ranged from 1 (very low quality, solution not plausible or appropriate) to 5 (very high quality, solution very plausible and appropriated, very logical), and the rating scale for originality ranged from 1 (very low originality, no extrapolation, highly structured by the problem) to 5 (very high originality, large degree of extrapolation, not structured by the problem). In line with Harrington et al.’s (1983) recommendations, the average quality and originality scores of the final solution were then multiplied to create a creativity score.

In addition to this measurement, an amended version of Lonergan et al.’s (2004) quality, originality and feasibility rating scales was used (see Appendix C). This questionnaire consisted of three items, each measuring a facet of creativity. The rating scale ranged from 1 (Low) to 5 (High). A composite score for creativity was created by adding the ratings from each of the three scales.

Study 1 used a total of four raters. Two of the raters were psychology doctoral students, and two were final-year psychology undergraduate students. After obtaining their consent to take part in the study, the raters were provided with anonymised written solutions in a randomised order. They were asked to independently evaluate the solutions by filling out a questionnaire for each participant. The raters based their judgement solely on the text written by the participants. The nature of the study was not disclosed to the judges, nor were they shown the recordings of the participants.

2.2.4. Procedure

The participants were asked if they would be interested in taking part in a problem-solving task. Because prior studies have shown that participants are likely to consciously think of something creative or original if they are asked to participate in a creativity task, influencing their responses, the creative element of the study was not disclosed when briefing the participants.

Once the participants had been briefed about the study, they were informed of their right to withdraw from the study and the possibility of being contacted for a second study. Informed consent was then obtained, and an ID code was provided to each participant.

The participants were then instructed to complete a short demographic questionnaire on a laptop using their ID code. Once the participants completed the questionnaire, they were briefed on how to think aloud using an amended version of Ericsson and Simon's (1993) *Protocol Analysis* instructions, and two practice questions were given.

Participants were then provided with the same laptop that they had completed the questionnaire on and were informed that they were about to start the experimental task. Before the dilemma was presented, the participants were reminded to think aloud while solving the dilemma and to use the computer provided if they wished to use the Internet. They were also told that they could take as much time as they wished to solve the problem, and they were instructed to write down their final idea. They were reminded that their responses and actions on the computer would be recorded throughout the experiment. While the participants were informed that breaks were allowed, they were also notified that time spent on a break would be captured as part of the research. If they fell silent for a duration of 5s, they were prompted to think out loud. Once the participants completed the timed experimental task, they were debriefed about the study.

This study obtained ethical clearance from the Research Ethics Review Panel in March 2017. This study followed the ethical guidelines outlined by the School of Psychology at London Metropolitan University and the British Psychological Society.

2.3. Results

2.3.1. Data Analysis

For the following analyses, SPSS statistical package version 25 was used. Tests of normality were conducted on all variables. The creativity scores were found to be normally distributed via the Shapiro–Wilk test, $W(24) = 0.98$, $p = .822$. However, most of the cognitive process variables were not found to be normally distributed. Therefore, non-parametric Spearman's correlation tests were conducted for the subsequent analyses. Furthermore, only two participants took a break during the experiment. Thus, the effects of incubation were not observed in the subsequent analyses.

2.3.2. Interrater Reliability

Given that Pearson correlation coefficient is only a measure of correlation, and therefore, deemed to be a non-ideal measure of reliability (Koo & Li, 2016), interrater reliability was assessed using the intraclass correlation coefficient (ICC). This measures both the degree of correlation and agreement between measurements. ICC estimates along with their 95% confident intervals were calculated using SPSS statistical package version 25 based on an average rating, consistency, two-way mixed-effects model.

The ICC of Lonergan et al.'s (2004) quality, originality and feasibility rating scales and Reiter-Palmon et al.'s (1997) quality and originality scales were first examined individually with all four raters. The average measure ICC for Lonergan et al.'s (2004) quality rating scale was .74, 95% CI [.52, .88]. Meanwhile, the average for the originality rating scale was .65, 95% CI [.34, .83] and for the feasibility rating scale, .41, 95% CI [-.09, .72]. The average measure ICC for Reiter-Palmon et al.'s (1997) quality rating scale was .67, 95% CI [.38, .84], while for the originality rating scale, the value was .55, 95% CI [.15, .78].

The results indicated a disagreement between the fourth judge's evaluations and those of the rest of the judges. Therefore, Judge 4 was dropped from the study, and the ICC for each scale was recalculated. Excluding Judge 4, the average measure ICC for Lonergan et al.'s (2004) quality rating scale increased to .84, 95% CI [.68, .92], while the originality rating scale decreased slightly to .62, 95% CI [.26, .82], and the feasibility rating scale increased to .49, 95% CI [-.01, .76]. The average measure ICC for Reiter-Palmon et al.'s (1997) quality rating scale increased to .72, 95% CI [.44, .87], and the value for the originality rating scale was .56, 95% CI [.13, .79].

The average score of Lonergan et al.'s (2004) quality, originality and feasibility rating scales was then calculated for Judges 1, 2 and 3 to form an overall creativity score. The resulting average measure ICC for the overall creativity score was .77, 95% CI [.54, .89], which was deemed an adequate reliability coefficient. A second overall creativity score was calculated using only Lonergan et al.'s (2004) quality and originality rating scales given that the average measure ICC for the feasibility rating scale was relatively low. The average measure ICC for the second overall creativity score increased to .79, 95% CI [.59, .90], when excluding the feasibility rating scale. Based on Reiter-Palmon et al.'s (1997) recommendations, the judge's quality and originality scores were multiplied together to form a creativity index, for which the average measure ICC was .70, 95% CI [.40, .86].

2.3.3. Creativity Scores

Next, the classification of the top and bottom creativity scorers was explored to determine the impact of implementing each creativity score in this study. Three overall creativity scores were investigated for this analysis: Lonergan et al.'s (2004) quality, originality and feasibility rating scales (overall creativity *z-score*); Lonergan et al.'s (2004) quality and originality rating scales (overall creativity *z-score*; quality and originality); and Reiter-Palmon et al.'s (1997) creativity index *z-score*.

Each overall creativity score was standardised and then ranked from highest to lowest. The top five and bottom five creativity scorers were highlighted (see Table 2). Minimal differences were observed between the classifications across all three creativity scores. In this case, the Pearson's r correlation between the overall creativity *z-score* and the creativity index *z-score* was .91, p = .001. Therefore, the average *z-score* between these two scales was calculated to form a final creativity score.

Table 2: *Classification of the Top and Bottom Creativity Scorers*

Participant	Overall creativity *z-score*	Overall creativity *z-score* (quality and originality)	Creativity index *z-score*	Average *z-score* of overall creativity and creativity index scores*
1	1.54>	1.35>	2.34>	1.94>
2	1.23>	1.16>	1.31>	1.27>
3	1.38>	1.55>	1.15>	1.27>
4	1.08>	1.35>	1.15>	1.11>
5	0.92	0.76	0.75	0.84>
6	0.92	0.96>	0.67	0.80
7	0.31	0.56	1.07>	0.69
8	1.08>	0.76	0.19	0.63
9	0.62	0.16	0.43	0.52
10	0.46	0.56	0.51	0.49
11	0.15	0.36	-0.05	0.05
12	0.00	-0.24	-0.05	-0.02
13	0.00	0.16	-0.13	-0.06
14	0.15	-0.24	-0.29	-0.07
15	-0.15	0.16	-0.05	-0.10
16	-0.31	-0.04	-0.52	-0.42
17	-0.62	-0.64	-0.92<	-0.77
18	-0.92	-0.64	-0.68	-0.80
19	-0.77	-0.64	-0.92<	-0.85<
20	-1.23<	-1.44<	-0.84	-1.04<
21	-0.92<	-1.24<	-1.24<	-1.08<
22	-1.54<	-1.44<	-0.68	-1.11<
23	-1.54<	-1.24<	-1.32<	-1.43<
24	-1.85<	-2.04<	-1.88<	-1.86<

Note. * Excludes overall creativity *z*-score (quality and originality). >Top creativity scorers in each classification. <Bottom creativity scorers in each classification. Scores displayed are *z*-scores.

2.3.4. Occurrences of Cognitive Processes and Creativity

To test the first hypothesis, the occurrences of each cognitive process were computed for each participant and correlated with their creativity scores. The means and standard deviations of the occurrences can be found in Table 3, along with the results from Spearman's rho analysis. The results revealed a statistically significant relationship between idea generation and creativity, $r_s = .57$, $p = .004$, evaluation and creativity, $r_s = .57$, $p = .004$, and implementation, $r_s = .43$, $p = .035$.

Table 3: *Means, Standard Deviations, and Spearman's rho Analysis Results Between the Frequencies of Each Cognitive Process and Creative Output*

		M	*SD*	Creativity	1	2	3	4
1	Problem finding	33.3	35.1	-.16				
2	Information gathering	25.0	27.7	.01	.25			
3	Idea generation	81.5	62.7	.57**	.10	.13		
4	Evaluation	73.7	67.5	.57**	.09	.31	.71**	
5	Implementation	87.7	70.4	.43*	-.03	.05	.76**	.69**

Note. *N* = 24. Two-tailed.
**p* < .05. ***p* < .01.

Using the detailed coding scheme, Spearman's rho correlations were performed on the occurrences of these processes and creativity scores. Table 4 displays the results. All sub-processes of idea generation and evaluation were found to be positively related to creativity scores. Additionally, the number of times participants went back to read the dilemma was found to be positively linked to creative output, $r_s = .44$, $p = .032$.

Table 4: *Means, Standard Deviations, and Spearman's rho Analysis Results Between the Frequencies of Each Sub-Process and Creative Output*

Cognitive processes	Sub-processes	*M*	*SD*	Creativity
Problem finding	Not coming up with an idea or evaluating strategies	0.2	0.4	.21
	Coming up with ideas or strategies for generating a solution	22.4	21.7	-.19
	Evaluating strategies for generating a solution	10.0	14.1	-.08
Information gathering	Using the Internet to acquire new information not related to an idea	11.7	15.8	-.16
	Evaluating new information acquired for solution while on the Internet	4.5	6.6	-.16
	Re-reading dilemma/searching relevant information for an idea	4.7	3.0	.44*
	Using the Internet to gather relevant information for an idea	8.6	16.1	.29
Idea generation	Coming up with an idea	77.0	60.3	.53**
	Coming up with an idea during idea evaluation	4.5	4.4	.52**
Evaluation	Evaluating an idea	39.2	34.2	.51*
	Re-reading/evaluating output	29.9	37.3	.58**
Implementation	Implementing/writing up the solution	87.7	70.4	.43*
	Retrieving information from memory/past experiences	3.3	4.4	.07
Other	Writing notes that are not related to final idea	2.6	3.7	-.08
	Editing and formatting solution, deleting sentences and words	49.8	46.2	.48*

Note. *N* = 24. Two-tailed.
**p* < .05. ***p* < .01.

2.3.5. Time Spent Engaging in the Cognitive Processes and Creativity

The second hypothesis was tested by computing the time in seconds that each participant spent engaging in each cognitive process and correlating these values with their creativity scores. The means, standard deviations and results from Spearman's rho analysis are displayed in Table 5. On average, participants spent more time generating, evaluating, and implementing ideas than engaging in other processes such as problem finding. The three most occurring cognitive processes also correlated positively with creativity scores and highly correlated with each other. In contrast, problem finding was revealed to be related to time spent generating ideas, $r_s = .46$, $p = .023$. However, it was not observed to be correlated with evaluation or implementation.

Table 5: *Means, Standard Deviations, and Spearman's rho Analysis Results Between Time Spent Engaging in Each Cognitive Process and Creative Output*

		M	*SD*	Creat-ivity	1	2	3	4
1	Problem finding	172.7	254.2	-.01				
2	Information gathering	206.4	267.4	.04	.33			
3	Idea generation	321.0	237.9	.51*	.46*	.43*		
4	Evaluation	312.7	313.2	.58**	.23	.38	.84**	
5	Implementation	310.1	240.8	.57**	.19	.18	.70**	.74**

Note. $N = 24$. Two-tailed.
*$p < .05$. **$p < .01$.

Table 6 displays the means, standard deviations, and results from Spearman's rho correlation analysis between time spent engaging in the cognitive processes based on the detailed coding scheme and creativity scores. Participants spent more time generating and implementing ideas, on average, according to the detailed coding scheme. The time spent evaluating ideas appeared to be roughly split between time spent evaluating ideas generated and time spent evaluating the final idea/solution written. However, the correlation between time spent evaluating the final idea/solution written and creativity scores, $r_s = .68$, $p = .001$, was stronger than that for time spent evaluating ideas, $r_s = .43$, $p = .038$. All sub-processes feeding into idea generation, evaluation and implementation positively related to creativity scores.

Table 6: *Means, Standard Deviations, and Spearman's rho Analysis Results Between Time Spent Engaging in Each Sub-Process and Creative Output*

Cognitive processes	Sub-processes	*M*	*SD*	Creat-ivity
Problem finding	Not coming up with an idea or evaluating strategies	1.1	3.5	.18
	Coming up with ideas or strategies for generating a solution	116.8	162.0	-.06
	Evaluating strategies for generating a solution	52.1	95.5	.02
Information gathering	Using the Internet to acquire new information not related to an idea	99.0	143.3	-.11
	Evaluating new information acquired for solution while on the Internet	21.3	36.6	-.17
	Re-reading dilemma/searching relevant information for an idea	29.4	21.5	.34
	Using the Internet to gather relevant information for an idea	77.9	168.6	.26
Idea generation	Coming up with an idea	302.5	227.5	.50*
	Coming up with an idea during idea evaluation	18.5	20.4	.49*
Evaluation	Evaluating an idea	178.2	186.0	.43*
	Re-reading/evaluating output	116.1	159.1	.68**
Implementation	Implementing/writing up the solution	310.1	240.8	.57**
	Retrieving information from memory/past experiences	22.8	27.6	-.01
Other	Writing notes that are not related to final idea	7.9	12.6	-.03
	Editing and formatting solution, deleting sentences and words	79.1	87.9	.56**

Note. $N = 24$. Two-tailed.
$^*p < .05$. $^{**}p < .01$.

2.3.6. Distribution of Time Spent Engaging in the Cognitive Processes and Creativity

Exploring the third hypothesis – There will be a difference in how high and low creative scorers engage in their cognitive processes – entailed calculating the percentage of time spent engaging in the cognitive processes for each participant. This approach standardised time spent across all participants, and thus enabled the comparison of how the participants spent their time engaging in the cognitive processes in relation to the other cognitive processes. Two measures were created for this purpose, one that included time spent in silence (uncoded time) and one without.

In order to identify differences in terms of how individuals with high creative output engaged in the cognitive processes, the participants' creativity scores were ordered from highest to lowest and split into two groups. A series of independent samples *t* tests were then conducted between the top and bottom 50% creative output scorers in the percentage of time spent engaging in the cognitive processes. Table 7 displays the results.

Table 7: *Average Percentage of Time Spent on Each Cognitive Process Between High and Low Creative Output Groups, Including and Excluding Uncoded Time*

		PF	IN	IG	EV	IM
Excluding silences						
	High creative output	8%**	11%	24%	23%*	26%
	Low creative output	19%**	16%	22%	14%*	20%
Including silences						
	High creative output	7%*	9%	20%	19%*	21%
	Low creative output	15%*	14%	18%	12%*	16%

Note. N = 24. Two-tailed. PF = Problem Finding; IN = Information Gathering; IG = Idea Generation; EV = Evaluation; IM = Implementation. *p< .05. **p < .01.

A significant difference emerged between the high and low creative output scorers in the amount of time individuals spent engaging in problem finding (excluding silences), $t(22) = -2.85$, $p = .009$. The magnitude of the differences in the means was large, eta squared = .30. This finding was replicated when including the silences, $t(22) = -2.62$, $p = .016$. Another significant difference was found in the amount of time individuals spent engaging in evaluation, where high creative output individuals spent proportionally more time evaluating ideas (excluding silences), $t(22) = 2.56$, p = .018. The magnitude of the differences in the means was large, eta squared = .23. This result was also found when including the silences, $t(22) = 2.59$, $p = .017$. These results suggest that high creative output scorers dedicated less time engaging in problem finding and more time evaluating ideas compared to those with low creative output scores.

Next Spearman's rho analyses were conducted between the percentage of time spent engaging in the cognitive processes with and without silences (uncoded time) and creativity. The results are displayed in Table 8. Those who proportionally spent more of their time problem finding compared to the other cognitive processes achieved poorer creativity scores, $r_s = -.54$, $p = .006$. This relationship was also found when controlling for uncoded time, $r_s = -.51$, $p = .011$.

In contrast, those who spent more time engaging in evaluation produced more creative solutions when not controlling for uncoded time, $r_s = .64$, $p = .001$, as well as controlling for uncoded time, $r_s = .66$, $p = .001$. A significant positive correlation was also observable between the percentage of time spent engaging in implementation when controlling for uncoded time, $r_s = .41$, $p = .047$. This relationship was marginally significant when not controlling for uncoded time, $r_s = .38$, $p = .07$.

Table 8: *Means, Standard Deviations and Spearman's rho Analysis Results Between Percentage of Time Spent Engaging in Cognitive Processes and Creative Output, Including and Excluding Uncoded Time*

Cognitive processes	*M*	*SD*	Creativity	Creativity[1]
Problem finding	0.14	0.10	-.54**	-.51*
Information gathering	0.14	0.12	-.31	-.34
Idea generation	0.23	0.08	.20	.25
Evaluation	0.19	0.10	.64**	.66**
Implementation	0.23	0.10	.38†	.41*

Note. $N = 24$. Two-tailed. [1]When controlling for silences (uncoded time).
†$p < .08$. *$p < .05$. **$p < .01$.

All cognitive processes, apart from information gathering, were normally distributed. Therefore, Pearson's *r* correlation analyses were conducted on the variables that did not violate the assumptions. Similar results were found, but the relationship between implementation and creativity was stronger. Table 9 displays the results.

Table 9: *Pearson's Correlation Analysis Results Between Percentage of Time Spent Engaging in Cognitive Processes Excluding and Controlling for Uncoded Time, and Creative Output*

Cognitive processes	Creativity	Creativity[1]
Problem finding	-.52**	-.48**
Idea generation	.16	.20
Evaluation	.57**	.61**
Implementation	.44*	.48**

Note. $N = 24$. Two-tailed. [1]When controlling for uncoded time.
*$p < .05$. **$p < .01$.

When fleshing out the relationship between the percentage of time spent engaging in the cognitive processes and creativity, a similar picture emerged. Table 10 demonstrates the correlations between the percentage of time spent engaging in the detailed cognitive processes when excluding and controlling for uncoded time, and creativity.

Table 10: *Means, Standard Deviations, and Spearman's rho Analysis Results Between Percentage of Time Spent Engaging in Cognitive Processes Using Detailed Coding Scheme and Creativity Scores, both Excluding and Controlling for Uncoded Time*

Cognitive processes	Sub-processes	Creativity	Creativity[1]
Problem finding	Not coming up with an idea or evaluating strategies	.19	.20
	Coming up with ideas or strategies for generating a solution	-.51*	-.52**
	Evaluating strategies for generating a solution	-.31	-.31
Information gathering	Using the Internet to acquire new information not related to an idea	-.27	-.28
	Evaluating new information acquired for solution while on the Internet	-.31	-.28
	Re-reading dilemma/searching relevant information for an idea	-.14	-.15
	Using the Internet to gather relevant information for an idea	.26	.26
Idea generation	Coming up with an idea	.10	.13
	Coming up with an idea during idea evaluation	.43*	.43*
Evaluation	Evaluating an idea	.31	.36
	Re-reading/evaluating output	.61**	.65**
Implementation	Implementing/writing up the solution	.39†	.42*
	Retrieving information from memory/past experiences	-.21	-.20
Other	Writing notes that are not related to final idea	-.12	-.12
	Editing and formatting solution, deleting sentences and words	.43*	.45*

Note. $N = 24$. Two-tailed. [1]When controlling for uncoded time.
†$p < .06$. *$p < .05$. **$p < .01$.

Spending proportionally more time developing ideas or strategies for generating a final idea (problem finding) was found to be negatively related to creativity scores when excluding uncoded time, $r_s = -.51$, $p = .01$. Additionally, the percentage of time spent on formulating an idea and evaluating an idea were not related to creativity. However, significant positive correlations were found between generating ideas during evaluation and re-reading/evaluating written solutions and creativity (when not controlling for uncoded time), $r_s = .43$, $p = .038$, and $r_s = .61$, $p = .001$, respectively. Lastly, the percentage of time spent implementing ideas was also positively correlated with creativity (marginally significant when not controlling for uncoded time, $r_s = .39$, $p = .062$, and significantly correlated when controlling for it, $r_s = .42$, $p = .041$. However, writing notes was not found to be related with creativity, $p = .572$.

2.3.7. The Transitions Between Cognitive Processes and Creativity

Examining the transitions between from one cognitive process to another required computing the various combinations of the overarching cognitive processes. The number of transitions observed throughout the creative problem-solving effort was then calculated for each participant. Silences (uncoded codes) were removed from the computations. A total of 1,787 transitions were identified, *M* = 66.4, *SD* = 41.5. These results are presented in Table 11. One participant was removed after being identified as an outlier.

Table 11 demonstrates that the most common transitions took place between idea generation, evaluation, and implementation. Out of all the transitions observed, 71% happened between these three cognitive processes. These transitions were also positively correlated with creativity scores. The most frequent transition seen among participants was from idea generation to implementation. This observation suggests that participants, on average, implemented their ideas immediately after idea generation rather than evaluating an idea before implementation. This transition was also positively correlated with creativity, $r_s = .57$, $p = .004$. Nevertheless, the transition from idea evaluation to implementation had the highest correlation with creativity scores, $r_s = .72$, $p = .001$.

Using the Shapiro–Wilk test, the total number of transitions observed per participant was found to be normally distributed, $W(23) = 0.98$, $p = .848$. Given that both the creativity scores and total number of transitions were normally distributed and other assumptions were met, a Person's *r* correlation analysis was conducted on their relationship. The results revealed a positive correlation between the total number of transitions between the cognitive processes the participants engaged in and creativity scores, $r = .67$, $p = .001$. This outcome suggests that those who engaged in the cognitive processes in a more dynamic manner obtained higher creativity scores, supporting the fifth hypothesis.

Table 11: *Means, Standard Deviations, Range, Transition Frequency, and Spearman's rho Analysis Results Between Total Number of Transitions Observed and Creative Output*

Transitions						
From	To	*M*	*SD*	*Range*	Total number of transitions	Relationship with creativity scores
Problem finding						
	Information gathering	5	5.7	0–22	120	-.05
	Idea generation	4.7	5.3	0–24	114	.30
	Evaluation	2.6	2.1	0–7	69	.59**
	Implementation	1.4	2.0	0–7	32	-.04
Information gathering						
	Problem finding	5.3	6.4	0–28	126	-.23
	Idea generation	2.1	2.9	0–11	50	.16
	Evaluation	3.8	5.6	0–23	90	.28
	Implementation	0.3	0.6	0–2	6	—
Idea generation						
	Problem finding	2.3	2.2	0–7	56	.37
	Information gathering	11.9	11.9	0–59	285	.41*
	Evaluation	16.7	13.8	1–46	443	.60**
	Implementation	20.2	14.5	0–50	601	.57**
Evaluation						
	Problem finding	5.0	5.4	0–23	132	.30
	Information gathering	3.9	5.6	0–22	94	.14
	Idea generation	16.2	11.7	0–44	457	.68**
	Implementation	15.4	12.3	1–44	417	.72**
Implementation						
	Problem finding	1.4	1.8	0–7	33	.26
	Information gathering	0.3	0.8	0–3	7	—
	Idea generation	18.5	13.2	0–49	525	.53**
	Evaluation	17.2	15.1	1–51	478	.64**

Note. $N = 23$. Two-tailed. Observations <10 were excluded from the correlational analysis.
$^*p < .05$. $^{**}p < .01$

2.3.8. Overall Time Taken and Creativity

Testing the third hypothesis initially involved investigating the link between time spent on the task and creativity using Pearson's *r* correlation analyses. Two participants were flagged as outliers and excluded from the analysis. The overall time data were found to be normally distributed via the Shapiro–Wilk test, $W(22) = 0.91$, $p = .053$.

The results revealed a significant positive correlation between time taken and creativity scores (two-tailed), $r = .61$, $p = .003$. Despite the small sample size, curvilinear analyses were then explored to test the third hypothesis that the relationship between time taken and creativity would be an inverted-U. The linear regression was found to be significant, R^2 Adjusted = .33, $F(1, 20) = 11.52$,

p = .003. The quadratic term was also significant, R^2 Adjusted = .30, $F(2, 19) = 5.60$, p = .012, but the increase in R^2 from linear to quadratic was not significant, p = .698.

2.4. Study 1 – Qualitative Analysis

2.4.1. Thematic Analysis

Arriving at a more comprehensive view of how the cognitive processes are related to creativity required conducting an in-depth qualitative analysis of the extremes. The approach was similar to that undertaken in Amabile et al.'s (2004) study into leadership behaviour and creativity using diary narratives, which allowed the researchers to identify several fundamental differences in their participants' behaviour.

Using the classification of the top and bottom creativity scorers in Table 2, the top five and bottom five creativity scorers were identified using the average *z-score* of overall creativity and creativity index scores. The participants' experiments were transcribed, including their actions on the computer. A deductive thematic analysis (e.g. following Braun & Clarke, 2006) was then conducted to examine the behaviours of the high and low creative output participants using the overarching cognitive processes (see Figure 1). Incubation was not observed, as none of the 10 participants took a break.

Examination of the behaviours and actions of the high and low creative output scorers revealed a number of fundamental differences, as the following analyses will reveal.

2.5. Qualitative Study Findings

2.5.1. Problem Finding

Problem finding is the process of outlining the goals and objectives of an ill-defined problem and constructing a plan to structure and guide the problem-solving effort. This cognitive process was evident in both low- and high-scoring creative output participants. However, clear differences were apparent in how both groups engaged in this process.

Compared to the high-scoring group, most participants in the low-scoring group spent more time trying to come up with a strategy or plan to help them generate an idea. For example, one participant decided to look on the App Store after reading the dilemma. They wondered whether the app should be paid or free, despite not having thought of an idea. They then proceeded to search on the Internet for an idea, generating search strategies and evaluating them as they searched:

> [00:01:30] So, I'm just going to go onto the App Store and have a look at the top charts, just to get a bit of inspiration. Um, so, again, need to probably debate whether it's a paid app or a free app with, um, advertising or a way to monetise the idea because it's a bit pointless making an app if it's not gonna make any money. So, some of the top things are more for a Mac rather than for, um, iPhone or similar mobile device, so that's not actually particularly helpful. (SAJ5599, low creative output scorer)

This participant completed their task in 7 minutes, yet they spent the first 6 minutes trying to structure the problem. Another low-scoring participant, PAT4946, adopted a similar approach. The participant appeared to struggle to generate an idea, and therefore, spent time formulating different plans (e.g. researching her phone apps, trying to think of an app that they had previously generated). Yet another low-scoring participant, MIC8032, also struggled to come up with an idea and, therefore, spent their time trying to assess the dilemma. For example:

> [00:01:46] Okay, so first of all, I would want to do, um . . . I will want to discover why sales declined. Was it because [pause] of an internal issue with the company, maybe a change of leadership, or maybe some other operational issue that's making it less effective? Basically, is the problem in the company? Because, if so, then coming up with a new mobile app idea will not restore their place in the market. Um, so, would an app even solve their problem? (MIC8032, low creative output scorer)

This participant spent most of their time constructing the problem and failed to come up with a final solution, eventually deeming the task impossible to solve. Although strategies among the low creative output scoring group differed, the majority spent their time constructing the problem. It must be noted, however, that two of the participants in the low-scoring group (BOR0900 and RIS1695) did not spend their time constructing the problem. Nor did they did spend much time engaging in any of the other processes; in fact, both finished their tasks within 4 minutes.

In contrast to the low-scoring group, none of the participants from the high-scoring group spent time constructing the problem. They all appeared to generate a general concept for their solution relatively quickly (e.g. an app about travelling, dating, finance, etc.) and then generated multiple solutions to the problem. For example, 1 minute into COL5599's task, the participant said:

> [00:01:04] You know what, I've fe . . . I've been thinking of because of my job at the moment is something that is like, helps like, um finan . . . like access to finance. Um, so I've been try . . . I've been thinking about like groups of people, like um who . . . everyone has access to a mobile phone but doesn't necessarily like have access to a bank account. (COL5599, high creative output scorer)

A stream of ideas followed, each being elaborated and evaluated. Ultimately, 5 minutes into the experiment, COL5599 had formulated an idea and thoroughly evaluated it by checking the requirements from the dilemma. A similar approach was observed in another high-scoring participant, STE3662. This participant also generated a general theme/concept immediately:

> [00:01:37] So, the first thing I think, the most popular thing is like some kind of dating app, something that absolutely everybody would want to use. I think . . . hmm, yeah, my mind goes straight to dating, but maybe something just a bit more . . . like with the ease of Tinder, but with the less shady vibe of it. (STE3662, high creative output scorer)

After trying to think of something related to dating, the participant decided to change course and then immediately developed a solution. In summary, STE3662 generated a rough solution within

3 minutes into the experiment. Similarly, DAV8200 generated a strategy 1 minute into the experiment and then immediately generated a theme or general concept:

> [0:00:59] So, the easiest way to think about this is, what annoys me about my phone? So, the app, in order to . . . to get a crazy new app, it can't be about something that's already quite well known, like there's a million apps about travelling. There's a million apps about travelling, though, like I love fucking travelling, and I . . . I do think that maybe there's something . . . what about airport? (DAV8200, high creative output scorer)

The participant then came up with an app idea about airports. Similar thinking patterns were observed in the other two high-scoring participants, JER8106 and ADA8106. Altogether, the low-scoring participants appeared to spend more time formulating a plan to help them structure the problem than the high-scoring group.

2.5.2. Information Gathering

Two forms of information gathering were observed in this study: (a) gathering new information about the task, and (b) gathering relevant information for their solution. These different search strategies also reflect the sub-processes in Table 1 presented in this chapter. For example, the sub-processes *2.1 Using the Internet to acquire new information not related to an idea* and *2.2 Evaluating new information acquired for solution while on the Internet*, are reflective of gathering information about the task.

In contrast, *2.3 Re-reading dilemma/searching relevant information for an idea* and *2.4 Using the Internet to gather relevant information for an idea* are reflective of gathering relevant information for an idea. In both the low creative output group and the high-scoring group, 3 out of 5 participants used the Internet. That said, the high and low creative output groups differed in their approach when searching for information relating to the task and to their solution. Therefore, these search strategies will be explored separately.

2.5.2.1. Gathering new information for the task

Gathering novel information for the task involved using the Internet or phone to acquire knowledge about the task that had called for the participants to create a new app. Notable differences were evident in terms of how the high and low creative output groups used the Internet to help them, the search terms they used and how much time they spent on the Internet.

Participants in the low creative output group tended to use the Internet or their phone to search for mobile apps to help them generate an idea. For example, SAJ5599 went on the Internet for some "inspiration" but soon recognised that it might not help:

> [00:02:21] Um, so what I'm going to maybe do instead is go into the featured, just to see whether there's any mobile apps. . . . No, I might need to go back onto the Internet and [typing – search mobile apps]. Um, again, that's not massively helpful. Oh, this one's a bit more difficult, um, so I'm just narrowing down my search to

> look at um iOS applications, but, again, that's not really narrowed it down enough. So, um [typing – iOS store]. Okay, this looks a bit more promising cos I'm going onto the iOS App Store, hopefully, apart from it's just the website, so that's sort of pointless. Okay, this isn't working out very well. (SAJ5599, low creative output scorer)

Similarly, PAT4946 researched currently existing mobile apps by using their phone as they struggled to come up with an idea:

> [0:06:55] Yeah, so I'm just looking at the apps that I have. So, again, I'm like plan . . . I'm plundering existing things just to answer the question, cos I don't like this sort of exercise at all, and I think it's a bit bonkers. (PAT4946, low creative output scorer)

After going through their phone for mobile apps proved fruitless, these participants decided to go back to the dilemma. Another participant from the low creative output group, BOR0900, also used the Internet to help them formulate an idea. They initially typed in "most needed apps" in the Google search bar before deleting the phrase and typing "biggest problems in 2017". After coming across a picture of Donald Trump after clicking on one of the search results, they generated an idea:

> [00:01:34] Oh okay, no. I mean what am I gonna . . .? Okay, let me Google [typing – biggest . . . oh like I dunno, the most needed app [laughs] um, biggest problems in 2017]. Okay um, maybe um, or risks, they can . . . ah, maybe I can create an app about the stuff that Donald Trump says [laughs]. Why? I would download that app [laughs]. Technology um The White House, [techy], no this isn't the right thing. Maybe I can create . . . I don't know. What if I create an app. . . . I don't know. (BOR0900, low creative output scorer)

This participant soon abandoned the Internet and decided to come up with another idea on their own. In all, the low creative output scorers appeared to rely on the Internet in the first instance to help them come up with an idea. Participants appeared to abandon the search for mobile applications once they generated an idea.

In comparison, the high-scoring group did not spend time researching mobile apps. For example, one of the participants in the high creative output group who did not use the Internet (DAV8200) recognised that using the Internet might not help them to generate a solution, saying, "[0:13:10] Mmm, if I start looking on the Internet for new app ideas, I'm gonna spend three hours doing that and come up with nothing" (DAV8200, high creative output scorer).

Another participant from the high creative output group, COL5599, only used the Internet to conduct more tailored searches after generating an idea. Along the same lines, high creative output scorer JER8106 initially used the Internet to search for virtual reality games after they had come up with a general idea to create an app around VR. They later generated a viable VR app solution but decided to turn their efforts to another, "simpler" solution:

> [00:07:52] A simpler idea would be to just, uh make an addictive game that, um makes money quicker, that's something like those games where you just like put some sort of . . . what do you call it? Like diamonds and that kind of stuff, that's kind of just copying others. Um, so we're gonna come up with some magic app. Um [sighs] I'm gonna do the . . . maybe a little bit of searching here, um and it doesn't have to be a game at all. Uh [typing – top money-making apps], no, that is [typing – top selling . . . the most . . . the most successful apps]. Um, 15 most successful app companies, "top grossing apps are making way too much money", that sounds pretty good. (JER8106, high creative output scorer)

Both COL5599 and JER8106 had an idea before searching the Internet. ADA8106 was the only high creative output scorer to use the Internet to conduct a general search of the most popular mobile apps as the members in the low creative output group had done. However, their Google searches quickly changed from "most popular apps" to searching, "What do people want from an app?" This search led them to a Buzzfeed article, "28 Phone Apps That Need to Exist Right Now". Using this article, they were able to understand the gaps in the market. After quickly reading the article, ADA8106 decided to revise his strategy for finding a solution:

> [00:08:02] An app where you enter a book which I'm reading, gives you a playlist to match the plot, so you've got . . . oh, that's a great idea, I'm into that. That's stupid. This is a great idea [laughs], I feel like Claire may have already got my idea for me, so that's really useful because I would be into that app as well. I might ditch the competitor research. I feel like this is gonna be more successful if I start off by being passionate about it and trust my own judgement and then try and back up with other stuff. Yeah, okay, that's a plan; I'm gonna start with the idea, and then I'm gonna research to see whether it exists or not. That's – that's good. (ADA8106, high creative output scorer)

Shortly following their change in strategy, ADA8106 immediately generated an idea for an app that would end up becoming their solution.

2.5.2.2. Gathering relevant information for their solution

As well as using the Internet to help generate ideas, some participants also used the Internet to gather related information for their solution or re-examined the dilemma for relevant information. However, not all participants engaged in this process. For example, only one participant from the low creative output group (PAT4946) gathered related information for their solution. In contrast, 4 out of 5 participants from the high creative output group engaged in this process.

PAT4946 devised their first idea, a driving app, about halfway through their experiment. They decided to use the Internet to confirm whether their idea existed:

> [00:12:08] Um yeah, somehow you get points for doing things, I don't know if you have an app that records . . . now I have to go and search what there is. Apps for driving. [Clears throat]. No, not an app to use in your car, [unintelligible 00:12:41] apps. Whoops . . . [types – apps for driving well], apps for driving well. Uh, smartphone apps that monitor how you drive, okay, so it already exists, just as I said. Let's have a look. Score, 86, okay, so great, so something I thought would be good, let's have a look. Confused.com, what is that for? "Has been testing two mobile

> phone apps which use telematics to monitor driver's behaviour behind the wheel. If telematics aren't in your life, they will be soon. Insurers are using them . . . I was recently looking into mobile phone apps and discovered some insurance companies that now have apps that sit on your phone and provide a snapshot, sits on" . . . so you did get discounts. (PAT4946, low creative output scorer)

After gathering more information about their driving app idea, they decided to abandon it and go back to a general film app idea that they had thought of at the beginning of the task. They then proceeded to search online for film apps:

> [00:15:30] I don't know, this all about . . . iCarPark, where you parked your car . . . oh my God. Uh, alright, um yeah, so that's a sort of info thing, I'm sure there's a film app already. I'm bored with this now, so I'm going on to something else. Um hmm, that's not . . . here we are, smartphone . . . [sniffs] um okay, so now I'm researching . . . yeah, IMDb, okay, dozens of apps. Okay, already exists. Its presentation, Film Distributor's Association, represents all the theatricals in the UK, cinema release, that's boring. Um To-TodoMovies 3, Quick Film, Trailers, of course, yeah, [tuts]. Um, it has trailers, DVD releases, Amazon, Sky Go, this is GetGlue TVTag . . . right, "we all tweeted and texted furiously". TVTag, so you can comment, vote, poll, "check in", okay. So maybe like a film app that does that, let's see. (PAT4946, low creative output scorer)

The high creative output group tended to gather more specific information from the Internet following idea generation. For example, COL5599 came up with a semi-well-thought-out finance app idea 1.5 minutes into the experiment and only went on the Internet to determine whether her app idea would be viable for 16-year-olds and up:

> [00:06:30] Which age group downloads the most apps? Breaking down the most used Android apps by age group. I'm trying to determine how users are likely to download my app. Start-ups. Hmm. "Drill down specific types of markets", okay, this is not helpful. "Downloading apps by age in the UK", that statistics one. [Clears throat]. So, 16% . . . seven uh, "yes I have", "can't recall", "no I haven't", so it is 18–24, that's the most downloading apps, it doesn't give you anything lower than that, which is interesting. Cos I wanna know like under the age of 18, cos you're most likely to be opening a bank account like between . . . well, from 16 on . . . upwards. But that would suggest that it's definitely younger, a younger market, so an app on like financial inclusivity wouldn't appeal that much to the plus-55s, but they're not the biggest market share. (COL5599, high creative output scorer)

COL5599 also frequently went back to the dilemma to ensure that their solution would fit the dilemma. This process led to more ideas being generated/elaborated:

> [00:19:30] So I think this could get them a lot of publicity because, um, organisations like the UN are really behind [typing – organisations like the UN are behind . . . are behind um this kind of initiative]. [Clears throat]. Um [Reads dilemma] "past 6 months a sharp decline in app sales" so . . . and with publicity, you hope that people will down . . . download the app. They can a-also team up with consumer bodies, um and [typing – consumer lobbyists] like, you know, your Martin . . . who does the Moneysaving Expert? He has his own show as well. (COL5599, high creative output scorer)

ADA8106, on the other hand, went back to make sure they had not missed anything:

> [00:53:00] That's the market placement. I'm just gonna check the problem again to make sure I haven't missed anything. It's a diverse range of mobile apps, so this is . . . and like it will appeal to a wide audience, so it's like tick, tick. They're a key global player. New mobile app idea to restore Techappboratory . . . I mean, it might be too small, but I think it's really good, so I'm gonna go with that. (ADA8106, high creative output scorer)

Interestingly, no one in the low creative output group went back to check or re-read the dilemma. Overall, the high creative output scorers not only tended to gather related information via the Internet to help them elaborate their ideas, but they also checked the dilemma to ensure their solutions were fit for purpose.

2.5.3. Idea Generation

Naturally, idea generation was evident in all participants regardless of their creativity score. However, the number of ideas generated as well as the type of ideas differed significantly between the two groups. Three types of ideas were observed: (a) a strategy to come up with an idea, (b) a general theme or concept for an idea, and (c) a specific idea or solution to the problem. All participants in the high creative output group generated a wide range of themes and ideas for the app. For example, DAV8200 produced a number of themes and ideas in a very short period of time:

> [0:12:20] Maybe actually . . . oh, gelato, find the best gelato. I don't know why, I'm also thinking about something to do with [clears throat] driving, but actually no, apps are not a good idea when you drive cos then you look at your phone. So, that's not very useful. An app for the bike, an app for biking? Is there like an app for biking? (DAV8200, high creative output scorer)

Similarly, STE3662 generated one idea after another after having settled for a general concept/theme "cats". For example, only 5 minutes into the experiment, this participant was thinking aloud:

> [00:05:32] Uh some kind of cat thing, uh maybe some kind of thing like you [typing – upload a photo of your cat, and then you play games to gain cat skills] and then [laughs] you like [typing – fight other people's cats on the game [laughs] and then] there's like – like a cat hall of fame. Uh, and then like you get cat – cat nip in the app, so like uh [typing – boost cat skills], you can be . . . your cat can be catnapped, and so you need to like start again. (STE3662, high creative output scorer)

This pattern was also observed among the other high-scoring participants. In contrast, the low-scoring group struggled to generate ideas or themes for the app. They also experienced difficulty elaborating on their ideas. For example:

> [00:04:24] Yeah, I'm just stuck, I was thinking about how I never even used to understand what apps were, and now they're just downloading everything for everything. I mean, they're probably . . . this probably exists, maybe an app . . . and it's got to be . . . appeal to a wide audience. Something about [typing – something about finding content in one place, where could I find it?] I guess then I'd have to research what exists already [sighs]. Um, what's frustrating is, [typing – having had ideas and not written them down]. (PAT4946, low creative output scorer)

Furthermore, the low-scoring group typically came up with one idea/solution and stuck with it, whereas the high-scoring group developed multiple solutions. For example, RIS1695 articulated an idea within 2 minutes of the experiment and submitted it:

> [00:02:35] So, what about, um an online app where . . . which is restricted to younger people to share their opinions, which, you know, obviously they have, um that will . . . that they can share with each other and that other people can go on to have a look at as well. So, by young people, I mean something like maybe like 15 and under because no one really listens to what 15 and under have to say, so that would be my idea. (RIS1695; low creative output scorer)

Other participants from the low-scoring group tried to "cheat" and/or took shortcuts by basing their idea on the one generated in the previous task. For example, PAT4946 tried to remember an app idea that they had come up with in the past with a colleague, saying:

> [00:00:52] Um uh um, so I'm trying to think of apps which, when I've gone, "oh, there should be an app for that" and recently. So, again, I'm like trawling my . . . I'm trying to cheat, basically" (PAT4946, low creative output scorer).

PAT4946 then struggled to come up with a theme and then generated an idea around their previous idea from the other task. Furthermore, the low-scoring participants typically skirted around the problem rather than develop ideas or solutions for the dilemma. Indeed, MIC8032 recognised this choice by observing:

> [00:04:37] I feel like I'm going really, really off-piste with this problem" (MIC8032, low creative output scorer).

Generally, the low creative output group did not find it easy to generate themes and ideas, choosing to remain within their parameters of expertise or ideas generated. In contrast, the high creative output scoring participants developed a wide range of concepts and solutions to the problem.

2.5.4. Evaluation

Similar to idea generation, various forms of evaluation were observed in all participants. Evaluation occurred at different stages of the problem-solving effort, from (a) evaluating a strategy or plan to (b) evaluating a general concept and, finally, (c) evaluating a solution. Although both high and low creative output groups engaged in evaluation, some noteworthy differences were noted.

Generally, the low-scoring group evaluated their ideas less than the high creative output group. Given that the high-scoring group generated multiple themes and ideas, they instantly evaluated each idea until they were able to select the best one. For example, DAV8200 generated a wide range of themes and ideas but also evaluated each rapidly:

> [0:03:05] So, the id – so I should just have the idea of what the app should do, basically. Hmm, exchanging data? No, that's fucking useless cos you have emails. Organising emails into folders and shit? That would be very useful for me, but I may never use it, so why would anyone else use it? What about . . . oh, what about an app

> that reads your emails or reads your emails? No, you can actually select to share emails with the app, and then the app will pull out the details from the emails for, say, if it's a flight reservation, the app will pull out the booking codes, the date and the price. And then the app will create for you a calendar and budget, or even better, it can actually link up your . . . it can link up your, say, your banking app; or you have like a . . . well, I have the spreadsheets for my budget, so maybe you can do that. And then you make a reservation, for example, and it . . . comes up directly in . . . that's like kind of a fucking [folder], so an app is pretty useless at that. Okay, let's think about something else, let's think about something else. Um, an app, fitness apps, I'll never think of that because I'm fucking useless at this. Mmm, an app for animals, an app for animals. Mmm, to look like, recognise your dog? No, that's fucking stupid. Mmm. (DAV8200, high creative output scorer).

In contrast, the low-scoring group did not evaluate their strategies or ideas. They typically went with the first solution they thought of without evaluating it (e.g. RIS1695). Similarly, BOR0900 articulated an idea and did not evaluate it:

> [00:04:28] So, then, you'd have like things that were overheard or like pictures of London and like, um events going on, and it would just all be together. So, you know how like the BBC has like the best pictures of the week and the best quotes and like, then, it'll also have like the best events, so it'll combine everything together. So, maybe that's what I'll do, and then each city will have its own thing, so um, I guess I will call it "what's app?" [Laughs]. [Typing – what's . . . what's up London?] Okay, so then . . . and it's going to have . . . or like or "x" city, and it's going to have, um events, quotes, pictures, um news about each city. Done. [End of experiment]. (BOR0900, low creative output scorer)

Neither did the low-scoring participants re-read or check their output as much as the high creative output group. Generally, the latter meticulously checked their solution and output. For example, COL5599 spent a long time reading her solution and cross-checked her ideas using the Internet:

> [00:13:42] Um okay, and then . . . and then it could be, um it could have a broad appeal [typing – to people just looking for new financial products or services], kind of like a um moneysaving expert, um but on an app. So, to group together all those things. Um [unintelligible 00:14:17] "key global players and developing unique mobile apps", is this unique? Let's see if something exists. [Typing in Google– apps about finance]. I should have looked at that first, maybe, whether if it was unique. "four best personal finance apps", Investopedia, "best apps for managing your money", it's not quite the same as teaching you about finance. So, all of these apps on here assume you've already got a knowledge of how the system works already, this one comes with a credit score. Okay, it sends you payment reminders, but my app would be . . . okay, let's [unintelligible 00:15:24] up the idea again, [typing – it would be a section on like basic financial skills, um such as transactions, how interest works, how credit works, um a section on how to . . . this is all your basic stuff, open a bank account. Your credit score, um like a budgeting tool. (COL5599, high creative output scorer)

In total, not only were the high creative output group quick to evaluate their ideas, but they also spent a long time evaluating those ideas.

2.5.5. Implementation

Naturally, implementation was a requirement for the task, as participants were instructed to write their final solution down. However, I observed noticeable differences on when and how they implemented their ideas. In the low-scoring group, 3 out of 5 participants wrote their idea at the very end of the experiment, while the other two participants wrote notes throughout their experiment. Specifically, PAT4946 wrote notes throughout her experiment until they turned into an idea:

> [00:18:00] [typing – okay, um some kind of um conversation app, so type in] but how is that interesting, though? Uh, because it will have a spoiler on it . . . mmm. That sort of thing, what was I really thinking about? Oh, I know [typing – maybe an app for um film ideas], which is . . . probably exists. (PAT4946, low creative output scorer)

A film app would end up becoming PAT4946's final solution. MIC8032 also wrote their ideas down as they thought of them but ultimately failed to come up with a solution:

> [00:07:21] Yeah, yeah, um [typing – if app sales decline generally, don't sweat it and try to design an app to fit the new uh market]. Um okay, so other things they could do, so [typing – other ideas] um uh, they could come up with a mobile app idea to capitalise on things that are already proven to work, so um, they could [typing – design a copycat app for short-term gain] uh, they could um . . . they could [typing – design an app to [pause] support a trend to ride the tailcoats of something else]. Um, or they could um . . . [typing – they could design an app to . . .] uh, what I'm trying to say is, they could design an app to um leverage their existing apps. (MIC8032, low creative output scorer)

The other participants from the low-scoring group wrote their solutions at the very end of the experiment after settling on a solution. For example:

> [00:03:18] [Typing – I would say an app for young people to express their opinions in current events, which they may not be able to express otherwise]. Um yeah, but then maybe they don't really care about politics, although I think a lot of them do, but maybe they will be able to [unintelligible 00:03:43] otherwise. [Typing – um a platform for chat and opinion sharing]. Yep. [End of experiment]. (RIS1695, low creative output scorer)

In contrast, the participants in the high creative output group typically implemented their ideas as soon as they thought of an idea. They then went through a process of generating ideas, implementing them and evaluating them straightaway. For example, STE3662 devised an app idea and immediately started to implement it, adding more details as they thought of more ideas:

> [00:07:34] Like um maybe [typing – Kitty Cat Adventure or something] uh yeah, [typing – load a photo of your cat, gets turned into a unique cat um cartoon uh] no, maybe upload a photo of your cat. Um, how would this work? Uh, I think for gaining cat skills is definitely a winner [typing – including um including purring, uh chasing mice, um being cute to get human attention, um um prowling]. Um purring, chasing mice, being cute to get human attention, prowling um al-ali . . . no something to do with an alley cat, [typing – uh alley cat fighting maybe. Uh, and napping in unusual locations] something like that, those are the cat skills, and then uh . . . yeah, actually, yeah. And then you can [typing – use money . . . use your money to buy catnip to

> boost skills, um [laughs] and [laughs] uh um, then [typing – play little mini games as your cat and go on adventures]. (STE3662, high creative output scorer)

COL5599 also implemented their ideas as they thought of them or evaluated them:

> [00:10:50] Um, disadvantaged groups who have been excluded from finance, so, for example, victims of domestic violence [typing – violence, refugees, um] this is on the basis that it's well known that all these groups own a mobile phone, so I think there's been a lot of like, um newspaper articles recently on, um like refugees and refugee camps like using mobile phones and taking selfies and stuff. [Typing – refugees mobile phones]. Yeah, the "mobile connectivity, a lifeline for refugees", "surprised that refu . . . Syrian refugees have smartphones". Um, but not necessarily . . . "disadvantaged groups who have been . . ." so like these groups have access to mobile phones, so [typing – groups that have access to mobile phones, but not necessarily access to finance]. (COL5599, high creative output scorer)

Lastly, the high creative output group tended to format their solution so that it would be clear and appealing, whereas the low creative output scorers did not spend any time formatting their ideas. For example, DAV8200 took approximately 50 minutes to submit his solution but started implementing their idea about 20 minutes into the experiment. They elaborated and refined their solution for roughly 30 minutes. Similarly, ADA8106 spent time formatting his solution and turning it into a sales pitch:

> [00:50:30] What else do I want to put on there? I'm just gonna add in a couple more stuff, I might as well make it into a pitch now. So, is that . . . um, I just wanna . . . yeah, you know, make it into like . . . I'm making it into a little script for a pitch almost, so I know what I'm saying if somebody wants me to sell it in, I am ready to sell in Cracker Jack. Um uh. (ADA8106, high creative output scorer)

2.5.6. Transitions from One Process to Another

In many process models, problem finding is typically outlined as the first stage in the creative process and is believed to be the prerequisite for all other cognitive processes underlying creativity. Although all participants in the high and low creative output groups started with problem finding, the participants in the high-scoring group tended to engage in the processes in a more dynamic manner than those participants who scored low in their creative output. For example, DAV8200 was very quick to jump between problem finding, idea generation and evaluation:

> [0:16:29] Oh, what about an app that shows you . . . and you can take a picture of it, of your clothes, say, and it will tell me not . . . these two things don't – don't go together. That is very subjective, so people are gonna be pissed off about it, so it's not really gonna work, is it? Mmm, what else? What else? What else? What else? An app about . . . an app about works of art. No, or would you . . . like, how would we sell it? Mmm, what about an app . . . oh, what about an app where you draw something and then you submit it? Like you draw something on your phone with your finger? No, that's stupid, it's not gonna work. An app about trains, what the fuck do you do with trains? I'm not gonna do an app about trains, that's stupid. (DAV8200, high creative output scorer)

In contrast, the low creative output group appeared quite linear in their thought processes, generating an idea, evaluating it and then implementing it. For example, RIS1695 went directly from problem finding to generating a single idea to implementing it:

> [00:02:15] In the past 6 months, uh we've had a lot of um events in the . . . in politics, so like with Brexit, I don't remember when that was, and with Trump. And maybe, um a lot of young people's voices aren't being heard with things that are going on, because no one really wants to listen to them. So, what about um an online app where . . . which is restricted to younger people to share their opinions, which, you know, obviously they have, um that will . . . that they can share with each other and that other people can go on to have a look at as well. So, by young people, I mean something like maybe like 15 and under because no one really listens to what 15 and under have say, so that would be my idea…[Typing – I would say an app for young people to express their opinions in current events which they may not be able to express otherwise]. Um yeah, but then maybe they don't really care about politics, although I think a lot of them do, but maybe they will be able to [unintelligible 00:03:43] otherwise. [Typing – um a platform for chat and opinion sharing]. Yep. (RIS1695, low creative output scorer)

BOR0900 also took a very similar approach but did think of a rough idea beforehand:

> [00:03:30] So, apps . . . I don't know, people like-like the hot new thing or like something that's like a social thing. Um but then there's like the top 10 in London and stuff. Maybe like a what to do this weekend app. [Typing – best thing to do this weekend]. No . . . okay, or like um . . . okay, I was thinking that maybe I can combine the two and do like um like a what's going on in your city app. So, then you'd have like things that were overheard or like pictures of London and like um events going on and it would just all be together. So, you know how like the BBC has like the best pictures of the week and the best quotes and like then it'll also have like the best events, so it'll combine everything together. So, maybe that's what I'll do and then each city will have its own thing, so um I guess I will call it "what's app?" [Laughs] [00:05:00]. [Typing – what's . . . what's up London?] Okay, so then . . . and it's going to have . . . or like or "x" city, and it's going to have um events, quotes, pictures, um news about each city. Done. (BOR0900, low creative output scorer)

Interestingly, BOR0900 and RIS1695, who were identical twins, received similar creativity scores and completed the task in roughly the same time, only 1 minute apart.

2.6. Discussion

Study 1 examined individuals' cognitive processes that underpin creativity and its relationship with creative output. The results from the quantitative and qualitative analyses fleshed out the role that each cognitive process may play in creativity and how they might differ between high and low creative output. The first and second hypotheses, that the frequencies of use and time spent engaging in each cognitive process – (a) problem finding, (b) gathering information, (c) incubation, (d) idea generation, (e) idea evaluation, and (f) idea implementation – will be positively related to creative output were partially supported.

The number of ideas generated, evaluated, and implemented, as well as time spent engaging in each of them, were found to be linked to creative output as opposed to problem finding or information gathering, which were not. These results support previous studies observing the links between fluency (idea generation) and creativity as well as between idea evaluation and creativity (e.g. Basadur et al., 2000; Lonergan et al., 2004; Runco, 2003). However, this investigation is the only known study that has examined idea implementation and creativity in depth, and the results from this experiment demonstrate the importance of this mental operation. This cognitive process was coded every time a participant wrote their final idea. If they deleted a letter or word, a different code (7.3) was assigned. In some cases, entire paragraphs and sentences were deleted. This code was also found to be related to creativity. Therefore, this may suggest that that those who wrote more – or perhaps elaborated their idea more – and spent time editing their idea produced more creative solutions.

In contrast to previous research, problem finding and information gathering were not found to be related to creativity. However, when exploring the third hypothesis (that there will be a difference in how high and low creative output scorers engage in their cognitive processes), a slightly different picture emerges. When exploring standardised time spent engaging in the cognitive processes, those who spent proportionally more time than others engaging in problem finding achieved poorer creative output scores. This finding was supported in the qualitative analyses of the extremes. The participants in the low creative output group appeared to spend a long time trying to structure the problem, perhaps due to their inability to generate ideas. In contrast, the participants in the high creative output group did not waste time trying to structure the problem but generated numerous ideas, evaluating each as they went, and they were quick to implement their ideas. This observation contradicts the previous literature on problem finding, which suggests that creative individuals spend more time structuring the problem (e.g. Getzels & Csikszentmihalyi, 1975, 1976; Reiter-Palmon et al., 1997).

The detailed coding scheme allowed a microscopic view of the cognitive processes and their relationship with creativity. Problem finding, for example, was broken down into three sub-processes: (a) problem finding without coming up with an idea/strategy nor evaluating it; (b) coming up with ideas or strategies for generating a solution; and (c) evaluating strategies for generating a solution. Interestingly, the first sub-process was rarely observed. In fact, the average occurrence for this process was 0.2, $SD = 0.4$. In comparison, the average occurrence for generating strategies to help come up with an idea was 22.4, $SD = 21.7$, and evaluating strategies was 10, $SD = 14.1$. The occurrences or time spent on these sub-processes were not found to be linked to creativity. However, the percentage of time spent generating strategies to help develop an idea, relative to other processes, was found to be negatively correlated with creative output. This correlation might have been the key driver for the negative relationship observed between problem finding and creativity and, thus, suggests that those who proportionally spent more time generating strategies produced poorer creative solutions.

To date, generating and evaluating strategies to help develop an idea have not been incorporated in any process model before. These components would typically be placed under problem finding as they are required to shape the problem. Previous studies into problem finding have documented positive relationships with creativity (e.g. Redmond et al., 1993; Reiter-Palmon et al., 1997). Such studies have usually involved asking participants to write as many problem restatements or creative questions of a problem as they can think of. The generated problem restatements are then judged on originality and quality. However, creating problem restatements or questions would involve some form of idea generation and implementation. Moreover, idea evaluation was likely to have taken place before or after the participants wrote their questions down. Therefore, the participants in these studies probably engaged in other processes, such as idea generation, evaluation, and implementation. Overall, these findings may suggest that problem finding or coming up with a good question could involve other processes.

In this study, information gathering involved gaining new or relevant information required to solve the dilemma using the Internet. Although the occurrences and time spent in information gathering were not significantly related to creative output, noticeable differences were observed in terms of how the participants acquired information in the qualitative analysis of the extremes. The results from this analysis revealed a notable distinction between how the high and low creative output groups chose to use the available resources (i.e. laptop, phone and dilemma) to help them come up with a solution. The low creative output group tended to use the Internet or their phones as a first resort to help stimulate idea generation. Moreover, they did not search for related information in the dilemma. Strikingly, only 1 out of 5 participants in the low creative output group gathered relevant information compared to 4 out of 5 in the high-scoring group.

The high creative output group appeared to rely on their ability to generate ideas and mostly used the Internet to help collate evidence for their solution. They also spent time scanning the dilemma to ensure that their solution had met all goals, which in turn stimulated further idea generation. The quantitative results partially supported these findings. In general, the direction of correlations for the sub-processes acquire new information or knowledge about the task (sub-processes 2.1 and 2.2) were negative even though they were not significant. For example, the correlation coefficients of the frequencies of and time spent in the sub-process *2.1 Using the Internet to acquire new information not related to an idea* were -.16 and -.11, respectively. Meanwhile, in the sub-process *2.2 Evaluating new information acquired for solution while on the Internet*, the correlation coefficients for frequency/time spent were -.16 and -.17, respectively.

On the other hand, the direction of the correlations for gathering related or relevant information was positive, reflecting that the number of times participants scanned the dilemma for relevant information for their solution was significantly positively correlated. For example, the correlation coefficients of the frequencies of and time spent in the sub-process *2.3 Re-reading dilemma/searching relevant information for an idea* were .44 and .34, respectively. Likewise, the correlation coefficients of the frequencies of and time spent in the sub-process *2.4 Using the Internet to gather relevant information for an idea* were .29 and .26, respectively. The non-significant findings may be due to the small sample size, which reduced the power of the analyses conducted. In all, this outcome illustrates the different search strategies that individuals take when solving an ill-defined problem as well as how the various strategies are linked to creativity. These results support previous studies investigating information gathering and creativity (e.g. Alissa, 1972; Mumford, Baughman, Supinski et al., 1996) where creative individuals tended to focus their efforts gathering relevant information.

Study 1 also examined the prediction that the more creative individuals would go through the cognitive processes in a more dynamic fashion and would engage is more transitions, from one process to another. The results from this study both supported these predictions and demonstrated how non-sequential the creative cognitive process is regardless of creative ability. Perhaps most importantly, the findings revealed which transitions are related to creativity.

Interestingly, the most common transition was between idea generation and implementation and was found to be statistically positively correlated with creativity. This outcome suggests that a form of the “trial-and-error” approach appears to be an effective method in generating creative solutions. However, the participants did not randomly test out their ideas; instead, they had a general concept and frequently went back to build on and refine their final solution. Nonetheless, idea evaluation appears to play a key role in the creative process as well. The transitions between idea generation, evaluation and implementation were all positively correlated with creativity. These findings mirrored the results from the qualitative analyses of the extremes. The high creative output group jumped between idea generation, evaluation, and implementation relatively quickly. In contrast, the low creative output scorers took a more linear approach in their creative problem-solving effort, generating a small number of ideas, hardly evaluating them and implementing them at the end of the experiment.

Finally, this study explored the sixth exploratory hypothesis (there will be a relationship between overall time taken to complete the task and creativity). The results suggest that this relationship may be linear. That said, an inverted-U relationship was observed when including the outliers in the analyses, indicating the possibility of an optimal amount of time that creative individuals take to solve an ill-defined problem, which supports prior studies that have examined the link between time pressure and creativity (e.g. Amabile et al., 2002; Baer & Oldham, 2006). However, a bigger sample size would be required to establish the type of relationship involved.

Altogether, the findings from both the qualitative and quantitative studies suggest that idea generation, evaluation and implementation are the key cognitive processes underlying creativity. The results indicate that those who produced more creative solutions spent more time and were more effective at engaging in these processes. Moreover, they also appeared to bounce between the processes in a more dynamic and rapid manner compared to those who produced a low creative output.

2.7. Limitations

This study has yielded novel and interesting results, which may further scholarly understanding of the cognitive processes underlying creativity. However, the study also has several limitations that must be considered.

The main limitation lies in the sample characteristics. The sample size was small, and most of the participants were highly educated, limiting the ability to generalise the study results to a larger population. Additionally, certain variables were not controlled for, which could have influenced the conclusions drawn. For example, the participants' familiarity with the dilemma was not captured or controlled for.

Moreover, the participants' creativity evaluations were based solely on their written solutions. The judges or raters did not watch the footage of the participants developing their solutions. As a result, some details of the participants' ideas might have missed. Nevertheless, this procedure followed the requirements of Amabile's (1982) Consensual Assessment Technique, and the participants were briefed that the raters would base their evaluations on their written solutions only.

It must also be noted that the raters would be considered non-expert raters. According to Amabile (1996), certain tasks in some domains may only require raters with limited expertise and training in the field. However, the author further advised that not all raters (e.g. psychology undergraduate students) could be appropriate judges. Nevertheless, good inter-rater reliability was observed among the raters, which is considered one of the acceptable replacement standards set by Kaufman et al. (2009).

2.8. Outlook on Chapter 3

In summary, the mixed-method approach used in Study 1 yielded some interesting and promising findings, particularly in regard to the dynamism of the creative process and how transitions relate to creative output. However, this study was conducted on a small sample size, limiting the ability to generalise its findings to the wider population. Given that examining footage of participants solving an ill-defined problem on a large scale would not have been practical, an objective and reliable tool was required to capture the creative process, including their dynamism.

The next chapter explores the details of an online experiment devised to capture the creative process and their dynamism. Study 2 in this dissertation comprises the first known experiment to capture the entire creative process, including its dynamism, in real time and in an objective manner. The question of the tool's validity must be addressed, however. In Study 2 (which Chapter 3 presents), the online experiment was piloted on the same participants from Study 1, enabling their responses and actions in the online experiment to be cross-validated. A discussion of the results from this validation study will also be included.

Chapter 3: Study 2

3.1. Introduction

The results from Study 1's quantitative and qualitative analyses suggest that idea generation, evaluation and implementation are the core mental operations that underlie creative thought. Occurrences and time spent engaging in these processes were positively correlated with creative output. Furthermore, when investigating the transitions between the cognitive processes, the findings demonstrated the dynamic nature of these mental operations. Circa 70% of all transitions occurred between idea generation, evaluation and implementation, and these transitions were all correlated with creative output.

The general introduction to the thesis established the need to develop measures that explicitly capture the fundamental mental operations. In response, and because analysing footage of participants solving an ill-defined problem on a large scale would not be feasible, developing an experiment to capture the dynamic processes was necessary.

In this study, an online experiment was devised with the aim of objectively capturing the dynamism of the creative process. However, prior to testing the experiment with the wider population, this approach was pilot-tested on the participants who took part in the first study. Therefore, the aim of Study 2 is to demonstrate the development and initial validation of the online experiment.

The online experiment consisted of a homepage with six clickable images, each representing a cognitive process (e.g. viewing the dilemma, information gathering, incubation, idea generation, evaluation, and implementation). The participants were instructed to click on the images/processes in the same way as their thoughts progressed as they solved an ill-defined problem. The cognitive processes under investigation in this study were the same as Study 1, with the exception of problem finding. Given that the occurrences of and time spent engaging in problem finding were not found to be related to creativity in Study 1, the decision was taken to omit problem finding from Study 2 and focus on the core cognitive processes that were identified in Study 1.

The online experiment was designed to capture the frequency of and time spent engaging in the various processes as well as the transitions between the processes. However, unlike Study 1, where participants had to think out loud as they solved the problem, this online experiment required the participants to click on the various images/processes to demonstrate their thinking pattern. As such, achieving absolute task equivalence would prove challenging. Nevertheless, this method was designed to objectively capture the frequencies of, time spent engaging in, and transitions between these processes, allowing the replication of this study with a larger sample size.

Given that the online experiment might not have been as refined in capturing the creative process as Study 1, the following hypotheses were posed to fulfil the aim to demonstrate adequate validity:

> *H1*: The frequencies of gathering information, idea generation, evaluation and implementation in Study 1, including their respective sub-processes, will correlate positively with the frequencies of the corresponding processes in the online experiment.

> *H2*: Time spent engaging in gathering information, idea generation, evaluation and implementation in Study 1, including their respective sub-processes, will correlate positively with time spent engaging in the corresponding processes in the online experiment.

> *H3*: The total number of transitions observed in Study 1 will positively correlate with the total number of transitions engaged in Study 2.

Given that the frequencies of and time spent in idea generation, evaluation and implementation were found to be related to creative output in Study 1, the following hypotheses were also posed for Study 2:

> *H4*: The frequencies of idea generation, evaluation and implementation will be positively related to creative output.

> *H5*: Time spent engaging in idea generation, evaluation and implementation will be positively related to creative output.

When investigating the percentage of time spent engaging in each cognitive process in comparison to the other processes, Study 1 revealed statistically that the high creative output group spent proportionally less time problem finding and more time in evaluation. Because problem finding would not be included in Study 2, the following exploratory hypothesis was posed once more:

> *H6*: There will be a difference between high and low creative output scorers in how much relative time they spend engaging in the processes.

Study 1 demonstrated that the cognitive processes underlying creativity operate dynamically. Since the number of transitions between idea generation, evaluation and implementation were significantly linked to creativity and a positive relationship was found between the total number of transitions engaged and creativity, observing these relationships could be expected when using the online experiment. Therefore, the following hypotheses were posited:

> *H7*: The cognitive creative process will not follow a linear sequence.

H8: Individuals who engage in more transitions from one process to another will produce more creative solutions.

H9: The occurrences of transitions between idea generation, evaluation and implementation will be linked to creativity.

Lastly, overall time taken in Study 1 appeared to be linear and positively related to creative output. Study 2 explored this relationship again, and thus, the following exploratory hypothesis was posited:

H10: There will be a positive relationship between overall time and creativity.

3.2. Method

3.2.1. Study Design

This study employed an experimental design. The participants undertook an online experiment where they were asked to generate a solution to an ill-defined problem. Similar to Study 1, these participants were asked to demonstrate their thinking as they solved the dilemma. The independent variables of the study were the frequency of and time spent viewing the dilemma, gathering information via the Internet, and engaging in idea generation, evaluation and implementation throughout the creative problem-solving effort. The dependent variable was the creative output (the final solution submitted).

3.2.2. Participants

Participants who took part in the first experiment were asked to provide their email address if they wished to take part in a similar experiment online. Although all participants indicated their interest in taking part in the second study, only 22 of the original 24 participants completed the online experiment. The total number was evenly divided in terms of sex: 50% were male and 50% female. Average participant age was 30 (SD = 4.7). Most of the participants were highly educated, with 63.3% having listed “Masters” as their highest level of education. No reward or incentives were provided to participants for their involvement in the study.

3.2.3. Materials and Procedure

Experimental task

Gorilla Experiment Builder (www.gorilla.sc) was used to create and host the experiment (Anwyl-Irvine et al., 2020).

The participants were invited via email to take part in an online problem-solving study, where they were asked to solve a dilemma for a fictional company. Like Study 1, the creative element of the study was not disclosed in Study 2. Once the participants had read the brief about the study, their informed consent was obtained. Participants were then asked to provide their ID code that they had used in Study 1 to allow matching their data. They were also reminded of their right to withdraw from the study. An instructional video about the experiment was then presented to the participants. Figure 3 describes the dilemma presented in the video.

Figure 3: *Practice Dilemma Used in the Instructional Video*

Practice Dilemma

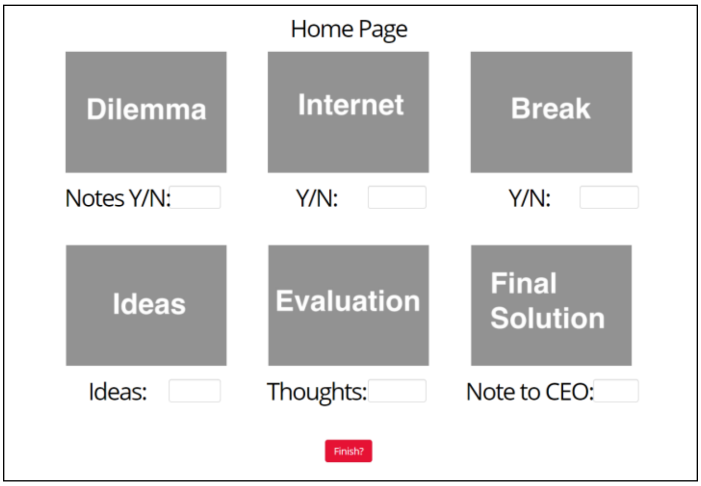
You have just been informed that you have won one million pounds in the "24-hour lottery". In the terms and conditions, it states that you only have 24 hours to spend your lottery winnings. What would you spend it on?

N.B. Please come up with a new solution if you have already thought of one in the past.

The online experiment consisted of six clickable screens: Dilemma, Internet, Break, Ideas, Evaluation, and Final Solution (see Figure 4). The participants were instructed to solve the dilemma by navigating through the screens in the same way as they think their way through the problem.

The dilemma screen (Figure 8 in the Appendix D) displayed the dilemma for the task. The dilemma presented to participants can be seen in Figure 5. A free text box was provided for participants if they wished to write any notes about the dilemma. Participants were asked to separate each note using a semi-colon. If any participants wanted to use the Internet, they were asked to click on the "Internet" screen (Figure 9 in the Appendix D) and open another tab. They were also asked to note down their web searches, each separated with a semi-colon. Whenever the participant desired a break, they were instructed to click on the "Break" screen (Figure 10 in the Appendix D) and to leave the experiment running in the background as they took their break. They were also asked to note "Y" for Yes and "N" for No if they took a break after completing the experiment.

Figure 4: *Homepage of the Online Experiment*



The participants were instructed to click on the "Ideas" screen (Figure 11 in the Appendix D) whenever they had an idea about the solution. They were asked to write down their ideas, separating each idea using a semi-colon. Whenever the participants had a thought about the dilemma, or one of their ideas or their final idea, they were instructed to click on the "Evaluation" screen (Figure 12 in the Appendix D). Similar to the "Ideas" screen, they were asked to make a note of their thoughts separating each with a semi-colon. They were told that what they wrote on this screen did not matter, provided that they clicked on the evaluation screen to signal that they had made an evaluation. The "Final Solution" screen consisted of a free text box for participants to write down their solution (Figure 13 in the Appendix D). They were informed that they could go back and edit their solution as many times as they wanted. They were also instructed to write their final solution clearly, as the characteristics of their solution would be judged by independent raters. Before submitting their final idea, the participants were instructed to write "N" which stood for No, in the free text boxes under dilemma, Internet and Break if they did not feel the need to write notes or engage in these processes.

Figure 5: *Dilemma Presented to Participants*

Top Toys

Top Toys are a toy manufacturing company. They are known for being one of the best toy invention companies in the world, producing a diverse range of toys that appeal to a wide audience. This year, the CEO of Top Toys has decided to call on all employees to come up with a new toy invention with a quick and/or high return on investment. The employee who comes up with the best toy idea will be rewarded financially. For this task, you will need to send a note to your CEO describing your new toy invention. It can be any kind of toy that you would like.

N.B. Please come up with a new toy invention if you have already thought of one in the past.

The participants' responses and actions were recorded, including time spent in each screen as well as the sequence in which they engaged in them. Once participants submitted their final solutions to the dilemma, they were then asked a couple of questions to ascertain how familiar they were with the task. The first question read: "Have you ever tried to come up with a new toy before?", to which the response options were "Yes", "No", or "Other (please specify)". The second question read: "How many times have you tried to come up with a new toy in the past?" In this case, the response options ranged from 0 to 20+ in increments of 1.

Creativity Scores

The three raters who had exhibited the highest degree of agreement in Study 1 (Judges 1, 2 and 3) were contacted and asked to take part in Study 2 as raters. Two of three judges agreed to act as raters. Both raters were doctoral students, one of whom was undertaking a PhD in Creativity. Given that there was a very high correlation, $r = .91$, $p = .001$, between Reiter-Palmon et al.'s (1997) quality and originality rating scales and Lonergan et al.'s (2004) quality, originality and feasibility rating scales in Study 1, only the latter was chosen for Study 2.

Thus, for this study, Lonergan et al.'s (2004) quality, originality and feasibility rating scales, which were constructed in line with Amabile's (1982) Consensual Assessment Technique, were used. Like Study 1, the nature of the study was not disclosed to the raters, and they were asked to base their judgement on the solution alone that each participant had written. The solutions were extracted from the "Final Solution" screen and anonymised before sending them on to the raters.

3.3. Results

3.3.1. Data Analysis

SPSS statistical package version 25 was used for the following analyses. Tests of normality were conducted on all variables. Extreme cases were removed. Using the Shapiro–Wilk test, the creativity scores were found to be normally distributed, $W(22) = 0.94$, p = 0.173. However, some of the cognitive process variables were not normally distributed. Therefore, non-parametric Spearman's rho correlation tests were conducted for the subsequent analyses. None of the participants indicated familiarity with the dilemma; thus, there was no need to control for this potential confounding variable. Lastly, unlike the case in Study 1, nine participants took a break during the experiment. Although I was unable to validate this process, the effects of incubation on creativity were investigated in Study 2.

3.3.2. Interrater Reliability of Creativity Scores

Interrater reliability was assessed using the ICC. The ICC estimates and 95% confident intervals were based on an average rating, consistency, two-way mixed-effects model. The average measure ICC for Lonergan et al.'s (2004) quality rating scale was .69, 95% CI [.26, .87], while the originality rating scale yielded .88, 95% CI [.70, .95], and the score for the feasibility rating scale was .46, 95% CI [-.31, .78].

The composite score was then created using Lonergan et al.'s (2004) quality, originality and feasibility rating scales to form an overall creativity score. The average measure ICC for the overall creativity score was .76, 95% CI [.43, .90], which was deemed an adequate reliability coefficient. A Pearson's r correlation analysis was then conducted between the creativity scores in Study 1 and Study 2. The scores were not found to be statistically significant, $r = .24$, $p = .146$.

The judges' individual ratings for quality, originality and feasibility, and their overall creativity scores in Study 1 were then correlated with their respective ratings in Study 2. Judge 1's individual ratings for quality, $r = .38$, $p = .043$, and feasibility, $r = .45$, $p = .017$, in Study 1 were correlated with their respective ratings in Study 2. Their originality score, however, was not found to be related. Their overall creativity score in Study 1 was also found to be correlated with their overall creativity score in Study 2, $r = 38$, $p = .042$. In contrast, Judge 2's ratings were not found to be related to each other, apart from their quality rating, $r = .42$, $p = .027$.

3.3.3. Validation of Cognitive Processes

Testing the first, second and third hypotheses involved comparing the participants' thought processes in Study 1 with their processes in the online experiment in Study 2. More specifically, the frequencies of, time spent engaging in, and transitions between processes in the online experiment were correlated with those in Study 1. Table 12 displays Spearman's rho correlation results between the amount of time spent engaging in gathering information, idea generation, evaluation and implementation in Study 1 and Study 2. Next, Table 13 demonstrates Spearman's rho correlation results between the amount of time spent engaging in sub-processes in Study 1 and the processes in Study 2.

The number of times participants engaged in a process was computed by adding up the total amount of clicks a participant made to the "Dilemma", "Internet", "Break", "Ideas", "Evaluation" and "Final Solution" screens/processes. Total time spent engaging in each of the processes/screens was also explored. Additionally, as the participants had been instructed to write each idea or thought separated with a semi-colon, the total number of ideas and thoughts in each screen were investigated.

Given that the dilemma screen might have been used for various reasons, such as reading the dilemma, gathering related information, and perhaps problem finding, an explorative approach was undertaken where the frequencies of this process were correlated with all Study 1 sub-processes. Spearman's rho analyses revealed no significant findings apart from a negative correlation with the problem finding sub-process *Problem finding: Not coming up with or evaluating strategies*, $r_s = -.41$, $p = .028$.

In terms of time spent engaging in the processes, no correlations were observed between time spent in the overarching cognitive processes in Study 1 and time spent in the dilemma screen/process in Study 2. However, time spent engaging in the problem finding sub-processes *Problem finding: Not coming up with or evaluating strategies* and *Problem finding: Evaluating strategies for generating a solution* were found to be negatively related to time spent on the dilemma screen, $r_s = -.39$, $p = .036$, and $r_s = -.37$, $p = .046$, respectively. Oddly, time spent on the dilemma screen in Study 2 was also marginally negatively related to the time spent re-reading the dilemma in Study 1, $r_s = -.34$, $p = .062$. Lastly, the total number of notes the participants wrote in the dilemma screen in Study 2 was positively correlated with the total number of notes written in Study 1, $r_s = .54$, $p = .005$. The total number of notes written in Study 2 also found to be correlated with the frequencies of the overarching process idea implementation in Study 1, $r_s = .46$, $p = .015$.

A similar approach was adopted for the "Internet" screen and the number of searches conducted. The information gathering process and sub-processes were correlated with participants' actions on the "Internet" screen. The results revealed that the total number of searches made in the online study was not linked to Internet use in Study 1, but the relationship was in a positive direction,

r_s = .28, *p* = .130. As only 18 participants chose to use the Internet in Study 2, this correlation could be significant if tested on a larger sample size. When looking at the sub-processes in Study 1, the number of Internet searches conducted in Study 2 was found to be correlated to the sub-process *Information Gathering: Using the Internet to gather relevant information for an idea*, r_s = .47, *p* = .024. However, this number was not found to be related to *Information Gathering: Re-reading dilemma/searching relevant information for an idea*.

Regarding time spent gathering information in Study 2, however, a different picture emerges. Time spent using the Internet in Study 2 was found to be correlated with time spent gathering information, r_s = .48, *p* = .021. Both sub-processes *Information Gathering: Using the Internet to acquire new information not related to an idea*, r_s = .52, *p* = .013, and *Information Gathering: Evaluating new information acquired for solution while on the Internet*, r_s = .45, *p* = .03, were positively corelated with time spent using the Internet in Study 2.

Regarding the hypothesised core cognitive processes underlying creativity, the total number of ideas generated in Study 2 was found to be correlated with the total number of ideas generated in Study 1, r_s = .51, *p* = .013. The total number of ideas generated in Study 2 was also found to be correlated with the total number of ideas evaluated, r_s = .52, *p* = .011, and ideas implemented in Study 1, r_s = .44, *p* = .031. The number of ideas evaluated and implemented in Study 1 were not found to be linked to the total amount of ideas evaluated and implemented in Study 2, however.

When investigating time spent engaged in each of these processes, however, implementation as well as idea generation were found to be correlated with their respective cognitive process in Study 1, r_s = .42, *p* = .026, and r_s = .45, *p* = .017, respectively. Time spent engaging in idea generation in Study 2 was also found to be related to evaluating, r_s = .47, *p* = .015, and implementing ideas, r_s = .47, *p* = .014. Implementation was also correlated with idea generation, r_s = .51, *p* = .007, and evaluation, r_s = .54, *p* = .005. However, idea evaluation was not found to be correlated to any the overarching cognitive processes in Study 1.

Table 12: *Spearman's rho Analysis Results Between Time Spent Engaging in Cognitive Processes Underlying Creativity in Study 1 and Study 2*

		IN	IG	EV	IM
1	Information gathering	.52*	.26	-.04	.09
2	Idea generation	.06	.45*	.47*	.47*
3	Evaluation	-.26	.07	.14	.21
4	Implementation	.15	.51**	.54**	.42*

Note. *N* = 22; *n* = 18 in Information Gathering. One-tailed. IN = Information Gathering; IG = Idea Generation; EV = Evaluation; IM = Implementation in Study 1.
**p* < .05. ***p* < .01.

When looking at time spent engaging in sub-processes in Study 1, time spent in implementation was positively correlated with all sub-processes related to idea generation and evaluation. Idea generation was linked to most sub-processes, including *Idea generation: Coming up* *with an idea*, r_s = .47, p = .014, and *Evaluation: Evaluating an idea*, r_s = .53, p = .006, but not *Idea generation: Coming up with an idea during idea evaluation* or *Evaluation: Re-reading/evaluating output*. Interestingly, the sub-process *Gathering Information: Re-reading dilemma/searching relevant information for an idea* was found to be correlated with both idea generation and implementation in Study 2. Idea evaluation in Study 2 was not found to be related to any of the sub-processes.

Testing the third hypothesis involved correlating the total number of transitions observed in Study 1 with the total number of transitions engaged in Study 2. The results revealed a non-significant relationship; however, the correlation coefficient is in a positive direction, r_s = .21, p = .179.

Table 13: *Spearman's rho Analysis Results Between Time Spent Engaging in Cognitive Processes Using Detailed Coding Scheme in Study 1 and Time Spent Engaging in the Processes in Study 2*

Cognitive processes	Sub-processes	IN	IG	EV	IM
Problem finding	Not coming up with an idea or evaluating strategies	.39	.18	-.05	.18
	Coming up with ideas or strategies for generating a solution	.24	.04	-.15	-.16
	Evaluating strategies for generating a solution	.29	-.26	-.24	-.27
Information gathering	Using the Internet to acquire new information not related to an idea	.52*	.20	-.20	.12
	Evaluating new information acquired for solution while on the Internet	.45*	.20	-.20	.12
	Re-reading dilemma/searching relevant information for an idea	-.12	.51**	-.03	.40*
	Using the Internet to gather relevant information for an idea	.34	-.05	-.11	.19
Idea generation	Coming up with an idea	.26	.47*	.07	.52**
	Coming up with an idea during idea evaluation	-.02	.33	.02	.57**
Evaluation	Evaluating an idea	-.08	.53**	.15	.50**
	Re-reading/evaluating output	.14	.32	.10	.46*
Implementation	Implementing/writing up the solution	.09	.47*	.21	.42*
	Retrieving information from memory/past experiences	-.12	.19	.02	0.17
Other	Writing notes that are not related to final idea	.04	.08	-.12	.14
	Editing and formatting solution, deleting sentences and words	.15	.41*	.03	.58**

Note. N = 22; n = 18 in Information Gathering. One-tailed. IN = Information Gathering, IG = Idea Generation, EV = Evaluation, IM = Implementation in Study 2.
**p* < .05. ***p*< .01.

3.3.4. Occurrences of Cognitive Processes and Creativity

As in Study 1, the total amount of each cognitive process engaged in the task was investigated. Table 14 displays the means and standard deviations of the frequencies and the results from Spearman's rho correlation analysis of the processes and creativity scores.

The results revealed a statistically significant correlation between idea generation and creativity, r_s = .62, p = .005, and implementation and creativity, r_s = .48, p = .024. The number of breaks taken was also found to be related to creativity, r_s = .71, p = .031. However, it must be noted that the sample size for this correlation was small, as only nine participants took a break.

Table 14: *Means, Standard Deviations, and Spearman's rho Analysis Results Between Occurrences of Each Cognitive Process and Creative Output*

	M	*SD*	Creat -ivity	1	2	3	4	5
1 Dilemma	2.5	1.6	.34					
2 Gathering information	2.8	1.8	.22	.55*				
3 Break	1.7	0.9	.71*	.50	-.20			
4 Idea generation	5.9	5.0	.62**	.35	.45	.80*		
5 Evaluation	4.9	3.8	.28	.23	.19	.35	.59**	
6 Implementation	2.3	1.5	.48*	.47*	.20	.85**	.60**	.54*

Note. N = 22; n = 9 in Break. Two-tailed.
*p < .05. **p < .01.

3.3.5. Time Spent Engaging in the Cognitive Processes and Creativity

Table 15 displays the means and standard deviations of each process (in seconds) as well as the results from Spearman's rho correlation analyses between time spent engaging in the processes and creativity scores. On average, participants spent 1.4 minutes, SD = 1.9, in each screen/process. Like Study 1, idea generation and implementation were found to be correlated with creativity, r_s = .47, p = .026, and r_s = .69, p = .001, respectively. However, evaluation was not found to be significantly correlated with creativity scores.

Time spent implementing their final idea was positively correlated with idea generation, r_s = .54, p = .01, and break, r_s = .87, p = .002. However, it was not found to be related to evaluation. The unusually high correlation between time spent taking a break and idea implementation may be due to the sample size observed.

Table 15: *Means, Standard Deviations, and Spearman's rho Analysis Results Between Time Spent Engaging in Cognitive Processes and Creative Output*

	M	*SD*	Creat-ivity	1	2	3	4	5
1 Dilemma	27.8	16.1	-.26					
2 Gathering information	39.8	38.5	.07	-.03				
3 Break	20.2	26.8	.62	.07	-.15			
4 Idea generation	74.9	56.9	.47*	-.25	-.18	.53		
5 Evaluation	58.0	53.4	.14	.25	-.32	.07	.38	
6 Implementation	112.2	111.2	.69**	.08	.07	.87**	.54**	.15

Note. N = 22. n = 9 in Break. Two-tailed.
*p < .05. **p < .01.

3.3.6. Distribution of Time Spent Engaging in the Cognitive Processes and Creativity

The percentage of time spent engaging in the cognitive processes was calculated for each participant and correlated with their creativity scores. Table 16 displays the results from Spearman's rho correlation analyses along with the mean and standard deviations. Proportionally spending more time implementing their final idea was correlated with creativity, r_s = .44, p = .038. Interestingly, those who proportionally spent more time on the dilemma screen achieved poorer creativity scores, $r_s = -.68$, $p = .001$.

Table 16: *Means, Standard Deviations, Spearman's rho Analysis Results Between Percentage of Time Spent Engaging in Cognitive Processes and Creative Output*

Cognitive processes	*M*	*SD*	Creativity
Dilemma	0.11	0.09	-.68**
Information gathering	0.14	0.10	-.10
Break	0.04	0.05	.36
Idea generation	0.24	0.12	.03
Evaluation	0.18	0.14	-.17
Implementation	0.33	0.17	.44*

Note. $N = 22$. Two-tailed.
$^*p < .05$. $^{**}p < .01$.

Exploring whether high creative output scorers engaged differently in the cognitive processes was achieved by splitting the group equally into two by their creativity scores. Independent samples *t* tests were then conducted between the high and low creative output groups on the percentage of time spent engaging in the cognitive processes in Study 2. No significant differences were observed between the high and low creative output scorers. Nevertheless, the high creative output scorers spent proportionally more time, on average, implementing their final idea compared to the low scorers. Table 17 displays these results.

Table 17: *Average Percentage of Time Spent on Each Cognitive Process Between the High and Low Creative Output Scorers*

	D	IN	B	IG	EV	IM
High creative output	8%	14%	6%	23%	17%	38%
Low creative output	15%	14%	2%	26%	20%	27%

Note. $N = 22$. D = Dilemma, IN = Information Gathering, B = Break, IG = Idea Generation, EV = Evaluation, IM = Implementation.

3.3.7. The Transitions Between Cognitive Processes and Creativity

Investigating how the cognitive processes transitioned from one to another entailed computing all possible combinations using sequences of two and three processes for each participant. The different codes were as follows: viewing the dilemma (1), using the Internet (2), taking a break (3), generating an idea (4), evaluating an idea (5); implementing the final idea/solution was coded as 6. Occurrences of each combination for each participant were then computed (e.g. occurrences of 4 and 5 throughout the task were calculated per participant). Given that occurrences of three cognitive processes were scarce, the subsequent analysis focused on combinations of two cognitive processes, instead. A total of 376 transitions were identified, $M = 17.1$, $SD = 9.8$. Table 18 displays these results.

The most common transition observed was between idea generation and evaluation. No statistically significant correlations were found between the transitions and creativity, apart from the transition from information gathering to implementation, r_s = .53, p = .012. However, it must be noted that only eight observations of this transition were made.

When exploring the relationship between the total number of transitions engaged and creativity, Spearman's rho analysis revealed a positive significant correlation, r_s = .42, p = .025. Like Study 1, this result indicates that those who engaged in the cognitive processes in a more dynamic manner achieved higher creativity scores.

Table 18: *Means, Standard Deviations, Range, Frequency of Transitions, and Spearman's rho Analysis Results Between Total Number of Transitions Observed and Creative Output*

Transitions						
From	To	*M*	*SD*	*Range*	Total number of transitions	Relationship with creativity scores
Dilemma						
	Information gathering	0.6	1.0	0–3	13	-0.01
	Break	0.1	0.3	0–1	2	—
	Idea generation	1.0	0.9	0–3	22	0.04
	Evaluation	0.1	0.4	0–1	3	—
	Implementation	0.5	0.7	0–2	10	0.22
Information gathering						
	Dilemma	0.2	0.5	0–2	5	—
	Break	0.2	0.4	0–1	4	—
	Idea generation	0.8	0.8	0–2	17	0.12
	Evaluation	0.6	1.2	0–5	14	-0.27
	Implementation	0.4	0.6	0–2	8	.53*
Break						
	Dilemma	0.1	0.2	0–1	1	—
	Information gathering	0.1	0.2	0–1	1	—
	Idea generation	0.4	0.7	0–2	9	0.29
	Evaluation	—	—	—	0	—
	Implementation	0.1	0.3	0–1	2	—
Idea generation						
	Dilemma	0.5	0.7	0–2	10	0.13
	Information gathering	0.9	1.1	0–3	20	0.32
	Break	0.1	0.3	0–1	2	—
	Evaluation	3.5	3.6	0–11	76	0.15
	Implementation	0.4	0.5	0–1	8	0.31
Evaluation						
	Dilemma	0.6	0.8	0–3	12	0.16
	Information gathering	0.4	0.8	0–3	8	-0.10
	Break	0.1	0.3	0–1	2	—
	Idea generation	2.8	3.5	0–11	61	0.31
	Implementation	0.9	0.7	0–2	19	-0.06
Implementation						
	Dilemma	1.0	0.7	0–3	21	-0.15
	Information gathering	0.3	0.6	0–2	6	—
	Break	0.1	0.4	0–1	3	—
	Idea generation	0.3	0.6	0–2	7	0.24
	Evaluation	0.5	0.7	0–3	10	0.35

Note. $N = 22$. Two-tailed.
$^*p < .05$.

3.3.8. Overall Time Taken and Creativity

The relationship between time spent on the task and creativity was investigated using Spearman's rho correlation analyses, as the overall time data were not found to be normally distributed. The results revealed a significant positive correlation between time taken and creativity scores, $r_s = .56$, $p = .007$ (two-tailed). Curvilinear analyses were not explored, as the assumptions had been violated.

3.4. Discussion

The aim of Study 2 was to validate the online experiment with the data from the experiment conducted in Study 1. The results from testing the first and second hypotheses produced a mixed picture. Frequencies of information gathering (Internet use) in Study 2 did not appear to correlate with the total number of searches conducted in Study 1. However, time spent gathering information in Study 2 was related to time spent gathering information in Study 1. Examining the sub-processes revealed that the number of Internet searches conducted in Study 2 correlated with the sub-process *Information Gathering: Using the Internet to gather relevant information for an idea*. Time spent using the Internet in Study 2 was positively correlated with both sub-processes *Information Gathering: Using the Internet to acquire new information not related to an idea* and *Information Gathering: Evaluating new information acquired for solution while on the Internet*. No other relationships were observed, including any with other sub-processes. This suggests that Internet use in Study 2 was solely correlated with the information gathering process and sub-processes in Study 1, even though not all relationships were significant.

The total number of ideas generated in Study 2 correlated with the total amount of ideas generated in Study 1. Time spent engaging in idea generation in Studies 1 and 2 was also significantly correlated. Although the frequencies of implementation in Study 2 were not related to those in Study 1, time spent engaging in implementation in Study 2 was significantly correlated with time spent engaging in implementation in Study 1. Furthermore, idea generation and implementation were correlated with each other, as in Study 1. In fact, the strongest correlation was between time spent on idea generation and implementation.

When testing the third hypothesis, the total number of transitions observed in Study 1 was not found to be positively correlated with the total number of transitions engaged in Study 2. This outcome suggests that we retain the null hypothesis. However, this non-significant finding could be due to several reasons. For example, the small sample size lowered the statistical power of the analysis conducted. Additionally, a total of 376 transitions were observed in Study 2, while 1,787 transitions were observed in Study 1, which demonstrates that the online experiment may not be as sensitive in capturing the transitions. However, this result could also reflect the instructions provided to the participants. In any event, a positive relationship was observed between the total number of transitions and creative output, supporting the findings from Study 1 and the eighth hypothesis.

Frequencies of and time spent in idea evaluation were not found to be related to evaluation in Study 1. Several reasons are possible for this finding. For example, the online experiment relied on the participants' indication that they had made an evaluation by clicking on the respective screen. Therefore, the participants had to demonstrate their awareness that they were engaging in this process. However, as mentioned in the dissertation's general introduction, creative individuals are skilled at evaluating their ideas (e.g. Basadur et al., 2000; Lonergan et al., 2004; Runco, 2003). This phenomenon was seen in Study 1, where idea evaluation correlated positively with creative output. In a similar vein, Runco and Chand (1994) reported that individuals who were more accurate in their evaluations produced more original ideas. Therefore, a link between idea generation and evaluation might also be reasonably expected. In all, this outcome may indicate a possible issue with the experiment.

Nevertheless, investigating the relationship between the processes and creativity yielded results that were similar to those from Study 1. These findings partially support the fourth and fifth hypotheses. With the exception of idea evaluation, idea generation and implementation were consistently found to be related to creativity, highlighting the importance of these processes in creativity.

Interestingly, the percentage of time spent engaging in the dilemma screen was strongly negatively related to creative output. This finding appears to be similar to the negative relationship observed between problem finding and creativity in Study 1. However, engaging in the dilemma screen was found to be negatively related to two of the problem finding sub-processes as well as marginally negatively related to the time spent re-reading the dilemma in Study 1. Therefore, what this screen may be capturing could be a subject of debate. One possible explanation is that participants who were stuck for ideas might have proportionally spent more of their time looking at the dilemma rather than engaging in idea generation, evaluation, and implementation.

The online experiment illustrated that the cognitive processes underlying creativity operate in a dynamic manner, supporting the findings from Study 1 and the seventh hypothesis. However, when testing the ninth hypothesis, no significant correlations between the transitions and creative output were observed, apart from the transition from information gathering to idea implementation. Although this outcome may signal the need to retain the null hypothesis, as was the case with other hypothesis, it may be due to the small sample size and/or instructions provided to the participants on how to navigate around the homepage. Nevertheless, a relationship was found between the total number of transitions engaged and creativity, indicating that individuals who engaged in the cognitive processes in a more dynamic manner achieved better creativity scores.

Lastly, the tenth hypothesis (there will be a positive relationship between time spent on the task and creativity) was supported. However, curvilinear relationships were not explored due to violations of assumptions. A larger sample size would be required to clarify this relationship.

3.5. Limitations

The main limitation of this study involved the sample characteristics. As in Study 1, the sample size was small and highly educated. Another key limitation of this study was the reliance on participants to be self-aware or to acknowledge which process they were engaging in. As such, some participants might not have navigated through the experiment while employing their typical thought processes. A possible indicator of this phenomenon was that the number of transitions engaged in this study was substantially less than the total number of transitions they exhibited in Study 1. Furthermore, the evaluation process was not captured adequately compared to the other processes, which could signal an issue with the instructions provided to participants.

3.6. Outlook on Chapter 4

Although the online experiment produced some mixed results in its validation efforts, this study comprises the first known online experiment to capture the dynamic cognitive processes underlying creativity in terms of their occurrences, time spent and transitions. With the exception of the evaluation process, the experiment as a whole demonstrated adequate validity. In the process, the investigation produced similar results to Study 1, particularly when examining the relationship between the processes and creativity. However, the question remains as to whether the same results as seen in Studies 1 and 2 might hold with a larger sample size.

Study 3 (described in Chapter 4), which was designed to build upon the findings of Studies 1 and 2, tested the online experiment with a larger sample size with the aim to further investigate the dynamic cognitive processes underlying creativity and how they are related to creativity. As part of the design of this third study, the issues identified in Study 2 were addressed by slightly changing the instructions for the experiment and including an additional sample video.

Chapter 4: Study 3

4.1. Introduction

The previous chapter detailed how the online experiment in Study 2 was developed and validated. Except in the case of idea evaluation, the online experiment was found to have adequate validity in capturing the frequencies of use and time spent engaging in information gathering, idea generation and implementation. Moreover, the occurrences of engagement and time spent in idea generation and implementation were consistently found to be related to creativity in Studies 1 and 2.

Furthermore, the results from the two earlier studies demonstrate the non-sequential nature of the creative thinking process. Both studies produced moderate to strong positive relationships between the total number of transitions made and creativity. This finding suggests that individuals who go through the processes in a more dynamic manner may produce more creative solutions.

However, these studies were conducted using a small, highly educated sample, highlighting the need to conduct this study on a larger sample size to confirm these findings. Hence, Study 3's objective was to further examine the link between the dynamic cognitive processes underlying creativity and creative output by testing the online experiment on a larger sample size.

Most of the hypotheses in this study resemble those in Studies 1 and 2. However, the larger sample in the study allowed more sophisticated analyses, such as multiple regression analyses, to be carried out. This expanded effort facilitated addressing the overarching research objective set out in Chapter 1, which was to examine the independent and combined effect of the processes on creativity. Accordingly, the following hypotheses were posited:

H1: There will be an independent and combined effect of the frequencies of idea generation, evaluation and implementation on creative output.

H2: There will be an independent and combined effect of time spent engaging in idea generation, evaluation and implementation on creative output.

Studies 1 and 2 consistently demonstrated that the cognitive processes underlying creativity operate dynamically and that the total number of transitions that occur are related to creative output. In response, the third and fourth hypotheses were posed:

H3: The cognitive creative process will not follow a linear sequence.

H4: The total number of transitions engaged will predict creative output scores.

Although none of the transitions between idea generation, evaluation and implementation were found to be correlated with creative output in Study 2, such correlations were found in Study 1. This result may have been due to the greater number of transitions that were observed in Study 1. Given the larger sample in Study 3, the ability to reproduce these findings would therefore be of keen interest. Therefore, the fifth hypothesis was proposed as follows:

H5: The occurrences of transitions between idea generation, evaluation and implementation will be positively correlated with creativity.

The exploratory research questions posed in Studies 1 and 2 regarding the difference between high and low creative output scorers as well as the relationship between overall time taken and creativity yielded interesting findings. In Study 1, the high creative output group spent proportionally more time evaluating their ideas and less time in problem finding, and the differences were significant. In contrast, no significant differences were observed in Study 2. Therefore, investigating these differences with a larger sample size was another topic of interest. Thus, it was hypothesised,

H6: There will be a difference between high and low creative output scorers in how much relative time they spend engaging in the processes.

Studies 1 and 2 consistently produced positive correlations between overall time taken and creativity. However, curvilinear analysis was only conducted in Study 1. Therefore, determining if this relationship is indeed linear with a larger sample size was another question to consider. Thus, it was hypothesised:

H7: There will be a positive relationship between overall time and creativity.

As mentioned in the dissertation's general introduction, no known study has explored whether the relationships between each of these cognitive processes are linearly related to creativity or if some of the processes are curvilinear in nature. Although linear relationships between the processes and creativity were observed in Study 1 and Study 2, it was necessary to examine these relationships with a larger sample size. Therefore, the following exploratory research question was posed:

H8: The cognitive processes underlying creativity will be linearly related to creative output.

Lastly, given the importance ascribed to the number of ideas generated or fluency in creativity, understanding the nature of this relationship seemed a valuable pursuit. Therefore, the following exploratory hypothesis was put forth:

H9: How is the number of ideas generated linked to creative output?

In summary, these research aims were used to ascertain the link between the frequencies of and time spent engaging in the cognitive processes underlying creativity and their dynamism with creative output.

4.2. Method

4.2.1. Participants

A convenience sample of 146 participants was recruited via social networks (e.g. Facebook, SurveyCircle, etc.). The average participant age was 30.36, *SD* = 11.49, range = 18–74. Of the 146 participants, 143 listed their gender: 68% of whom were female and 32% male. Out of the 146 participants, 145 listed their highest level of education. Most of them had experienced some degree of higher education: 46% of participants outlined an undergraduate degree as their highest level of education achieved, while 28% listed a postgraduate degree, and 5% listed a doctorate. Meanwhile, 8% of participants listed "school" as their highest level of education and 11% "college". Lastly, 2% of participants listed their highest level of education as "other". Only 4% of the sample were students. The average work experience was 9.92 years, *SD* = 10.51; range = 1–47. Six participants who indicated that they were familiar with the task were accordingly excluded from the analysis. Lastly, none of the participants was provided with an incentive or reward for their involvement.

4.2.2. Materials and Procedure

Experimental task

Study 3 employed an experimental design. The study's independent variables were frequency of cognitive process use, time spent in each creative process, and the transitions between creative processes. The creative output (the final solution that each participant generated) was the dependent variable. While no changes were made to the task in the online experiment, in this study, the participants viewed two instructional videos instead of one. One of the instructional videos was similar to the one used in Study 2, but some details about the screens were clarified. The second instructional video consisted of a sample video that presented a practice dilemma (see Figure 2). The Gorilla Experiment Builder (www.gorilla.sc) was used to host the experiment (Anwyl-Irvine et al., 2020).

The participants were invited via social media (e.g. SurveyCircle, Facebook, Twitter, etc.) to participate in an online problem-solving study, where they were asked to solve a dilemma for a fictional company. As in Study 1 and Study 2, the creative element of the study was not disclosed. Once participants had read the brief about the study, their informed consent was obtained. The participants were then asked to provide an ID code, in the event that they wished to withdraw from the study, and to fill out a short demographic questionnaire. The two instructional videos about the experiment were then presented to the participants. After completing the task, the participants were debriefed, and the true nature of the experiment was disclosed.

Creativity Scores

Three judges with a background in creativity were asked to take part in the study as raters. However, only two of the three agreed to act as raters. One of the judges had a PhD in Creativity, and the other judge was in their final year of completing their PhD in Creativity. Both judges had studied the cognitive processes underlying creativity. As in Studies 1 and 2, amended versions of Lonergan et al.'s (2004) quality, originality and feasibility rating scales were used. The nature of the study was not disclosed to the judges, and they based their judgements solely on the anonymised solution that each participant wrote.

4.3. Results

4.3.1. Data Analysis

For the following analyses, SPSS statistical package version 25 was used. ICC estimates and their 95% confident intervals were calculated based on an average rating, consistency, 2-way mixed-effects model. Given the large sample size, parametric analyses such as Pearson's *r* correlations were conducted for the subsequent analyses (see Ghasemi & Zahediasl, 2012).

4.3.2. Interrater Reliability of Creativity Scores

The ICCs of Lonergan et al.'s (2004) quality, originality and feasibility rating scales were first examined individually with both raters. The average measure ICC for Lonergan et al.'s (2004) quality rating scale was .69, 95% CI [.56, .78], while that for the originality rating scale was .58, 95% CI [.41, .70], and for the feasibility rating scale, .43, 95% CI [.20, .60].

The composite score of Lonergan et al.'s (2004) quality, originality and feasibility rating scales was then calculated to form an overall creativity score. The average measure ICC for this overall score was .77, 95% CI [.68, .83], which was deemed an adequate reliability coefficient.

4.3.3. Occurrences of Cognitive Processes and Creativity

Pearson's *r* correlation analyses were performed to explore the possibility of a relationship between the frequency of cognitive processes engaged (total number of clicks on each screen) and creative performance. The results suggested that participants who engaged more in idea generation, $r = .25$, $p = .002$, evaluation, $r = .26$, $p = .001$, and implementation, $r = .30$, $p = .001$, produced more creative solutions. Interestingly, the highest correlation observed was between idea generation and idea evaluation. Table 19 details the results and inter-correlations between the cognitive processes.

Table 19: *Correlation Analysis Results Between Frequency of Cognitive Processes Engaged in the Task and Creativity Scores*

		Creativity scores	1	2	3	4	5
1	Dilemma	.12					
2	Information gathering	.15	.46**				
3	Break	.18	.23*	.55**			
4	Idea generation	.25**	.46**	.47**	.45**		
5	Evaluation	.26**	.41**	.42**	.44**	.95**	
6	Implementation	.30**	.51**	.24**	.37**	.47**	.47**

Note. *N* = 80–139. One-tailed.
**p* < .05. ***p* < .01.

Given that idea generation and implementation were associated with the creativity scores, a multiple linear regression was conducted to examine the cumulative and independent effect of these cognitive processes. Idea evaluation was omitted from the subsequent analysis as its inclusion would have violated the assumption of multicollinearity, $r = .95$, with idea generation. The two cognitive process variables were entered in a single step. Table 20 summarises the results of the regression of creativity scores onto the two cognitive process variables.

Table 20: *Summary of Multiple Regression Analysis for Frequency Cognitive Process Variables Predicting Creativity*

Variable	B	SEB	β	R	R^2
Idea generation	.02	.01	.11		
Implementation	.15	.07	.23*		
				.30	.09

Note. $N = 123$. *$p < .05$. $F(2, 121) = 6.02$, $p = .003$.

Table 20 demonstrates that, cumulatively, the cognitive process variables accounted for 7.5% of the variance in creativity scores, Adjusted $R^2 = .075$. However, only idea implementation had a significant independent effect on creativity, $\beta = .23$, $p = .019$.

4.3.4. Time Spent Engaging in the Cognitive Processes and Creativity

Pearson's r correlation analyses were then conducted to investigate the relationship between time spent engaging in the cognitive processes (time spent in each screen) and creative output. Table 21 displays the results. Participants who spent more time gathering information (using the Internet) obtained higher creativity scores, $r = .27$, $p = .005$, as well as those who spent more time evaluating ideas, $r = .18$, $p = .022$, and implementing ideas, $r = .48$, $p = .001$. Time spent generating ideas was marginally related to creative output, $r = .13$, $p = .08$. The strongest correlation among the processes was between idea generation and evaluation, $r = .64$, $p = .001$.

Table 21: *Correlation Analysis Results Between Time Spent Engaging in Cognitive Processes and Creativity*

		Creativity scores	1	2	3	4	5
1	Dilemma	.03					
2	Information gathering	.27**	.14				
3	Break	-.05	.20*	.06			
4	Idea generation	.13†	.25**	.12	-.07		
5	Evaluation	.18*	.07	.20*	.16	.64**	
6	Implementation	.48**	.19*	.20*	-.05	.41**	.37**

Note. $N = 73–134$. One-tailed.
†$p < .08$. *$p < .05$. **$p < .01$.

A multiple linear regression was then conducted to examine the cumulative and independent effect of time spent engaging in idea evaluation and idea implementation. The two cognitive process variables were entered in a single step. Table 22 summarises the results of the regression of creativity scores onto the two cognitive process variables.

Cumulatively, the two cognitive process variables accounted for 22% of the variance in creativity scores, Adjusted R^2 = .22. Implementation was the only process to have a significant independent effect on creativity, β = .49, p = .001. The assumptions of homogeneity of variance and linearity were met, and the residuals were normally distributed. Tolerance and variance inflation factor were both within acceptable levels.

Table 22: *Summary of Multiple Regression Analysis for the Time Cognitive Process Variables Predicting Creativity*

Variable	B	SEB	β	R	R^2
Idea evaluation	-2.80	.00	-.02		
Idea implementation	9.54	.00	.49*		
				.48	.23

Note. N = 121. $F(2, 121) = 18.11$, $p < .001$.
*$p < .001$

4.3.5. Distribution of Time Spent Engaging in the Cognitive Processes and Creativity

As in Studies 1 and 2, the percentage of time spent engaging in the cognitive processes was calculated for each participant and correlated with their creativity scores. Table 23 displays the means and standard deviations of the percentages, along with the results from the Pearson's r correlation analyses. Proportionally spending more time implementing the final idea was correlated with creativity, r = .44, p = .001. Participants who proportionally spent more time on the dilemma screen achieved poorer creativity scores, as in Study 2, r = -.28, p = .001.

A comparison of how the high and low creative output individuals engaged in the cognitive processes was made by computing the interquartile range of their creativity scores and splitting the group into two (Q1 vs. Q4). Independent samples t tests were then conducted between the high and low creative output scorers on the percentage of time spent engaging in the cognitive processes. Table 23 presents the mean percentage of time spent engaging in the processes, along with the results from the independent t tests.

Table 23: *Means, Standard Deviations, Pearson's r Correlation Analysis Results Between Percentage of Time Spent Engaging in Cognitive Processes and Creativity Scores*

Cognitive processes	M	SD	Creativity
Dilemma	0.20	0.16	-.28**
Information gathering	0.08	0.11	.06
Break	0.03	0.12	-.06
Idea generation	0.24	0.15	-.13
Evaluation	0.21	0.13	-.12
Implementation	0.24	0.17	.44**

Note. N = 128. Two-tailed.
*$p < .05$. **$p < .01$.

Low creative output scorers spent proportionally more time engaging in the dilemma screen, *M* = 0.23, *SD* = 0.16, as opposed to high scorers, *M* = 0.14, *SD* = 0.11, and this difference was significant, *t*(59) = 2.63, *p* = .011. The magnitude of the difference in the means was medium, r^2 = .10. Low scorers also spent proportionally more time evaluating ideas, *M* = 0.23, *SD* = 0.13, compared to high scorers, *M* = 0.18, *SD* = 0.12. However, this difference was marginally significant, *t*(66) = 1.94, *p* = .057, and the effect size was small, r^2 = .05.

In contrast, the high creative output scorers spent proportionally more time in idea implementation, *M* = 0.31, *SD* = 0.17, compared to low scorers, *M* = 0.14, *SD* = 0.12. This difference was significant, *t*(66) = -4.85, *p* = .001, and the effect size was large, r^2 = .26. These findings suggest that high creative output scorers dedicated less time looking at the dilemma and marginally less time engaging in idea evaluation, while they spent proportionally more time implementing ideas compared to low creative output scorers.

Table 24: *Average Percent of Time Spent on Each Cognitive Process Between Top and Bottom Quarter Creativity Scores*

	D	IN	B	IG	EV	IM
High creative output	14%*	9%	4%	25%	18%†	31%**
Low creative output	23%*	7%	6%	27%	23%†	14%**

Note. *N* = 68. Two-tailed. D = Dilemma, IN = Information Gathering, B = Break, IG = Idea Generation, EV = Idea Evaluation, IM = Idea Implementation.
†*p* < *.06*. **p* < .05. ***p* < .001.

4.3.6. The Transitions Between Cognitive Processes and Creativity

As described in Study 2, all possible combinations using sequences of two processes were calculated for each participant. The total number of combinations or transitions were then computed for each participant. In all, 1,908 transitions were identified, *M* = 13.3, *SD* = 12.7.

The most common transition observed was between idea generation to evaluation and vice versa. Examination of the Pearson's *r* correlations between the transitions and creativity revealed a number of significant findings, as shown in Table 25.

Interestingly, the number of transitions from idea generation to evaluation was significantly related to creativity, *r* = .20, *p* = .024, as well as the number of transitions from idea generation to implementation, *r* = .24, *p* = .005. However, the total amount of transitions from idea evaluation to generation was marginally significant, *r* = .16, *p* = .058, and the number of transitions from idea evaluation to implementation were not found to be statistically significant.

Furthermore, the transition from idea implementation to evaluation was significantly correlated with creativity, *r* = .26, *p* = .002, but the transition from implementation to generation was not. Lastly, going straight into idea generation from reading the dilemma was also found to correlate positively with creativity, *r* = .20, *p* = .021.

Table 25: *Means, Standard Deviations, Range, Frequency of Transitions, and Pearson's r Correlation Analysis Results Between Number of Transitions Observed and Creativity Scores*

Transitions						
From	To	*M*	*SD*	Range	Total number of transitions	Relationship with creativity scores
Dilemma						
	Information gathering	0.4	0.7	0–4	55	-.10
	Break	0.0	0.2	0–2	7	.04
	Idea generation	0.9	1.1	0–7	132	.20*
	Idea evaluation	0.6	0.9	0–5	82	-.01
	Idea implementation	0.2	0.4	0–2	24	.12
Information gathering						
	Dilemma	0.1	0.4	0–3	19	.03
	Break	0.3	0.5	0–2	44	-.12
	Idea generation	0.4	0.9	0–8	52	.00
	Idea evaluation	0.3	0.7	0–4	46	.18*
	Idea implementation	0.1	0.3	0–2	11	.09
Break						
	Dilemma	0.2	0.4	0–2	33	-.07
	Information gathering	0.1	0.2	0–1	9	-.06
	Idea generation	0.2	0.5	0–2	32	.17*
	Idea evaluation	0.1	0.3	0–1	10	.15
	Idea implementation	0.1	0.3	0–1	11	-.06
Idea generation						
	Dilemma	0.5	0.9	0–6	65	.02
	Information gathering	0.3	0.7	0–6	36	.05
	Break	0.1	0.3	0–2	11	.11
	Idea evaluation	2.9	4.4	0–41	413	.20*
	Idea implementation	0.2	0.5	0–2	31	.24**
Idea evaluation						
	Dilemma	0.5	0.8	0–5	69	.15
	Information gathering	0.3	0.7	0–5	49	.20*
	Break	0.1	0.3	0–2	15	.24**
	Idea generation	2.3	4.2	0–40	326	.16†
	Idea implementation	0.9	0.9	0–5	125	.15
Idea implementation						
	Dilemma	0.8	0.7	0–3	113	.13
	Information gathering	0.2	0.4	0–2	23	.02
	Break	0.1	0.3	0–1	18	.01
	Idea generation	0.1	0.4	0–3	14	.14
	Idea evaluation	0.2	0.6	0–5	33	.26**

Note. *N* = 134–144. Two-tailed.
†*p<0.06*. **p*<.05. ***p*<.01.

The total number of transitions was found to correlate positively with creativity, r = .23, p = .004, even when controlling for overall time, r = .23, p = .004. A linear regression was then performed to predict creativity based on the number of transitions.

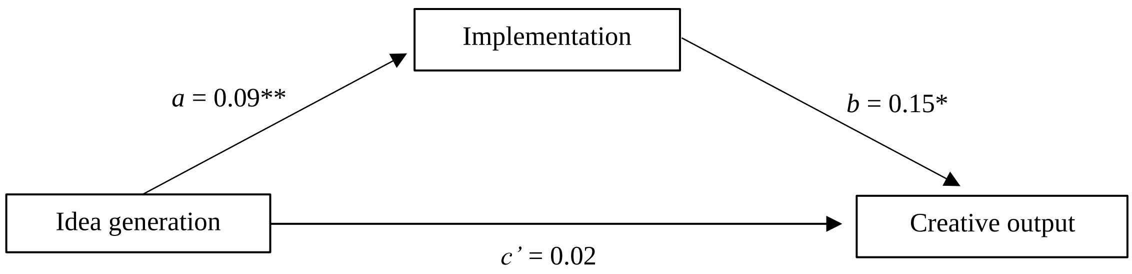
The total number of transitions accounted for 5% of creativity scores, R^2 adjusted = .045, and the regression equation was significant, $F(1, 130)$ = 7.16, p = .008. The beta-weight was .23. The assumptions of homogeneity of variance and linearity were met, and the residuals were normally distributed. Tolerance and variance inflation factor were both within acceptable levels. These results suggest that the total number of transitions engaged during the task is predictive of creativity scores.

4.3.7. Mediation Analysis

A simple mediation analysis was performed using PROCESS (SPSS version 3.5.3; Hayes, 2017) to explore whether the number of times individuals went back to implement their solution mediated the relationship between the number of ideas generated and creativity. The predictor variable for the subsequent analysis was idea generation, and the outcome variable was the creativity score. Implementation was the mediator.

Mediation modelling revealed a full mediation effect of idea implementation on the relationship between the number of ideas generated and creativity, Effect = .014, 95% CI [.001, .029]. The indirect effect explained 48.5% of the total effect, while 51.5% was explained by the direct effect. Figure 6 illustrates the model along with the coefficients.

Figure 6: *Simple Mediation Model*

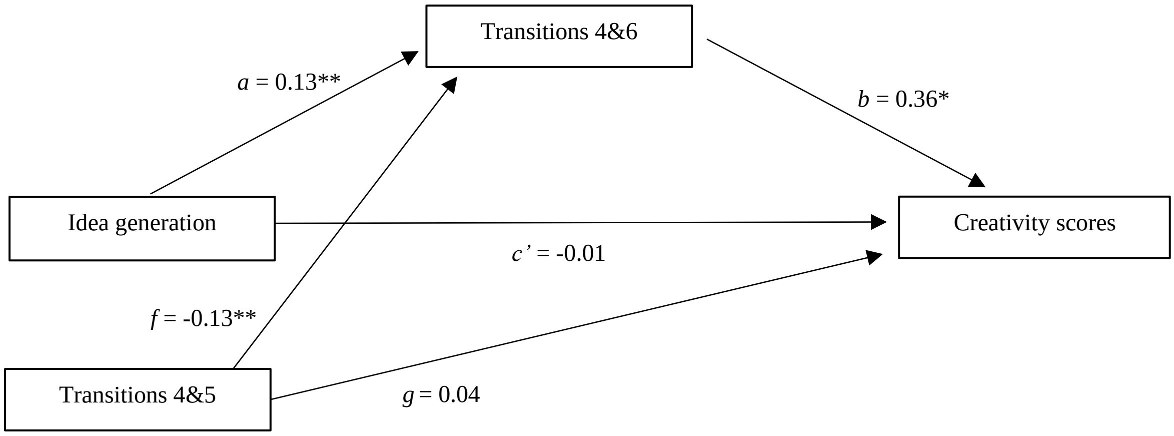


Note. N = 124. Idea generation is the predictor variable; idea implementation is the mediator; creative output is the outcome variable.
*$p < 0.05$. **$p < 0.001$.

In light of the results, a further mediation model was performed using the occurrences of transitions from idea generation to idea implementation as a mediator while controlling for the other transition from idea generation (i.e. the transition from idea generation to evaluation).

The predictor variable for the analysis was the number of ideas generated, and the outcome variable was the creativity scores. The mediator was the total number of transitions from idea generation to implementation (transitions 4&6). The total amount of 4&5 transitions (idea generation to idea evaluation) were entered as a covariate. Figure 7 displays the mediation model. The results demonstrated another full mediation effect of the number of ideas generated on creativity through the number of transitions from idea generation to implementation, Effect = .0478, 95% CI [.002, .111]. The indirect effect explained 56% of the total effect, while 44% was explained by the direct effect.

Figure 7: *Simple Mediation Model with a Covariate*



Note. N = 127. Idea generation is the predictor variable; transitions 4&6 is the mediator; creative output is the outcome; transitions 4&5 is the covariate.
*$p < 0.01$. **$p < 0.001$.

4.3.8. Time and Creativity

Overall time taken was found to be positively correlated with creativity scores, $r = .26$, $p = .002$. Curvilinear analyses were then explored between time taken on the task and creativity. X was entered as the linear term and X^2 as the quadratic term in Model 2. The results revealed that the addition of the quadratic predictor in Model 2 explained 4.9% of additional variance, Delta-R^2 = .079, $F(2, 142) = 6.06$, $p = .003$, compared to Model 1 (see Table 26). Therefore, there appears to be more evidence for an inverted-U relationship between time and creativity.

Table 26: *Linear and Quadratic Correlations Between Overall Time Taken and Creativity*

Model Summary and Parameter Estimates								
	Model summary					*Parameter estimates*		
Equation	R^2	*F*	*df1*	*df2*	Sig.	Constant	b1	b2
Linear	.030	4.461	1	143	.036	.063	.724	
Quadratic	.079	6.058	2	142	.003	.275	1.963	-2.088

Note. The independent variable is overall time taken (*z-score*), and the dependent variable is creativity scores.

The eighth hypothesis was investigated by exploring curvilinear analyses between the frequencies and time spent engaging in each cognitive process. All thought processes were linearly related to creativity, apart from time spent gathering information using the Internet. X was entered as the linear term and X^2 as the quadratic term in Model 2. The results revealed that the addition of the quadratic predictor in Model 2 explained 3.9% of additional variance, Delta-R^2 = .11, F(2, 91) =

5.62, *p* = .005, compared to Model 1 (see Table 27). Therefore, there appears to be more evidence for an inverted-U relationship between time spent gathering information and creativity.

Table 27: *Linear and Quadratic Correlations Between Time Spent Gathering Information and Creative Output*

Model Summary and Parameter Estimates								
	Model summary					Parameter estimates		
Equation	R^2	*F*	*df1*	*df2*	Sig.	Constant	b1	b2
Linear	.071	7.00	1	92	.01	-.021	2.38	
Quadratic	.110	5.62	2	91	.005	-.127	6.71	-1.69

Note. The independent variable is time spent in information gathering, and the dependent variable is creative output.

4.4. Discussion

Study 3 tested the online experiment with a larger sample size to confirm the links between the dynamic cognitive processes underlying creativity and creativity. The study hypothesised that there would be an independent and combined effect of the frequencies of idea generation, evaluation, and implementation on creative output. The results partially confirmed this hypothesis in that the total numbers of ideas generated, evaluated, and implemented were all found to be correlated with creativity scores. However, subsequent multiple regression analysis demonstrated that the number of times participants returned to implement their idea (implementation) was the only cognitive process to have a significant independent effect. Nevertheless, the multiple regression model was significant, and the frequencies of the total number of ideas generated and implemented accounted for 7.5% of the variance of creative output.

Time spent engaging in the cognitive processes produced a slightly different picture. Specifically, time spent generating ideas was not found to be linked to creativity, but time devoted to evaluation, implementation and information gathering was. A subsequent multiple regression analysis revealed that idea implementation was again the only process to have an independent effect. The multiple regression model was significant, however, and the time spent engaging in evaluation and implementation accounted for 22% of the variance of creative output. These findings partially support the research hypothesis that there would be independent and combined effect of time spent engaging in idea generation, evaluation, and implementation on creative output.

When investigating the distribution of time spent engaging in each process (the sixth hypothesis), an interesting picture emerged. As was shown in Study 2, time spent proportionally more on the dilemma screen was linked to lower creativity scores. In contrast, spending proportionally more time implementing ideas was related to higher creativity scores. Significant differences concerning these processes were also found when comparing the distribution of time spent engaging in each process between high and low creative scorers. However, a marginal difference emerged in terms of how much time creative individuals dedicated to idea evaluation. One interpretation of this finding is that the low creative output scorers struggled to come up with a solution and, thus, spent proportionally more time on the dilemma screen. These results appear to mirror the negative relationship found between time spent proportionally more in problem finding and creativity in Study 1.

The transition analysis results support the third and fourth research hypotheses that the creative process is not linear and that individuals who exhibit more transitions will produce more creative solutions. These findings parallel those from Studies 1 and 2, suggesting that individuals who switch between these processes more often will produce more creative solutions regardless of the time spent on the task. The results also revealed that frequently shifting from idea generation to evaluation and from idea generation to implementation was significantly correlated with creativity. This finding partly supports the fifth hypothesis that the transitions between idea generation, evaluation and implementation would be linked to creativity; nevertheless, the transitions from idea evaluation to generation or to implementation and the transition from implementation to idea generation were not found to be linked to creativity.

When testing the ninth hypothesis, however, the mediation modelling produced a clearer picture as to what might have been occurring in individuals when they were confronted with an ill-defined problem. Idea generation is commonly associated with creativity. However, the results in this study suggest that idea generation is futile unless the idea generated is implemented. The first full mediation model demonstrated this phenomenon. The second mediation model further explored this relationship and revealed that the transition from idea generation to implementation was a significant mediator, and the model demonstrated another full mediation effect. Overall, these findings suggest that the most effective strategy producing a creative solution is to generate an idea and to implement it straightaway.

Lastly, when testing the seventh and eighth exploratory hypotheses, the frequencies of and time spent engaging in the processes were found to be linearly related to creative output, apart from information gathering. A curvilinear relationship was observed between time spent engaging in information gathering and creativity scores. The investigation of overall time spent and creativity revealed another linear relationship, similar to the results found in Studies 1 and 2; however, there appeared to be more evidence for an inverted-U relationship. This finding indicates that spending too little or too much gathering information for an ill-defined problem is bad for creativity.

4.5. Study Strengths and Limitations

The characteristics of the sample comprised the study's main strength. The sample size was relatively large and included a wide range of people; in fact, only 4% of the sample were students. This large, diverse sample facilitated testing and replicating the findings from the previous studies that had been based on a small sample. Another strength of the study was that dilemma familiarity was captured, and participants who had solved a similar problem or had experience in coming up with an idea for a toy were removed from the analysis. However, a key limitation of this study was the amount of effort participants put into the task. Arguably, those who put in more effort came up with better ideas. In any event, an inverted-U relationship between time taken and creativity was observed.

Chapter 5: Discussion

5.1. Summary of Main Findings and Contributions to Research

The aim of this dissertation was to investigate the cognitive processes underlying creativity and determine how they relate to creative output. Overall, the findings across the three studies conducted in this PhD research endeavour demonstrated that idea generation, evaluation and implementation appear to be the core mental operations underpinning creative thought. The results from investigating the dynamism of the creative process for this thesis confirmed that the creative process does not follow a straight line. The process appears to be chaotic, with multiple feedback loops up to the point where a solution to an ill-defined problem is fully formed. However, in deciphering this chaotic process, this research also demonstrated that certain loops or transitions are predictive of creative output. This final chapter summarises the main findings and discusses them in light of the primary research objectives laid out in Chapter 1. A discussion of the study's overall limitations follows, along with suggestions for directions for future research.

Research Aim #1: Examine the independent and combined effects of the cognitive processes underlying creativity on creative output.

The following discussion will address this question by reviewing the independent effect of each cognitive process across all three studies. The cognitive processes displayed will adhere to the order set out in the process model in Figure 1 in Chapter 1.

5.1.1. Problem Finding

As outlined in the general introduction of this thesis, problem-solving is the process of outlining the goals and objectives of an ill-defined problem and constructing a plan to help structure and guide problem-solving (Mumford et al., 1994). This process was examined in Study 1, where it was deconstructed into three sub-processes: (a) problem finding – not coming up with ideas or evaluating strategies, (b) coming up with ideas or strategies for generating a solution, and (c) evaluating strategies for generating a solution.

Contrary to the previous research (e.g. Mumford, Baughman, Threlfall et al., 1996; Redmond et al., 1993; Reiter-Palmon et al., 1997), neither the frequency of nor time spent engaging in problem finding in Study 1 was found to be linked with creativity. However, assessing the distribution of time spent engaging in the processes revealed that those who spent proportionally more time in problem finding compared to other processes produced poorer creative solutions. Further investigation of this link demonstrated that time spent proportionally more in the problem finding sub-process *Coming up with ideas or strategies for generating a solution* in comparison to other processes was negatively correlated with creative output.

One interpretation of these findings is that low creative output scorers struggled to come up with a solution and, thus, spent proportionally more time trying to generate strategy or plan on how to solve the problem. This phenomenon was also evident in the qualitative analysis of the extremes. The low creative output group spent more time formulating plans or strategies compared to the high creative output group, who went straight into idea generation. Moreover, the transition from problem finding to idea generation was the most common transition compared to the transitions to other processes from problem finding. Although this transition was not significant, the correlation was .30, suggesting that the link could become significant with a larger sample size.

Another interpretation for these findings is that the research only focused on occurrences and time spent engaging in problem finding. Most studies concerning problem finding have tended to assess the quality and originality of the problem restatements themselves (Reiter-Palmon & Robinson, 2009). Therefore, this may indicate that the execution of problem finding is what differentiates creative individuals and not the frequency or time spent engaging in it. However, it must be noted that the sample size of Study 1 was very small and highly educated, therefore some caution must be taken when interpreting these findings.

5.1.2. Information Gathering

The previous research on information gathering has suggested that creative individuals tend to use a wide range of information in their search strategy (e.g. Alissa, 1972). No significant correlations were observed between the occurrences or time spent engaging in information gathering and creative output in Study 1 and Study 2. Nor were any differences found between high and low creative output scorers in terms of the proportion of time spent gathering information. However, time spent in the sub-process *Re-reading dilemma/searching for relevant information to an idea in dilemma* was found to be related to creativity.

The qualitative study conducted in Study 1 also revealed notable differences regarding how the high and low creative output groups used the Internet. Participants in the low creative output group tended to use the Internet to conduct general searches of the problem rather than looking for specific ideas. The high creative output group either conducted specific searches to verify their ideas or spent time scanning the dilemma to ensure they had not missed anything or to confirm that their final solution would address all requirements. These findings are similar to those reported in Mumford, Baughman, Supinski, et al.'s study (1996), where creative individuals were found to focus on relevant information and disregard irrelevant information. Arguably, those who were searching to verify their ideas were searching for relevant information. Indeed, the high creative output group barely conducted general searches, and the sub-process *Re-reading dilemma/searching for relevant information to an idea in dilemma* was positively correlated with creativity.

Meanwhile, testing information gathering with Study 3's larger sample size revealed an inverted-U relationship between time spent gathering information and creativity. This suggests that an optimal level of information gathering is required to produce a creative solution. These findings are similar to those of studies that investigated knowledge and/or expertise in a domain and creativity (e.g. Simonton, 1983; Weisberg, 1999), which also reported an inverted-U relationship. Moreover, such a relationship may explain why no difference was observed between high and low creative output scorers' engagement in the process in Studies 1 and 2. This finding suggests that too much information gathering could have a detrimental effect on creativity. Furthermore, the only transition from information gathering that was significant in Study 3 was evaluation. The transition from evaluation to implementation was also significant, suggesting that those who made frequent evaluations after gathering information, and vice versa, produced more creative solutions.

5.1.3. Break

As discussed in the general introduction, incubation plays a key role in the creative process. In this PhD project, incubation was assessed by the number of times and how much time an individual spent having a break during the task. As only two participants took a break in Study 1, it was not possible to observe its effects. However, time spent having a break was found to be correlated with creativity in Study 2. That said, only nine participants took a break; therefore, caution is needed when interpreting the results. Frequencies of, time spent, and proportion of time spent in breaks in comparison to other processes was not found to be linked to creativity in Study 3. These findings contribute to the mixed results observed from previous incubation research (Dorfman et al., 1996).

However, when looking at the transitions between having a break and other processes, Study 2 demonstrated that the most common transition from having break was idea generation. In Study 3, the transitions from having break to idea generation and to viewing the dilemma were the most common. However, the total number of transitions from break to idea generation was significantly related to creativity but not the transition from having a break to viewing the dilemma. This finding supports previous research suggesting that taking a break can stimulate idea generation (e.g. Ellwood et al., 2009; Sawyer, 2012). Interestingly, the results from Study 3 might indicate that creative individuals are more likely to generate an idea after taking a break. Although the incubation effects were not observed in all studies due to the small sample sizes in 2 out of 3 of them, the findings from Study 3 demonstrate the importance of taking a break while engaging in creative problem-solving.

5.1.4. Idea Generation

The number of ideas generated (fluency) was found to be correlated with creativity across all studies, supporting the previous research into idea generation and creativity (e.g. Guilford, 1950; Sawyer, 2012). However, when entered in a multiple regression model, only implementation had a significant independent effect in Study 3.

Meanwhile, time spent engaging in idea generation was related to creativity in Studies 1 and 2 but not 3. Interestingly, no difference in the proportion of time spent engaging in idea generation was detected between high and low creative output scorers, and this variable was not found to be correlated with creative output. This might suggest that the total number of ideas generated rather than time spent actively engaging in idea generation is linked to creativity.

The most frequent transition in Study 1 was between idea generation and implementation, which was found to be related with creativity. The second most frequent transition was between idea generation and evaluation, which was also revealed to be related to creativity. All other transitions from idea generation were linked to creative output, with the exception of the transition from idea generation to problem finding.

Study 2 yielded no significant findings between the transitions and creative output; however, this result may be due to lack of observations, as the total number of transitions observed differed significantly between Studies 1 and 2. Nevertheless, the most frequent transition observed in Study 2 was between idea generation and evaluation. In contrast, in Study 3, which tested the online experiment with a larger sample size, the transition from idea generation to evaluation was the most frequent transition and was also related to creativity. Interestingly, the correlation between the total number of ideas generated and evaluated was extremely strong, $r = .94$, suggesting a strong feedback loop between the two processes. The transition from idea generation to implementation was also significantly correlated with creativity.

The qualitative study of the extremes illustrated how rapidly the creative individuals were able to generate multiple themes, ideas, and solutions. The low creative output group appeared to struggle to develop ideas as well as general themes. However, this finding only explains part of the story. As seen later in Study 3, the link between the number of ideas generated and creativity disappeared when adding implementation or the transition from idea generation to implementation as a mediator. This result suggests that idea generation or fluency might have an indirect effect on creativity.

5.1.5. Idea Evaluation

Previous studies have consistently demonstrated that creative individuals are particularly good at evaluating their ideas (e.g. Basadur et al., 2000; Lonergan et al., 2004; Runco, 2003). Study 1 identified two forms of idea evaluation: evaluating an idea generated and evaluating the solution written. The occurrences of and time spent in the overarching evaluation process was found to be significantly related to creativity in Study 1. In contrast, Study 2 did not demonstrate a relationship between evaluation and creativity. However, this outcome may have been due to the instructions provided to participants. After clarifying this process in the instructions for Study 3, the number of evaluations and time spent evaluating ideas were linked to creativity, as in Study 1. However, time spent not found to have an independent effect when evaluation was entered in a multiple regression model along with implementation.

The proportion of time spent engaging in evaluation in Study 1 was found to correlate strongly with creativity. Moreover, high creative output scorers spent relatively more time in evaluation than low creative output scorers. However, the subsequent studies yielded the opposite finding. In Studies 2 and 3, the high creative output group evaluated less than the low creative output group. However, a marginal difference was observed in Study 3, and the effect size was small. Neither did the relative time spent in evaluation correlate with creativity. Therefore, the proportion of time spent in evaluating ideas, as with idea generation, did not make a difference in the creativity of individuals' solutions.

Study 1's exploration of the two evaluation sub-processes revealed that the frequencies of and time spent engaging in both sub-processes were linked to creativity. However, both time spent and the total number of times participants went back to re-read the solution/evaluate the solution produced stronger correlations than evaluating a specific idea. Thus, the proportional time spent evaluating the output was found to be significantly correlated with creativity, while the relative time spent engaging in evaluating specific ideas was not. This finding may suggest that evaluating the solution, or *implemented ideas*, may be more important than evaluating individual ideas, supporting Vincent et al.'s (2002) argument that idea evaluation is an aspect of idea implementation, as ideas are tested and revised following idea generation. However, the qualitative study focused on the extremes revealed that the high creative output group evaluated more than low creative output scorers and were effective at evaluating their multiple ideas.

The transition results in Study 1 revealed that the most frequent transition from evaluation was to idea generation, and the total number of transitions was strongly related to creativity. The second most frequent transition was from evaluation to implementation, which was also found to be strongly correlated with creativity. Although no significant correlations emerged in Study 2, the most frequent transition observed was between idea generation and evaluation. This transition was also the most commonly noted in Study 3, and it was positively correlated with creativity. However, the number of transitions from evaluation to idea generation in Study 3 was marginally related to creativity.

The results from the qualitative analysis in Study 1 support these findings, as individuals in the high creative output group were very quick to generate an idea and evaluate it. This feedback loop continued until they discovered a viable idea. In contrast, the low creative output group did not spend time evaluating their ideas or solutions; at times, they even skipped this process. In all, the results indicate that evaluation is a fundamental creative process.

5.1.6. Idea Implementation

Consistent findings emerged between the implementation process and creativity across all three studies. The frequency of and time spent engaging in implementation consistently correlated with creativity. Multiple regression analyses in Study 3 revealed that the number of times participants went back to implement their solution had a significant independent effect on creativity, as did time spent engaging in implementation.

Although no sub-processes were identified for idea implementation in Study 1, *writing notes not related to the idea* and *editing and formatting the solution* were captured under an “Other” category. Interestingly, writing notes that were not related to the idea was not correlated with creativity. However, occurrences of and time spent editing and formatting the solution were associated with creativity, including relative time spent engaging in this process.

As was first observed in Study 1 and reproduced in Study 2, those in the high creative output group spent proportionally more time, on average, implementing their ideas. Although the differences in both studies were not significant, the relative time spent engaging in implementation was linked to creative output. Nevertheless, when testing the online experiment with a larger sample size, the difference was statistically significant (31% vs. 14%), and the relative time spent engaging in implementation was also correlated with creativity. These results suggest that those who spent proportionally more time implementing their ideas produced higher quality as well as more original and feasible solutions.

The results from the qualitative study in Study 1 also confirm these quantitative findings. The creative output group tended to implement their idea throughout the task, constantly going back to the solution to add more information following idea generation. In contrast, the low creative output group typically left implementation to the end of the experiment. Although research studies into implementation are scarce, these findings support previous studies that have investigated idea implementation and creativity (e.g. Getzels & Csikszentmihalyi, 1975, 1976; Verstijnen, 1997).

Investigating the transitions from implementation showed that the most frequent transition in Study 1 was to idea generation, while Studies 2 and 3 featured the dilemma screen as the most frequent follow-on process from implementation. The total number of transitions from implementation to dilemma was not significantly related to creativity, however. Frequently transitioning from implementation to idea generation and to evaluation in Study 1 was strongly related to creativity. Although no significant correlations were found in Study 2, the correlation coefficients for the transitions from implementation to idea generation and evaluation were positive, $r_s = .24$ and $r_s = .35$, respectively. The examination of the transitions in Study 3 revealed that the transition from implementation to evaluation – but not to idea generation – was significant. As will be discussed later in the chapter, idea implementation was found to mediate the relationship between the number of ideas generated and creativity. Therefore, these findings demonstrate the importance of this process in creativity.

5.2. Overview of Cognitive Processes Underlying Creativity

Overall, some notable consistent findings were found across all three studies when investigating the frequencies of and time spent engaging in the cognitive processes underlying creativity. However, what is the combined effect of these processes on creative output? This question was addressed in Study 3, which featured a sufficient sample size to conduct multiple regression analyses.

Regarding the frequencies of each process, multiple regression analysis revealed that, cumulatively, the idea generation and implementation cognitive processes yielded a multiple R of .30, Adjusted R^2 = 7.5%. When investigating the cumulative effect of time spent engaging in evaluation and implementation, the multiple R was .48, Adjusted R^2 = 22%. Thus, time spent in these cognitive processes accounted for 22% of the variance of creative output. These findings support the only known study to have investigated the culminative effect of the processes (Mumford, 2002). Although idea evaluation and implementation were not included in Mumford’s study, he observed multiple correlations in the range .50–.60. The findings of the current study are consistent with his findings, demonstrating the importance of observing the cognitive processes together as well as the significant role played by implementation in the creative process. Indeed, implementation was the only process to have an independent effect on creativity in both regression models in this study.

Exploring the percentage of time spent engaging in a process compared to the other cognitive processes revealed a similar trend in the amount of time individuals spent in information gathering, idea generation, evaluation, and implementation (see Table 8, 16 and 23). These results suggest that individuals may typically spend roughly 25% of their time generating ideas, about 25% implementing them, and circa 20% evaluating them. Altogether, perhaps 70% of time spent engaging in creative problem-solving lies within these three cognitive processes.

The analysis of time spent engaging in each process and its relationship with creativity revealed that they were all linear, with the exception of information gathering. An inverted-U relationship was observed between time spent gathering information and creativity, supporting the previous research. An inverted-U relationship was also found between overall time taken and creativity. This result also supports previous studies that have observed a curvilinear relationship between creativity and time pressure (e.g. Amabile et al., 2002; Baer & Oldham, 2006).

However, the prior studies looked at time pressure and creativity. In contrast, this study exerted no pressure to generate a solution. According to Coombs and Avrunin (1977), as a general principle, “good things satiate and bad things escalate” (p. 224). This conceptualisation may suggest the existence of an approach–avoidance conflict between “time spent for the good” and “time spent for the bad". Possibly, time spent on a creative task may be beneficial for creativity, up to a point, but as time goes on, the benefit of spending time on the task becomes less salient. As demonstrated in the current research endeavour, the qualitative analysis in Study 1 showed that the low creative output group spent a long time trying to shape and define the problem, whereas the high creative output group worked relatively faster on defining the problem before going into idea generation mode. Perhaps this stage or viewing the dilemma screen in Studies 2 and 3 was beneficial up to a point before becoming unbeneficial.

In conclusion, this thesis developed two unique experiments that facilitated an exploration of the independent and combined effects of the cognitive processes underlying creativity from start to end. This investigation is the first known study to observe all the cognitive processes underlying creativity individually and holistically. As the study findings have demonstrated, each process seems to play a part in the creative process. However, idea generation, evaluation and implementation appear to be the most vital processes. Implementation, in particular, was consistently found to be related and predictive of creative output in all three studies. The number of times individuals went back to write the solution was related to creativity, as was time spent writing their solution. These findings suggest that implementation plays a key role in creativity – yet very few studies have investigated this process. After all, what is an idea if it cannot be implemented?

5.3. Dynamism

This section discusses the dynamism of the creative process in relation to the second research aim:

Research Aim #2: Explore how individuals go through the cognitive processes underlying creativity.

This dissertation has consistently demonstrated the dynamic and chaotic nature of the creative process. Amabile and Pratt (2016) postulated that multiple iterations or feedback loops are likely to exist throughout the entire creative process. The findings across all three studies in the current investigation support this notion. The results also reflect the findings from Botella et al.'s (2011) study investigating the dynamics of the creative art process. However, the transitions in their study were observed at two time points in a day (morning and afternoon). As seen in the results from this study, the shift between transitions occurred in a matter of seconds in Study 1 and minutes in Study 2. This phenomenon may explain why Botella and her colleagues reported multiple stages occurring at the same time point (e.g. preparation, concentration, incubation and ideation).

This research comprises the first known study to investigate the cognitive processes through a microscopic lens, and how the way they interact with each other is related to creative output. When looking at the sequences of creative thought or the transitions from one process to another, the results revealed that the transition between idea generation and implementation was the most common transition in Study 1, whereas the transitions from idea generation to evaluation were the most common in Studies 2 and 3. The total transitions made between idea generation, evaluation and implementation were all found to be related to creative output. Similar results were obtained in Study 3, but in that study, the transitions from evaluation to implementation and from implementation to idea generation were not correlated with creativity. All these findings provide further evidence for the importance of these three processes in creative thinking.

Mediation modelling demonstrated that the link between the number of ideas generated and creativity vanishes if implementation is added as a mediator. When a further mediation model was conducted using the transition from idea generation to creativity as a mediator, the results illustrated another full mediation effect, providing further evidence that the number of ideas generated is only linked to creativity if the ideas generated are implemented – or perhaps tested. This finding appears to reflect a form of the trial-and-error approach, as popularised in the famous saying by the inventor Thomas Edison: “I have not failed, I’ve found 10,000 ways that won’t work.” The trial-and-error approach has also been witnessed in other famous experimental inventors, such as Cézanne, Virginia Woolf, and Muhammad Yunus (Galenson, 2009), as well as Leonardo da Vinci (Güss et al., 2021).

However, the qualitative analysis in Study 1 revealed that the high creative output group did not test out random ideas. In other words, their trials were not random, but they were based on a general concept. For example, the high creative output group in the qualitative study (Study 1) did not randomly test out their ideas until they found an idea that worked. Instead, they implemented their idea and then went back to build and refine their solution, generating more ideas along the way or in response to incoming information from conducting relevant dilemma or Internet searches. This loop or process is similar to how chefs cook a dish or a stew, frequently adding different or additional spices until a perfectly flavoured stew has been achieved.

This form of generate-and-refine approach was also observed in Getzels and Csikszentmihalyi’s studies (1975, 1976) in which creative students continuously changed the overall composition of objects after having sketched their initial composition. The authors’ observations might demonstrate the transition from idea generation to implementation and how frequent loops between these two processes are linked to creativity. This process was also demonstrated in Verstijnen’s (1997) study where individuals who sketched out their ideas discovered and solved more problems than those who did not make such sketches. This finding suggests that creative individuals test their ideas before coming up with a final solution. Indeed, the qualitative analyses in Study 1 revealed that the high creative output group tended to implement their ideas throughout the creative problem-solving effort, while in contrast, the low creative output group did not implement their ideas or solution until they neared the very end of the task. Accordingly, this observation might indicate that individuals need a time constraint or a sense of urgency, self-imposed or imposed by others, in order to engage in creative problem-solving.

The total number of transitions engaged was also found to be predictive of creativity in Study 3, regardless of the time spent on solving the ill-defined problem. This finding suggests that those who go through the processes in a more dynamic manner will produce more creative solutions. Indeed, in everyday life or work settings, creativity would involve frequent shifts between processes in response to changing conditions and new information (Fisher & Amabile, 2008). This finding might suggest that those who fail to shift between the processes or respond to changing conditions produce poorer creative solutions. This could also explain why the low creative output group left implementation to the very end of the task. Quite possibly the low creative output group in Study 1 went through the processes in a more linear fashion.

This finding may also explain why the proportion of time spent in problem finding, compared to other processes, was negatively linked to creativity. Problem finding is typically the first stage in the creative problem-solving process and is believed to be the prerequisite for all other creative cognitive processes (Finke et al., 1992; Lubart, 2001; Mumford et al., 1991). Hence, it may be that individuals who spent proportionally more time engaging in problem finding were stuck in the first cognitive process. Unlike creative individuals, they lacked the ability to jump to another process.

Although Studies 2 and 3 did not investigate problem finding, the proportional amount of time spent on the dilemma screen in comparison to other processes was also negatively correlated with creativity. This finding was observed in Study 2 and reproduced in Study 3 with a larger sample size. That said, the dilemma screen in Study 2 was not found to be related to problem finding in Study 1, and some problem finding sub-processes were negatively correlated, which could indicate that some individuals were stuck viewing the dilemma. Given that reading the dilemma was the first stage, perhaps low creative output individuals were unable to jump to another process (i.e. to idea generation or going on the Internet to search for information). Furthermore, the total number of transitions from the dilemma screen to idea generation was also found to be significantly correlated with creativity in Study 3. Therefore, those who made frequent jumps from viewing the dilemma to idea generation produced more creative solutions.

Further support for the dynamic interpretation of the creative process comes from brain imaging studies. Recent developments in the neuroscience of creative cognition have demonstrated dynamic interactions between large-scale brain systems when engaging in the creative process (Beaty et al., 2016; Beaty et al., 2018). Using functional magnetic resonance imaging (fMRI), Beaty et al. (2018) investigated whether there was a specific brain connectivity profile that might characterise creative thinking ability as well as determine whether the strength of the functional connectivity within this network might predict individual creativity. The researchers discovered dense functional connections between principal nodes of the default, executive, and salience systems in high-creative thinking brains. They described these networks as having a tendency to work in opposition, indicating that creative individuals tend to simultaneously engage in these large-scale systems to a greater extent than non-creative individuals. Although the implementation process was not observed in their study, their findings provide organic evidence for a dynamic interpretation of the creative process.

5.4. Theoretical and Practical Implications

A number of theoretical as well as practical implications follow from this research. First, the cognitive process models underlying creativity were advanced by identifying the core and sub-processes underlying creativity. This research project is the first known study to have investigated the specific mental operations involved in solving an ill-defined problem. The analyses led to the discovery of multiple sub-processes in Study 1. In particular, problem finding was deconstructed into three sub-processes. That said, no known process model has incorporated the generation and evaluation of strategies and plans as processes, which would typically feed into problem finding.

This research has also demonstrated the importance of examining the processes individually and holistically. No known study has investigated the frequencies of and time spent engaging in the processes. The findings from this research revealed a difference between the total amount of engagement in a process and time spent engaging in a process. For example, the number of ideas generated was consistently found to be related to creativity; however, time spent engaging in idea generation produced mixed results. This observation supports the previous research and theory concerning fluency and creativity (e.g. Guilford, 1950; Sternberg, 1999). However, mediation modelling revealed that the link between the number of ideas generated and creativity disappeared when adding the number of times ideas were implemented as a mediator for one model and the transition from idea generation to implementation as a mediator in the second model. Nevertheless, this research also sheds light on the importance of implementation in the creative process.

The cognitive process models underlying creativity were also further developed by the inclusion of dynamism. Sawyer’s (2012) integrated process model appears to suggest a linear sequence to creative thinking. Although Sawyer (2012) mentioned that the processes might not be static, dynamism was not included in his model. In contrast, Amabile and Pratt (2016) theorised that the creative processes operate in a dynamic manner involving multiple feedback loops. The results from this thesis support the latter notion and develops it further by demonstrating how certain transitions are predictive of creative output.

This investigation is also the first known study to conduct mediation analysis on the cognitive processes underlying creativity. The results from Study 3 illustrate that an idea is useless unless it is implemented or tested. The generate-and-refine approach to solving an ill-defined problem has great practical implications for the measurement of creativity as well as training.

Fluency is one of four abilities underpinning divergent thinking, a notion that has led to a proliferation of standardised tests that include fluency as a key measure of creativity (e.g. Guilford’s

Alternative Uses Test and Torrance's Tests of Creative Thinking). However, divergent thinking tests have produced questionable predictive validity in relation to creative output as well as job performance (e.g. Clapham, 1996; Gough, 1979). The findings from this research suggest that creativity assessments might benefit from incorporating implementation – or how ideas are executed – in their assessments. Perhaps this approach could consequently help improve the lack of predictive validity observed among these tests and could also have implications for creativity researchers, as they tend to use divergent thinking tools as measures of creativity. For example, most brain imaging studies require individuals to generate as many ideas as possible (Beaty et al., 2016). Therefore, these studies may not have fully captured the entire creative process.

Instructing employees to generate as many ideas as possible is a commonly used brainstorming technique (Isaksen & Gaulin, 2005; Sosa & Gero, 2012). Osborn (1953), the father of brainstorming, believed that generating a large volume of ideas to a solution will increase the chances of producing a good idea. However, given that implementation and the transition from idea generation to implementation were found to be mediators, perhaps employees should adopt the generate-and-refine approach, instead. This technique might help employees generate more creative solutions. Also, given that dynamism is key in the creative process, it is possible that forcing employees to engage in a single process may not be as effective as getting employees to engage in multiple processes.

5.5. Limitations

While this research produced many interesting and significant findings, a number of key limitations must be taken into account when interpreting the results from this thesis. First, the studies conducted in this dissertation lack ecological validity, potentially affecting the generalisability of the findings to everyday life or work settings. For example, the participants were instructed that they could take as much time as they wished to complete the task, yet time to think creatively or innovate is considered a luxury in most organisations (Amabile et al., 2002).

The characteristics of the sample in Studies 1 and 2 is another key limitation, as it may limit the generalisability of the studies. The sample size was small, and most of the participants were highly educated. They were also recruited using snow-ball techniques, which are susceptible to bias (Kalton, 1983). In one study, for example, Kendall et al. (2008) found that the demographic characteristics of snowball samples mirror the demographic make-up of their recruiters. The majority of Study 1 and 2 participants had a background in the sciences; therefore, this might have resulted in different thinking patterns to those who are educated or work in the creative industries. Therefore, some caution must be taken when generalising the results from these studies. This includes the non-significant findings of certain processes such as problem finding and creativity. Nevertheless, the findings from these studies were largely replicated in Study 3 where the sample was larger and more diverse.

Another limitation is domain expertise. Although attempts were made to control for task familiarity in Studies 2 and 3, this research did not investigate the impact that domain expertise might have had on the engagement and transitions involved in the creative processes. Presenting an ill-defined problem tailored to an individual's domain or expertise might result in different processes and transitions being involved and/or predictive of creativity. In a similar vein, the nature of the task could also result in different processes or transitions being engaged. The tasks used in this research were simple compared to real-life projects at work that lead to the development of a product. These types of tasks are naturally complex and take days or weeks to complete. As a result, different processes or transitions could also be more critical or predictive of creativity, depending on task complexity.

The approach undertaken to investigate the cognitive processes in this research comprises another limitation. Although efforts were made to examine the processes individually throughout the creative process, only frequencies and time spent engaging in each process were captured. The quality or effectiveness of each cognitive process engaged was not examined. In recent decades, many research studies have demonstrated that creative individuals are highly effective at executing certain processes such as problem finding (Mumford, Baughman, Threlfall et al., 1996; Redmond et al., 1993; Reiter-Palmon et al., 1997) and evaluation (Basadur at al., 2000; Lonergan et al., 2004; Runco, 2003). Because only frequencies or time spent in each process were captured, the quality or execution of each process may have been overlooked. For example, contrary to the findings from some previous studies, Study 1 did not find the number of times and time spent engaging in problem finding to be related to creativity. Perhaps the creative individuals were more effective at defining and constructing the problem, and yet this was not captured.

Regarding the measurement of transitions, Study 1 was more accurate and objective at capturing the transitions compared to the online experiment used in Study 2 and 3. The online experiment relied on individuals to identify which processes they were engaging in. In practical terms, 1,787 transitions were observed in Study 1 versus 376 in Study 2. Also, in terms of time spent, the average time engaged in a process was 4 seconds, *SD* = 7 seconds, compared to 1.4 minutes, SD = 1.9, in Study 2. This difference suggests that the online experiment may have missed out on some key transitions. Nevertheless, the online experiment produced similar transitions to those found in Study 1 and facilitated an investigation of the research aims with a larger sample size.

Also, using a think aloud method in Study 1 may have altered the way in which participants solved the problem or their solutions. Indeed, research investigating the effects of verbalisation on insight problem-solving found that it can impair performance (Gilhooly at al., 2010; Schooler et al., 1993). In Studies 2 and 3, where participants were instructed to solve the dilemma by navigating through the screens in the same way as they think, may therefore have also been disruptive and affected their solution. Therefore, this may be an area that warrants further investigation.

Additionally, only one person coded the cognitive process engaged in Study 1. Ideally, the codes assigned should have been independently verified by another researcher with a background in creativity. Nevertheless, the use of a single judge or coder has been used previously when conducting discourse analysis (e.g., Gersick, 1988) and is believed to be important when the aim of the analysis is to produce an in-depth understanding of the whole event (Donnellon, et al., 1986). However, future research should consider the use of multiple coders when assessing the cognitive processes underlying creativity and establish how congruent their codes are throughout the problem-solving effort.

Lastly, this research did not control for intrinsic motivation to complete the task or personality traits that might influence the engagement in the processes. However, according to Amabile and Pratt's (2016) dynamic componential model of creativity and innovation, intrinsic motivation as well as skills in the task domain are the individual components that are required for individual creativity to thrive in the workplace.

5.6. Directions for Future Research

Despite its limitations, this research has opened up a range of new opportunities for future research. The following sections discuss the various possibilities, organising them by themes.

Shift From the Environment to the Individual

Previous creativity studies conducted in a work setting have focused largely on the features of organisational environment that affect creativity (e.g. Hennessey & Amabile, 1988). Despite numerous studies that have observed and discussed how to facilitate creativity in the workplace, most of the research has targeted environmental climate and job design (Redmond et al., 1993). More studies that focus on the individual are needed. After all, the source of novel ideas or solutions to ill-defined problems is the individual.

An overwhelming amount of research has examined the link between individual characteristics, such as intelligence and personality, and exceptional job performance. For example, meta-analyses (amalgamations of individual research studies on a particular topic) have shown that intelligence and specific cognitive abilities, such as numerical and verbal reasoning ability, can successfully predict job performance (Hunter & Hunter, 1984; Salgado et al., 2003; Schmidt & Hunter, 1998), as do certain personality traits, such as emotional stability and conscientiousness (e.g. Barrick & Mount, 1991; Salgado 1997; Tett et al., 1991).

Although these tests have proven useful in the selection and development of individuals, there is an overwhelming amount of "unexplained variance" (unexplained phenomenon/factors) linked to job performance. For example, Schmidt and Hunter's (1998) meta-analytic study found that general mental ability and personality together accounted for 36% of the variance of job performance. That leaves a staggering 64% of unexplained variance. Given the importance ascribed to the role of innovation by experienced managers and business leaders (Criswell & Martin, 2007), an individual's execution of these processes is likely to account for hitherto unexplained variance in job performance. Thus, future research should examine the independent and cumulative effect of the cognitive processes underlying creativity and their dynamism on overall job performance as well as creative performance in natural work settings.

However, in order fully to understand the impact of these mental operations underlying creativity on creative performance, the issues raised around the methods used to measure these cognitive processes need to be addressed. Future research could look into creating more objective measures that would not involve getting participants to actively engage in the processes (e.g. problem finding experiments). Indeed, employees in organisations often have to take the initiative to identify a problem, or develop something new, or identify potential obstacles (Staw, 1995). Therefore, research that asks participants to engage in these processes at work in order to observe the effects of the processes on creative performance might not be applicable to a real-world setting. However, it would be tricky to develop more effective measures of these processes if their nature is still unclear (e.g. How do individuals problem find? How do people evaluate ideas?).

Measurement of Creativity

In response to the calls to integrate approaches to understanding and assessing creativity in real-life work settings (e.g. Mumford et al., 2009; Sternberg, 2006a), future research should focus on gaining an understanding of the cognitive processes underlying creativity and their dynamism. Efforts to measure the creative processes in experimental studies have proved successful in terms of increasing scholars' understanding of creativity. However, most methods have had to manipulate the construct in order to measure it.

For example, many studies on problem finding have measured the effects of the process by asking one group of participants to define and construct the problem before solving it, while asking another group to solve the problem straightaway (e.g. Redmond et al., 1993). As Reiter-Palmon and Robinson (2009) argued in their review of problem identification and construction research, the issue with such measurement is that asking participants to engage actively in problem finding could result in more creative solutions because they are encouraged to think of as many problem restatements as possible. This method also diverts the participants' attention to turn their focus on the goals rather than the other features of the problem representation (e.g. procedures, limitations, or information needed to solve the problem). That said, Mumford, Baughman, Threlfall and colleagues (1996) did not find a focus on goals to be predictive of high quality or more original solutions.

The same methodological limitations outlined by Reiter-Palmon and Robinson (2009) in problem construction research can be applied to other processes, such as information gathering, idea generation, conceptual combination, and idea evaluation. Most studies investigating these processes have measured or observed these constructs by instructing participants to engage actively in the processes (e.g. Drach-Zahavy & Somech, 2001; Lonergan et al., 2004; Mobley et al., 1992; Mumford, Baughman et al., 1997).

Additionally, encouraging participants to actively engage in a process in order to observe it could introduce confounding variables, including the other cognitive processes. For example, studies into problem finding have typically involved having participants write as many problem restatements as they can think of (Reiter-Palmon & Robinson, 2009). These problem restatements were then judged on their originality and quality. However, coming up with problem restatements/questions involves some form of idea generation and implementation. Moreover, idea evaluation is likely to have taken place before or after the participants wrote their questions down. Therefore, the participants in these studies were likely to have been engaging in other processes, such as idea generation, evaluation and implementation, resulting in positive findings between problem finding and creativity.

Other methods used to measure the cognitive processes have included self-report measures, where participants were asked to indicate on a 1- to 5-point Likert scale how likely they would be to engage in certain processes when thinking of a creative solution to a problem (e.g. Baer, 2012; Carmeli et al., 2013). However, self-reports are notoriously susceptible to response biases such as faking, acquiescence, and extreme response styles (Ones et al., 1996; Palermo et al., 2013).

Lastly, the methods employed to assess how the various cognitive processes are related to creativity have relied on the use of judges to determine the quality, novelty, and elegance of solutions generated (e.g. Lonergan et al., 2004; Mobley et al., 1992; Mumford, Baughman et al., 1997). Although some studies have used experts in the field to judge the solutions generated, most have used novices to assess the solutions for practical reasons (Kaufman, 2009). However, one study that explored the role of expertise in evaluating creative products found novices to be particularly poor at evaluating creative work (Kaufman et al., 2013).

This research has illustrated the importance of the cognitive approach to creativity. Therefore, future research should turn its attention towards refining the existing measures of each of the cognitive processes to make them more objective, reliable, and valid. In this study, the experimental approach used proved useful in its ability to capture the dynamic creative process from start to finish. Although the online experiment in Study 2 was not as refined as the experiment conducted in Study 1, it facilitated an investigation of the frequencies of each cognitive process as well as the time spent engaging in each of them and the dynamism of the creative process in an objective and cost-effective manner.

This online experiment could easily be replicated to further confirm the research findings as well as examine the creative process across different domains or even cultures. However, as mentioned in the discussion of the limitations of this thesis, this online experiment did not capture the execution of the processes (i.e. the quality of ideas generated or evaluations made). Therefore, future research might also further develop this online experiment to incorporate the assessment of the quality or execution of these processes.

The Creative Process Across Different Domains

This thesis has demonstrated the importance of investigating the cognitive processes underlying creativity and how they relate to creative output. However, questions remain as to how these cognitive processes differ across domains (Lubart, 2001; Simonton, 2012). Scholars have long debated whether creativity is a domain-general (e.g. applied similarly across domain content areas) or domain-specific ability (e.g. applied differently across domain content areas; e.g. Baer, 2015; Plucker, 1999). This dispute has led to a proliferation of studies that have investigated domain-related creativity, often resulting in support for both views (e.g. Huang et al., 2017; Plucker, 1999; Schoevers et al., 2020), which implies that creativity may involve both domain-general and domain-specific abilities.

However, although few studies have examined how the cognitive processes underlying creative thought differ across domains, their results have suggested that differences exist. For example, one study revealed that the effective execution of various cognitive processes, such as problem construction, conceptual combination and idea generation, differed in health, biological, and social sciences students (Mumford et al., 2010). More specifically, health-related doctoral students exhibited stronger problem construction, information gathering, implementation planning and idea evaluative skills. Meanwhile, social scientists demonstrated stronger conceptual combination, idea generation and idea evaluative skills, while biological doctoral students showed greater information gathering and organisation, idea generation, and idea evaluative skills.

In the same vein, although Rostan (1994) found that successful scientists spent more time structuring and defining problems before starting their work, Study 1 did not reveal a link between problem finding and creative output. Future research should therefore investigate how individuals from different domains engage in these cognitive processes as well as how the transitions from one process to another might differ across domains. For example, in light of the possibility that scientists might encounter challenges in testing out their ideas due to time, budget and resource constraints, different transitions may be more predictive of creative achievement.

As mentioned previously, while the online experiment devised in this thesis could be replicated to confirm the findings, it could also be used to test whether the processes and their dynamism differs across domains. For example, the dilemma used in the online experiment could be adapted to examine domain-specific processes, or a neutral dilemma could be created to investigate domain-general processes in various occupations, such as artists, scientists, IT developers or others.

The results from such studies could help address the ongoing debate about whether creativity is a domain-general or domain-specific ability.

Lastly, the complexity of the task at hand, which differs across domains, could influence how people engage in these processes. Some tasks, such as developing a cure for cancer, can take years to develop and implement. Perhaps such problems require meta-processes with the micro-loops that have been observed in this research. Therefore, future research should investigate these processes and their transitions over time in domains that feature high complex tasks. In such an endeavour, the experiment used in this research could be a useful tool in capturing this process.

Persistence in Creativity

The importance of perseverance in creativity has been highlighted in creativity theory and research (Amabile, 1983; Baas et al., 2011; De Dreu et al., 2008; Lucas and Nordgren, 2015; Simonton, 1977; 2003). Persevering in a task or goal is believed to be critical for creative performance (Lucas & Nordgren, 2015). The value of persistence is also emphasised in Amabile's (1983) componential model of creativity where she explains that creativity-relevant skills depend on various characteristics including "perseverance in the face of frustration" (p. 365). Whereas in De Drue et al.'s (2008) dual pathway to creativity model, they posit that creativity can be achieved through cognitive flexibility (ability to think flexibility) and cognitive perseverance and persistence. They believe that perseverance manifests itself in the generation of many ideas within a limited number of cognitive categories or over a long time-on-task.

Numerous research studies have also demonstrated how perseverance is related to increased creative output. For example, Simonton (1977) investigated 10 classical composers and their creativity productivity over time. He found that the creative geniuses persevered regardless of their circumstances (e.g., anxieties, distractions etc.). Simonton (2003) achieved similar results when investigating creativity in the science domain. De Drue et al. (2008) also found that negative mood was linked to higher number of ideas generation because of greater levels of persistence.

Taken together, existing theory and empirical findings might explain why the number of ideas generated was linked to creative output throughout Studies 1-3. Time spent engaging in idea generation was also linked to creative output in Study 1 and 2, but a marginally significant relationship was observed in Study 3. Although persistence in engaging in the implementation process has not been investigated before, the findings from this research suggest that there might be a link too as the frequency of and time spent engaging in implementation was consistently found to correlate with creativity.

Additionally, contrary to previous research in persistence, an inverted-U relationship was found between time taken and creative output. This suggests that the link between persistence and creative performance might not be as straightforward. Although Zhang and Bartol (2010a) found that creative process engagement of problem finding, information gathering and idea generation predicted employee creativity, Zhang and Bartol (2010b) reported an inverted-U relationship between creative process engagement and job performance.

Drawing on Kahneman's (1973) attention capacity theory, they suggest that trade-offs exist between creative process engagement to achieve creative outcomes and fulfilling wider job responsibilities in complex roles. They concluded that a moderate level of engagement in the creative cognitive processes is most beneficial to job performance. However, seeing as frequencies of and time taken in idea generation and implementation were largely consistently found to be related to creative output throughout all three studies in this thesis, perhaps persistence in other processes such as information gathering may have detrimental effects on creative output.

Future research should, therefore, examine the role persistence plays in each process independently and holistically, but also its transitions. For example, does perseverance influence or explain the relationship between the number of transitions and creative output? Which transitions are more predictive perseverance? Seeing as the transition from idea generation to implementation was found to be predictive of creative output, perhaps this transition is also predictive of perseverance as the iterative process of coming up with an idea and implementing it may require a great deal of effort. The number of transitions from other processes to taking a break, however, may not be linked to perseverance as frequent breaks could disrupt the creative process and potentially discourage individuals from continuing. In sum, understanding how the processes and their transitions are related to perseverance could help unpick the phenomenon and potentially help individuals to generate more creative solutions.

Punctuated Equilibrium Model of Creative Development?

The findings from this thesis highlights the predictability of certain transitions in creative problem-solving. However, future research should consider investigating how the transitions might change and develop throughout the creative problem-solving effort. Research into group development has demonstrated how attentional switches in groups can facilitate change and, therefore, performance (e.g., Gersick, 1988, 1989; Labianca et al., 2005; Okhuysen, 2001; Okhuysen & Eisenhardt, 2002; Okhuysen & Waller, 2002).

Gersick's (1988, 1989) research into group development revealed that groups working on an ambiguous task do not develop in a linear or stage like fashion, but oscillated between stages. Likening this process to the punctuated equilibrium theory of evolution (Eldrege & Gould, 1972), she postulated that task groups go through a period of inertia (*phase 1*) up until halfway through the task after which they undergo a *mid-point transition*. This transition consists of a sudden concentrated spurt of activities within the group that helps shape their approach and perspective of the task, leading to dramatic progress being made. Task groups then enter a second phase of inertia (*phase 2*) where plans that were formed at the mid-point transition get executed. The final phase *completion* occurs just before the deadline, where groups engage in a final spurt of activities to finish their work.

In her research, she observed that externally driven deadlines were the catalyst for a transition at the mid-point of a group's allocated time. Other studies reported that interruptions in a group's conversation, or clusters of attention switches, serves as an opportunity for group change (Okhuysen, 2001; Okhuysen and Waller, 2002). Interruptions, such as joking or discussing time, can cause the group's attention to shift away from the task providing members an opportunity to raise any additional issues or concerns in the group. When these opportunities are seized by the group, it allows them to become more flexible and therefore, perform more effectively (Gersick, 1988; 1989; Okhuysen, 2001).

Although the experiments in this research did not involve any interruptions, Gersick's (1988) punctuated equilibrium model of group development might explain how the transitions might occur throughout the creative process. Perhaps frequent shifts or transitions from one process to another occur in stages, from a period of inertia to a sudden burst of transitions which help shape and define the solution. Interestingly, Gersick (1988) also noted that those who failed to make a transition performed poorly or didn't complete the task at all. This appears to mirror the findings from this thesis where poor creative performers failed to make frequent jumps in their thought processes.

Future research should, therefore, examine whether the transitions occur from a period of inertia, or whether they are gradual. The qualitative results in Study 1 appears to demonstrate that the transitions occurred frantically throughout the creative-problem-solving effort. However, future research should determine whether these transitions occur in clusters and at which timepoint. Another direction for future research is to examine the impact of interruptions on the transitions. Research into incubation has shown that taking a break helps facilitate creative problem-solving (Beeftink et al., 2008; Ellwood et al., 2009). Therefore, would interruptions facilitate a cluster of transitions and enhance creative performance?

Lastly, Gersick (1988) observed that time deadlines were the catalyst for transitions. However, the participants in this research were not under time pressure to complete the task. Therefore, future research should examine the impact of time restrictions on the processes and transitions. Would a deadline cause a mid-point cluster of transitions as observed in Gersick's (1988; 1989) studies? Seeing as an inverted-U relationship was observed between time taken and creativity, could this suggest that those who can better at managing their time or pacing themselves, generate better solutions? Understanding how deadlines might have an impact on the cognitive processes and their transitions would be an interesting future research path.

Sub-facets of Creativity

Another area for future research is to understand how the cognitive processes and their transitions might be related to the various facets of creativity. For example, this research utilised Lonergan et al.'s (2004) quality, originality and feasibility rating scales as a measure of creativity. However, the relationship between the processes and each facet of creativity were not investigated.

The relationship between quality, originality and feasibility appears to be complex. Previous research investigating the relationship between originality and feasibility has produced mixed results, some demonstrating a positive link and some negative (cf., Kohn et al., 2011). Another study reported that a simultaneous focus on originality and feasibility enhanced the quality of ideas (Baruah et al., 2021). However, studies investigating the relationship between the processes and the facets of creativity are scarce and there is no known research that has examined the link between the transitions and each facet of creativity.

Perhaps some processes are related to certain facets of creativity, but not others. For example, idea generation might be related to originality, but it might have a weaker relationship with feasibility. Information gathering and idea evaluation might be linked to feasibility, whereas idea implementation might be related to the quality of solutions. Problem finding, on the other hand, might be linked to both originality and feasibility as it requires individuals to identify and construct a problem.

Certain transitions might also be related to the facets of creativity. For example, greater iterations of evaluation and implementation might be related to higher quality of solutions. Such research would be valuable for creativity interventions, where individuals could undergo specialised training to help develop or enhance each facet of creativity.

Creativity Interventions

A substantial amount of time and resources has been invested in the development and implementation of creativity training in organisations and educational institutions (Scott et al., 2004). Creativity interventions have been developed for many occupations, such as business management (Basadur et al., 1992) and marketing (Rickards & Freedman, 1979), as well as for various student populations, from kindergarten students (Meador, 1995) to college students (Daniels et al., 1985).

Although numerous approaches to fostering creativity among individuals or teams exist, most creativity interventions have focused on developing divergent thinking skills (Fasko, 2001). Perhaps the most popular creativity training method is brainstorming (Isaksen & Gaulin, 2005; Sawyer, 2012). This technique requires individuals to generate as many ideas as possible without criticising their own or other people's ideas. Osborn (1953), the father of brainstorming, believed that generating a large volume of ideas to a solution will increase the chances of producing a good idea.

Another popular method is morphological synthesis. This intervention requires team members to break down a problem into its elements, then identify the various possible solutions for each element and explore novel combinations of them. Because this method generates many different combinations, it offers the potential to generate various solutions to a problem. However, this method requires individuals to be able to dissect the problem into its elements, which in itself may require creativity (Sawyer, 2012).

Creative problem-solving is another creativity training programme that involves both individuals and group techniques, including brainstorming (Amabile, 1996). This approach teaches individuals to follow the five phases of problem-solving: fact finding (similar to gathering information), problem finding (defining the problem to be solved), idea finding (generating multiple solutions), solution finding (evaluating the solutions generated) and, lastly, acceptance finding (selling the final solution to others).

Most evaluations of creativity training have come from testing participants' creativity before and after an intervention. In Scott et al.'s (2004) meta-analysis of creativity training programmes, the researchers reported that most effective interventions involved developing cognitive skills and using domain-specific creativity exercises. In particular, training individuals in problem finding, idea generation and conceptual combination were found to be the most effective approach. Meanwhile, in educational settings, training children to solve insight problems can improve verbal and non-verbal insight skills (Ansburg & Dominowski, 2000; Cunningham & MacGregor, 2008; Sternberg & Williams, 1996). Considering all of these studies' findings leads to the suggestion that creativity training is effective. However, interventions that focus on developing cognitive skills typically involve training individuals on certain cognitive processes underlying creativity (e.g. idea generation or insight), and tend to train these processes in a linear manner (e.g. first focusing on problem finding, then idea generation, and then conceptual combination, etc.).

Given the importance of training individual creativity in the workplace (Amabile, 1996) and in schools (OECD, 2019), creativity interventions could be tailored around the dynamism of the cognitive processes underlying creativity. For example, future studies might explore whether training individuals to engage in the cognitive processes in a dynamic manner might lead to more creative solutions than training them to follow the processes in a linear manner. Another area of interest would be to determine if training individuals to engage in the generate-and-refine loop might produce more creative solutions. Accordingly, future research should investigate whether these interventions would be more effective than conventional methods.

Linking Cognitive Processes to Affect

Another vital issue for future research is how affective states might influence the execution of these cognitive processes. Many theoretical and empirical studies have demonstrated the importance of mood and its effects on creative performance at work (e.g. Amabile et al., 2005; George & Zhou, 2002). However, whether positive or negative mood can facilitate or inhibit creativity remains a point of debate among scholars. On the one hand, numerous studies have reported that positive mood facilitates creative performance (e.g. Amabile et al., 2005; Davis, 2009; Isen et al., 1985). On the other hand, a number of studies have reported that negative mood can stimulate creativity (Kaufmann & Vosburg, 1997), and some researchers have even reported contrasting effects, for example, that positive mood can hinder creativity and negative mood can facilitate it (George & Zhou, 2002).

Scholars have offered several explanations to illuminate the facilitative effect of positive mood on creativity. For example, Isen (1993) proposed in her cognitive priming explanation that positive mood stimulates access to more material from memory, allowing access to a richer, more diverse range of information. Thus, positive mood fosters creativity because it allows the individual to make more diverse associations. Along similar lines, Isen et al. (1985) reported that individuals evincing a positive mood generated more unusual, though appropriate, word associations (Isen et al., 1985). Moreover, in a longitudinal study involving over 200 employees from seven companies, Amabile and colleagues (2005) also found that positive mood was associated with peer-rated creativity.

In contrast, other theorists have presented explanations suggesting the possibility that negative affect can stimulate creativity. One such example is Martin and Stoner's (1996) mood-as-input model, where the authors claimed that individuals use their current mood as an informational signal. In other words, positive mood signals that all is well, while negative mood signals that something is wrong. Therefore, individuals experiencing a negative mood are likely to be more motivated than individuals in positive mood. George and Zhou (2002) applied the mood-as-input model (Martin & Stoner, 1996) to creativity. They posited that, under certain conditions, negative mood might facilitate creativity in a work context that stresses the importance of and rewards creative performance, as negative mood may cause individuals to be more critical and discerning. Thus, the individual might be motivated to generate more original and useful ideas. Moreover, according to Martin and Stoner (1996), negative mood might indicate the presence of issues or the need for improvements, prompting individuals to make changes, thereby stimulating creativity. Individuals who have a positive mood, however, may evaluate their current situation and ideas positively, making them less inclined to exert more effort and less motivated to make significant improvements. George and Zhou's (2002) study results, involving a large manufacturing organisation, supported their hypotheses. The researchers reported that a negative mood was positively correlated with creative performance in the presence of a perceived high level of recognition and rewards for creative performance. This finding suggests that the link between affect and creativity is context-dependent. Indeed, results from a recent meta-analytic study supported this view, despite having found a positive relationship between positive affect and creativity (Davis, 2009).

Although scholars still disagree as to whether positive or negative mood can facilitate or inhibit creativity, studies have to date focused on daily accounts of mood (e.g. George & Zhou, 2002). Only two known studies (Bledow et al., 2013; Mackay & Moneta, 2016) have observed changes in an individual's mood while engaging in the cognitive processes underlying creative thought, but both suggest that such changes are influential. Possibly, individuals' moods may change during their engagement in the creative processes, from problem finding to information gathering to idea generation and so forth. In this vein, Getzels and Csikszentmihalyi (1975, 1976) observed that creative students changed their ideas several times. Thus, intriguing topics for future research to address include an investigation into what motivated these students to go back a stage to refine their ideas and whether they were in a positive or negative mood. Going further, it would be interesting to determine whether creative individuals would experience a constantly negative or positive mood as they went through the stages or if their mood would change according to the stage they were engaged in.

5.7. Concluding Remarks

A considerable amount of current evidence suggests that employee creativity plays a key role in organisational innovation as well as organisational competitiveness and survival (Amabile, 1996; Nonaka, 1991). Therefore, understanding the factors that enhance or hinder employee creativity is paramount. In summary, this PhD research has fulfilled its objective of examining the independent and combined effect of the cognitive processes underlying creativity and how they are related to creative output. This research also empirically tested the dynamism of the creative process and showed how frequent shifts between these processes are predictive of creativity. Lastly, this thesis presented two mediation models demonstrating the predictivity of the generate-and-implement approach in creativity.

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Appendices

Appendix A: Talk-Aloud Instructions

In this experiment we are interested in what you say to yourself as you perform some tasks that we give you. In order to do this we will ask you to THNK ALOUD as you work on the problem. What I mean by think aloud is that I want you to say out loud EVERYTHING that you say to yourself silently. Just act as if you are alone in the room speaking to yourself. If you are silent for any length of time I will remind you to keep talking aloud. Do you understand what I want you to do? Good!

Before we turn to the real experiment, we will start with a couple of practice problems so I want you to talk aloud while you do these problems. First, I will ask you to multiply two numbers in your head.

So TALK ALOUD while you multiple 24x34!

Good! Now I would like you to solve an anagram. I will show you a card with scrambled letters. It is your task to find an English word that consists of all the presented letters. For example, if the scrambled letters are KORO, you may see that these letters spell the work ROOK. Any questions

Please talk aloud while you solve the following anagram!

NPEPHA = HAPPEN

Good! Now for the real experiment. I will show you a dilemma which I would like you to solve thinking aloud. I want you to tell me EVERYTHING that you are thinking from the time you see the dilemma until you give me an answer. Again, just act as if you are alone in the room speaking to yourself. If you are silent for any length of time I will remind you to keep talking aloud. Do you understand what I want you to do?

Appendix B: Creativity Index – Quality and Originality Rating Scales

Using the 1-5 ratings scale below, please judge the solution relative to the other solutions in the provided set. Please insert the chosen rating in the box provided.

Quality. The degree to which the solution is a plausible and appropriate solution to the problem presented. The degree of logic and coherence in solution.

1 - very low quality, solution not plausible or appropriate

2 - low quality, solution somewhat plausible, little logic and coherence

3 - average quality, solution plausible, somewhat appropriate, some logic

4 - high quality, solution plausible, appropriate, and logical

5 - very high quality, solution very plausible and appropriated, very logical.

Please insert rating here:	

Originality. The degree of extrapolation from the stimulus context (the problem scenario presented). The degree to which the solution is not structured by the problem and has gone beyond the rote. The degree of novelty and uniqueness of the solution.

1 - very low originality, no extrapolation, highly structured by the problem.

2 - low originality, little extrapolation, structured by the problem.

3 - average originality, some extrapolation, somewhat structured by the problem.

4 - high originality, moderate degree of extrapolation, little structure by the problem.

5 - very high originality, large degree of extrapolation, not structured by the problem.

Please insert rating here:	

Appendix C: Creativity – Quality, Originality and Feasibility Rating Scales

Using the 1-5 ratings scale below, please judge the solution relative to the other solutions in the provided set. Please insert the chosen rating in the box provided.

Low		Medium		High
1	2	3	4	5

1. **Quality**

Defined as: Were the answers logical, coherent, and well thought out? Would you say the answers represented a useful, workable solution? In terms of degree of quality, would you rate the overall performance low, medium, or high?

Please insert rating here:	

2. **Originality**

Defined as: Were the answers unique or clever? Would you consider the answers surprising and/or original? In terms of originality, would you rate the overall performance low, medium, or high?

Please insert rating here:	

3. **Feasibility**

Defined as: Were the answers practical and realistic? Would a company want to carry out or implement the plans? In terms of feasibility, would you rate the overall performance low, medium, or high?

Please insert rating here:	

Appendix D: Screenshots of Online Experiment

Figure 8: *Dilemma Page*

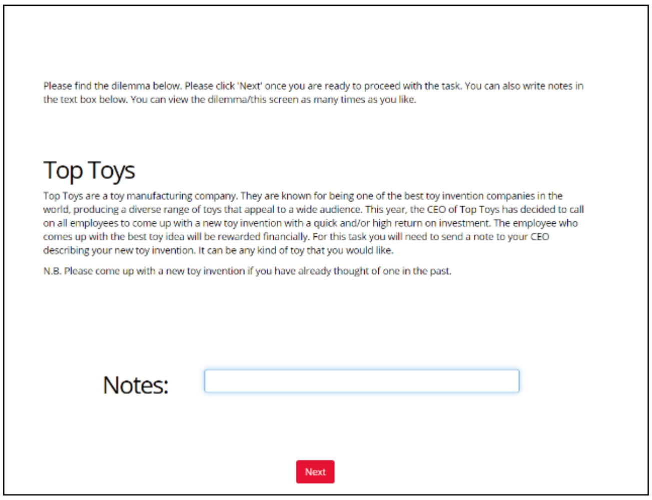

Figure 9: *Internet Page*

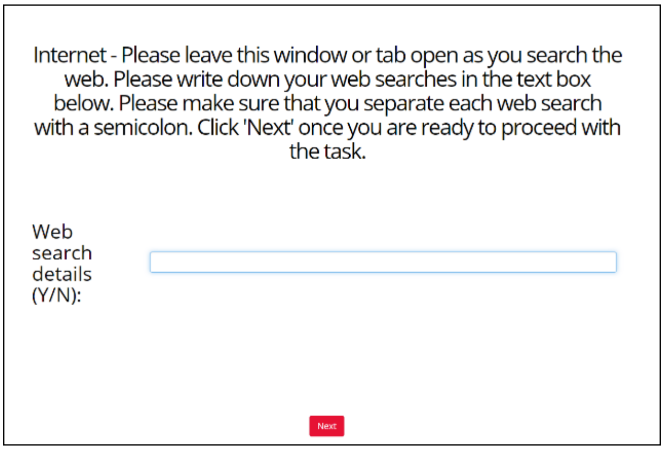

Figure 10: *Break Page*

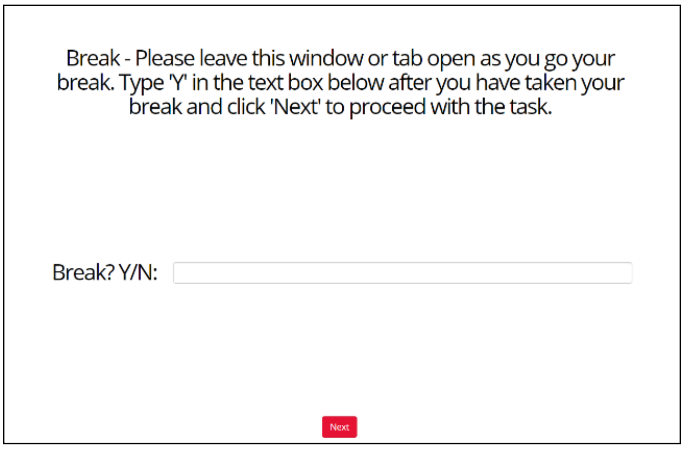

Figure 11: *Ideas Page*

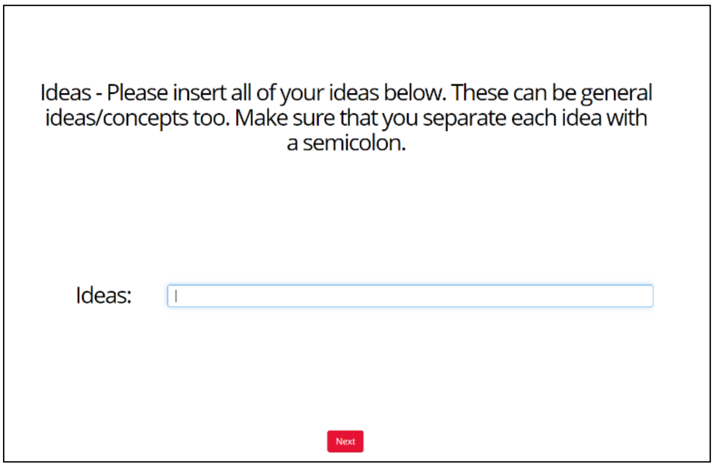

Figure 12: *Evaluation Page*

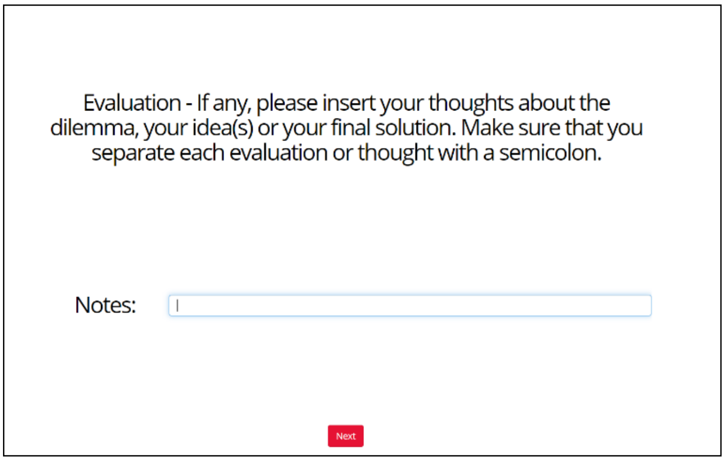

Figure 13: *Final Solution Page*