Reasoned connections: Complex creativity and dual-process theories of cognition

by

Nathaniel Barr

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Creativity is one of the most imperative of all psychological constructs to study, for the implications of understanding creativity have immense bearing upon our future as a species. Understanding creativity can reveal not only basic mechanisms of our minds, but also afford insight as to how we have devised the ideas and artifacts that improve our lives and suggest how we can set the stage for further societal innovation and improvement. Despite the obvious imperative to arrive at a fuller understanding of creativity, the field is largely lacking in terms of a unifying theoretical orientation that can provide descriptive and prescriptive information regarding creative thinking. A particularly poorly understood and contentious issue within the study of creativity is the extent to which relatively more or less executive processing is beneficial to creative thinking. To explore this issue, I adopted a Dual-Process Theories (DPTs; Evans & Stanovich, 2013) perspective in which cognition is characterized by an interaction between autonomous (Type 1) and working memory dependent executive processing (Type 2). I conducted several studies that test whether relatively more or less Type 2 thinking leads to relatively more or less success in creative thinking at the state and trait levels. At both levels of analysis, I found that relatively more Type 2 processing afforded relatively more success in making creative connections that entail the unification of disparate elements. I qualify these results by showing that this relation does not hold for some other indices of creativity, and in so doing, distinguish what I call complex creativity from other sorts of divergent thought. In discussing my results, I describe the sub-processes that allow complex creative thinking to unfold over time and consider empirical and theoretical works from diverse areas that relate to this view. I situate the ability to make complex remote connections alongside other advanced higher-order thinking capabilities that are unique to humans and strongly suggest that to be creative, one must deploy our most advanced cognitive abilities.

Acknowledgments

"Before we as individuals are even conscious of our existence we have been profoundly influenced for a considerable time (since before birth) by our relationship to other individuals who have complicated histories, and are members of a society which has an infinitely more complicated and longer history than they do (and are members of it at a particular time and place in that history); and by the time we are able to make conscious choices we are already making use of categories in a language which has reached a particular degree of development through the lives of countless generations of human beings before us. ... We are social creatures to the inmost centre of our being. The notion that one can begin anything at all from scratch, free from the past, or unindebted to others, could not conceivably be more wrong."
-Karl Popper (as quoted in *Popper* by Bryan Magee, 1973)

Given the infinite number of possible realities, I am extremely fortunate to have stumbled into a time and place on Earth in which I was supported at all steps in all ways. I am indebted to the following people, and many more, for their help in my attainment of my academic and personal goals.

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Thank you to my family. I am amongst the fortunate few who fell into a family that I would call friends even if it were not for the bond of blood. I love you all and thank you for helping me to find my way to where I am now. A special thank you to my brother for the original inspiration to question the way our minds work, and for his example of courage through adversity.

Finally, thank you to my dear wife, Johnny. Your patience, support, and love allowed me to do this. I love you more than anything and still consider convincing you to spend your life with me and build a family together to be my greatest accomplishment. It is amazing to think how much we’ve already accomplished and even more exciting to imagine where we might go next!

Dedication

Hi kids,

Not sure how old you will be when you decide to dust this old thing off, or even if you will. If what you see here doesn't make sense when you read it now, try again in a few years.

Even though you didn't yet exist when I started this degree, you kids were the reason I finished it. As soon as I knew I would be a father, I felt a compulsion to work harder, accomplish more and be more thankful for my opportunities. This urge was not only to provide for you, but also to show you that anything is possible. If I could do this, you could this. If we can do this, we can do anything. Thank you for making me better and I hope it makes you better too.

I write this to you now in part because by the time you would be old enough to talk about this era, I would surely be changed over the years and I want you to have insight into this important phase of our family history. In many ways these years have been a trade-off between career and family, and doing things for finances or fun. With both your mom and I going to grad school and having you kids, we ambitiously went for career *and* family, but fascinating rather than financially stable. Although it was hard, we never regretted anything. I am so glad we did it this way. Life is too short to not do things that you want to do. We don't really need that much in the end anyway. Experiences are worth more than objects and doing this degree and growing our family has been the best experience of my life.

You kids are truly blessed in that you have the most amazing mother and rich networks of people who love and care for you. I can't wait for the extent of the love that already exists for you to reveal itself to you as you grow. It is hard to overstate how excited I am to see how you fit into the wide world and decide what to do with your life. There are limitless possibilities for you both personally and professionally. It is tough to know what to do with yourself but think about this: Viktor Frankl wisely said that "success, like happiness, cannot be pursued; it must ensue, and it only does so as the unintended side effect of one's personal dedication to a cause greater than oneself or as the by-product of one's surrender to a person other than oneself." For me, I found that learning things and sharing what I learned with others was my cause, and that you are my people. I just focus on dedicating my time to that and to cherishing you, and wherever we end up, so be it. So far, so good. I am an incredibly lucky man in that I consider myself both happy and successful, and I hope that you can be as lucky as me by following this simple advice: Be kind and thankful, work hard, find things and people to love and you will live a happy life. Once you find your cause and persons to dedicate yourself to, you will find your way, even if it isn't exactly as you thought it might be.

I promise to help you kids do whatever it is you want in this life, as others did for me. It won't be easy, but if you really want something, let's try and do it. There will be lots of times where you doubt, and where you wonder, but we will help you. Even if it doesn't go as planned, we will know that we tried. It is about the journey and not the destination. No matter what happens in our lives, know that I love you and that everything I do is dedicated to you.

-Dad

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Humans are irrepressibly creative creatures. Whereas some species have flourished on our planet due to advanced specialization in particular tasks or routines essential to survival, we are massively successful due to our resourcefulness, adaptability, and capacity to re-combine the elements in our environment, and in our minds, in novel ways as to better ensure our survival and safety. This capacity for creation and the resultant innovations have culminated in our species flourishing in nearly every environment on Earth, and evidence of our advances is manifest in every aspect of our civilization.

We no longer forage only from the Earth that which is naturally before us, but rather feast upon the exploits provided through diverse techniques that we have developed over many generations. We hunt and domesticate animals, cultivate land, and grow crops extensively, even modifying the genetic code of particular organisms in such a way as to make them of greater utility in our collective survival. We no longer dwell in natural shelters; instead we use an incredibly diverse assortment of materials to create structurally sound, and sometimes even extravagant shelters that give us warmth, comfort, and safety. We have created tools that supplant our biological endowments, which in turn have allowed us to build incredible architecture, infrastructure, and technologies far surpassing our survival needs. We have established complex and diverse social and political structures that guide our interactions with one another and enable co-operation and co-ordination amongst billions of people. Massive interconnected communication networks—radio, telephones, television, cellular and satellite networks, and the internet—afford us the chance to interface and share knowledge with people thousands of kilometers away instantaneously. If we wish to actually traverse that distance, we have created elaborate transportation technology that allows us to move across water or land at speeds far beyond that allowed by our anatomy. We have produced machines that carry us through the sky, and even into space, defying the limits supposed by even our ancestors of only a few generations ago. Still accelerating medical and sanitation advances have increased our life span and quality of life significantly, allowing us the chance to postpone death in a controlled fashion unique amongst life forms on Earth. Music and art permeate all cultures, facilitating the transmission of information and emotion, and encapsulating the creative spirit of expression that characterizes man. We share knowledge through language, writing, and teach each other in a way that means we need not learn only from our own mistakes. Through scientific and academic inquiry we have a more accurate characterization of ourselves, our world, and our universe than any generation before us. Isaac Newton famously said: "If I have seen further, it is because I stand on the shoulders of giants." Indeed, all of us have seen further by virtue of the view afforded by standing on the tall, broad shoulders of our fore-bearers, as each subsequent generation builds upon and relates together the creations of those that came before. Our innovations have been innumerable and their impact immeasurable, other than to say that without the staggering collective creative output of our species, our world would be very much unlike the one we inhabit today.

As impressive as all of our accomplishments may be, as a species we still face constant challenges as we progress into our collective and inevitable future -- the Anthropocene. These challenges will require even greater creativity than that exhibited by those who came before, as our world has been irrevocably altered and has become more complex and challenging as a function of the consequence of the innovations that led us to reach such indomitable heights. Humans need creativity to both challenge the longstanding obstacles to our survival, as well as to solve the new problems posed by our previous creations, and this cycle seems likely to perpetuate so long as we populate the Earth.

Many of the technologies that have improved our lives are proving inefficient and appear likely to be unsustainable in the longer horizon. A growing population necessitates ever greater quantities of food be produced in ever shrinking pockets of cultivable land. Simultaneously we must accommodate the concomitant increase in waste and pollution that comes with a population growing at a rate unfettered by traditional predators. This lack of predation does not mean that if we can maintain potable water and produce sufficient food our ascent as a species will continue sharply upward. The globalization enabled by advances in communication and transportation has led to international conflict, which, given advances in warfare technology could prove unprecedentedly catastrophic to all. In *A Short History of Progress*, Ronald Wright warns that "the future of everything we have accomplished since our intelligence evolved depends on the wisdom of our actions over the next few years" and that the "Earth has grown too small to forgive us any big mistakes." (2004, p. 3). In order to ensure our long-term survival and success, social innovation, the generation and implementation of new ways by which people interact with each other and our planet, must become a priority (see Mumford, 2002; Marcy & Mumford, 2007; Mumford & Moertl, 2003; Mumford, Medeiros, & Partlow, 2012). Such innovations will have to arise in diverse realms such as "education, health care, law and regulation, technology, social movements, organizations and methods for organizing, and finance" (Jiang & Thagard, forthcoming), with all categories requiring great creativity.

Given both the centrality of creativity in understanding what we have already accomplished, as well as the critical role it will necessarily have to play in our species solving the problems we now face and those that have yet to emerge; it seems that the study of what creativity is, how it unfolds, and how to cultivate it, is of utmost importance. William James, amongst others, promoted the idea of meliorism. Meliorism refers to the notion that substantial and tangible progress can be made through interfering with the default, natural mode of operation. Put most simply, through human intervention we can improve the human condition, a fact seemingly true on the basis of the advances described above. Similarly, later in this thesis, I will argue that by intervening upon the default, natural mode of thinking, humans are capable of creating and identifying new and complex relations amongst seemingly disparate elements. I argue that this cognitive capacity has been a critical component of our creative accomplishments and is sure to figure prominently in the solutions we must generate for our mutual success. Before I can explain what this means more fully and can introduce the experiments that led to this conclusion, it is imperative to first review historical and contemporary literature on cognition, reasoning, and creativity to better understand what we have come to know about ourselves, and what it might mean for our future.

Dual-process Theories

Psychology is concerned with understanding the diverse ways that human mental activity relates to our experience and accomplishments. Accordingly, many researchers and theorists have attempted to generate large scale theoretical frameworks with which to understand the extremely broad set of processes and systems that underlie the unique mental phenomena of our species. One of the most ubiquitous and longstanding approaches in this effort is to distinguish two types, systems, or sorts of processes that together comprise the broader sphere of cognition. Conceptions of the mind and characterizations of thinking as being of two qualitatively distinct types have been around since antiquity (e.g. Aristotle) and were discussed by early pioneers of psychological science (e.g. James) (see Frankish & Evans, 2009). The terms ‘automatic’ vs.

‘controlled’ processes eventually seeped their way into common psychological parlance by way of the cognitive revolution and the accompanying notion of a capacity-limited information processor (e.g. Posner & Snyder, 1975; Shiffrin & Schneider, 1977). In his underappreciated article, *The Multiplicity of Thought*, Neisser (1963) asserted that the “psychology of thinking breeds dichotomies. Nearly everyone who has touched the subject has divided mental processing into two (or more) kinds” (p. 1). His observation was not only historically astute but prescient as well. Rather than dissipate over time, theories of this sort have proliferated and become more refined as increasing amounts of evidence come to support them in a wide variety of psychological domains, including reasoning, judgment, decision making, and social cognition (see Evans, 2008 for a review).

Modern Dual-Process Theories (DPTs), of which there are several (see Evans & Stanovich, 2013), carry on the tradition of distinguishing between two qualitatively dissociable types of processing to understand how our minds work. Although some variability exists in the exact form of such theories, and much could be said about such differences, there exists general consensus as to the nature of the two types of processing. Type 1 processing is characterized as automatic, relatively undemanding of cognitive capacity, and relatively fast, whereas Type 2 processing is seen as analytic, controlled, capacity demanding, and relatively slow (see Evans & Stanovich, 2013). There are many associated correlates with both types, but recent developments in the field of reasoning have provided a more concrete means of defining the two types of thinking and it is this model/view that I shall adopt throughout this thesis. Most simply, Type 1 processing is viewed as autonomous, whereas the defining feature of Type 2 processing is the engagement of working memory (WM; see Evans & Stanovich, 2013). Importantly, the theoretical view adopted here, and that preferred by the cited authors, is that of a default-interventionist view in which “fast Type 1 processing generates intuitive default responses upon which subsequent reflective Type 2 processing may or may not intervene.” (Evans & Stanovich, 2013, p. 227). In more general terms, such a perspective presumes that people tend to most often rely upon the less time-consuming and more energy efficient autonomous stream of processing, and relatively sparingly interject with analytic, reasoned thought. As such, theories of this sort provide a characterization of the states of thought that humans primarily engage in, and the manner in which people vacillate between autonomous and controlled thinking in a wide variety of scenarios (see Kahneman, 2011).

Importantly, such theories not only focus on thinking *states* but also *traits*. There are thought to be minimal individual differences in Type 1 processing, or the manner in which the autonomous mind operates, whereas there are known consequential variations in two aspects of Type 2 processing (Stanovich, 2009). Specifically, one can characterize individuals along two correlated, but distinct, dimensions. The first, what Stanovich refers to as the algorithmic mind refers to one’s capacity/ability to engage in Type 2 processing and is largely synonymous with intelligence. The second, what Stanovich refers to as the reflective mind, relates to the extent to which one exhibits a proclivity to intervene upon the autonomous stream of processing (i.e. Type 1) with controlled, WM dependent, Type 2 processing. Put simply, people differ in both their ability and disposition to engage in WM dependent Type 2 processing and these differences are consequential in many areas of psychology and cognition. As such, DPTs have the capacity to characterize both the moment-to-moment variation in cognitive processing states within an individual, but also meaningful differences at the trait-level in terms of thinking styles and ability across individuals, meaning that such theories have extremely broad import and exciting potential to account for variation in diverse areas of behaviour. As I will argue, DPTs are particularly well-suited to accounting for both the state-level cognitive mechanisms underlying creative thought, and trait-level individual differences in creative thinking. Before re-visiting this argument, it is important to characterize creativity more fully.

Creativity research: Chasms and confusions

Psychology has long endeavored to understand the types of processes, proclivities and people that potentiate creative thought, as it is widely acknowledged that creative output is an integral component of any advanced society, and any advanced mind. Regardless of the particular domain of creation, there is consensus about the two major defining features that make something creative -- the content must be novel, divergent, or unorthodox and must fit within the constraints of the task. Something deemed creative, whatever the domain, describes an output of a particular sort that is a result of a series of cognitive processes. Someone thought to be creative is one more inclined to generating creative output. As such, creativity can be seen as a process, an outcome, and a trait and is often interchangeably described in such terms, lending to the mystique of an already elusive construct. Given the value of creativity and such a broad, varied definition, it is not surprising that there exists a great deal of diversity in the types of research aimed at elucidating the nature of creative thought. A lack of mutual understanding as to the proper focus of research aimed at elucidating the nature of creative thought has resulted in huge differences in methodological/theoretical approaches across researchers purportedly studying the same construct. This diversity, though producing a large volume of research, has precluded a unified account of creativity and resulted in a fractionated literature in which advances in one domain are often isolated from other areas of creativity research (see Hennessy & Amabile, 2010). Creativity still might be considered, as it once was, as: “one of the vaguest, most ambiguous, and most confused terms in psychology” (Ausubel, 1964, p. 551). In this dissertation, I will advocate for the adoption of a DPT perspective in creativity research as it can accommodate the full breadth of processes and traits surrounding the construct and is a burgeoning presence in the field of psychology at large, providing potential for greater unification of diverse topics.

Creativity research: Autonomous vs. controlled processing

It has long been understood that different types of thinking must necessarily play a role in creative thought. This notion was perhaps most famously expounded by Graham Wallas (1926) in *The Art of Thought*, wherein he described the four stages of the creative process -- preparation, incubation, illumination, and verification -- which although not explicitly grounded in DPT terminology, was clearly suggestive that a vacillation between unconscious/conscious and/or automatic/controlled processing was required for creativity to emerge. Indeed, eighty-five years later, Allen and Thomas (2011), in the tradition of Wallas (1926) and drawing on the work of Ochse (1990), who identified the commonalities in most classic characterizations of the stages involved in creativity, described the stages of problem finding, conceptualization, incubation, illumination, verification, and dissemination in the context of DPTs. More recently, Sowden, Pringle, and Gabora (2014) connected creative thinking to DPTs by relating Type 1 processes to generative components of the creative process and Type 2 processes to evaluative components. Their framework draws on previous work by Gabora (e.g. 2003, 2010) centred upon contextual focus, that is, the shifting between a de-focused (i.e. Type 1 process) and a more focused attentional state (i.e. Type 2 process). Barr, Pennycook, Stolz and Fugelsang (2014) have added both empirical evidence and theoretical refinement to such conceptions, but as this work is included in the current thesis (Experiment 5), a more elaborated perspective shall come after consideration of further evidence.

Despite the growing acknowledgment that DPTs have utility in understanding creativity, a particularly thorny issue, which has yet to be fully clarified in the context of DPTs or other theoretical orientations, surrounds the relative utility of engaging executive processing in the creative process, either at the state or trait level. Randall W. Engle, a leading researcher in WM research has advocated a view in which WM capacity is conceptualized as "executive attention" (see Engle's 2002 paper; *Working memory capacity as executive attention*). Given this conceptualization of WM, and that the defining feature of Type 2 processing is the engagement of WM resources (Evans & Stanovich, 2013), it should become obvious that a DPT orientation can inform the as of yet ambiguous role of executive processes in creativity.

When one inspects the literature on the issue, it becomes immediately obvious that a stark divide exists between those who believe engaging such executive, or in the current terminology, Type 2 processes, is helpful and those who consider it a hindrance. One side has argued that "superior executive functioning, such as increased attentional control, may in fact be detrimental to reaching creative solutions" (Jarosz, Colflesh, & Wiley, 2012, p. 488). Others, however, point to a growing body of research showing the opposite -- that "executive cognition is… central to creative thought" (Nusbaum & Silvia, 2011, p. 36), resulting in an incongruous set of findings in an already fractionated literature (Hennessey & Amabile, 2010).

Those holding the view that executive processing can hinder creative problem solving often point to evidence that high attentional control and/or high working memory capacity (WMC) does not benefit creative problem solving as it does analytic problem solving, often leading to fixation or undue focus on aspects of a problem that will not yield a solution (see Wiley & Jarosz, 2012 for a review). These researchers posit that a more dispersed or fuzzy state of attention, such as that associated with alcohol consumption (Jarosz, Colflesh & Wiley, 2012), can allow for the type of mindset required to arrive at creative solutions. Such a view implies that relatively less executive engagement will generally lead to relatively more creativity (for other examples, see Aiello et al., 2012; Reverberi, Toraldo, D'Agostini, & Skrap, 2005; Wiley & Jarosz, 2012; Wieth & Zacks, 2011; Ansburg & Hill, 2003; Kim, Hasher & Zacks, 2007;; Schooler, Ohlsson, and Brooks, 1993; Kounios et al., 2006; Baird et al., 2012; Bowden et al., 2005; Dijksterhuis, & Meurs, 2006; Sio & Ormerod, 2009; Zhong, Dijksterhuis, & Galinsky, 2008).

Observations that intelligence and executive cognition are related to cognitive performance (e.g. Silvia, 2008; Nusbaum & Silvia, 2011; Beaty & Silvia, 2012; Silvia & Beaty, 2012; Beaty & Silvia, 2013; Batey, Chamarro-Premuzic & Furnham, 2009; Batey, Chamarro-Premuzic & Furnham, 2010; Gilhooly, Fioratou, Anthony & Wynn, 2007; Gupta, Jang, Mednick, & Huber, 2012; Atchley, Strayer & Atchley, 2012; Benedek, Franz, Heene & Neubauer, 2012; Ball & Stevens, 2009; Chein & Weisberg, 2014) have led others to adopt an alternative stance in which executive processing is seen as indispensable to creative thought. Such views often presume greater ability to maintain and manipulate information in the face of interference, and more effective strategy use as being the means by which such success is reached. This view would predict that relatively more executive engagement will generally lead to relatively more creativity.

In this dissertation, I will describe a series of studies that focus both upon the state-level of creativity (i.e. the moment-to-moment processing within an individual) and the trait-level of creativity (i.e. meaningful individual differences in creative ability) that hone in on the question of whether more or less executive intervention helps or harms creative thinking. Such an approach is grounded within the broad framework afforded by the adoption of a DPT orientation and will use diverse methods, manipulations, and measures. My aim is to illuminate whether relatively *more* or *less* analytic thinking is beneficial to the creative process and attempt to understand the interplay between distinct types of thinking in creativity, heeding previous suggestions that the study of creativity could benefit from a DPT perspective (see Allen & Thomas, 2011; Sowden et al., 2014) while addressing the lack of specification regarding the optimal balance between Type 1 and Type 2 thinking. In the context of state-level manifestations of creativity, I explore whether inducing (i.e. via experimental manipulation) or cuing (i.e. via instructional manipulation) relatively more or less intuitive/analytic thinking enhances or reduces creative performance. At the trait level, I explore the roles of cognitive ability and analytic cognitive style (as in Stanovich, 2009) and their roles in predicting creative ability using an individual differences approach. At the state level, if Type 2 processing helps the ability to make creative connections, then experimental/instructional manipulations that promote analytic thinking should enhance reasoning relative to manipulations that promote more intuitive approaches. At the trait level, if higher cognitive ability and a more analytic cognitive style are associated with increased creativity, it would suggest a greater benefit of executive processing than would be predicted by some accounts of creativity (e.g. Wiley et al., 2012). In contrast, if lower cognitive ability and a less analytic cognitive style is associated with increased creativity, it would suggest a greater benefit of non-goal directed, potentially unconscious processing than would be predicted by some accounts of creativity (e.g. Beaty & Silvia, 2012).

Analogical reasoning and complex creativity

As already noted, creativity can describe many things, so it is beneficial at this juncture to constrain our discussion to a particularly important type of creativity that will be of primary focus throughout this manuscript -- the ability to make connections amongst remote, and seemingly unrelated, elements. Given the complexity of the modern world and the problems which we face as a species, innovation cannot exist in a vacuum. Put another way, given the extent of our collective knowledge base and the intricacy of societal needs, generating novel ideas in isolation from extant ideas is not of most importance, or even necessarily possible- rather, creative ideas and solutions must be meaningfully connected to other concepts and evidence that bear on the problem at hand. Indeed, such connections between elements are considered to be indispensable to scientific discovery and technological invention (Thagard, 2012), are involved in all social innovations (Jiang & Thagard, 2014), and accordingly form an important cornerstone of not just our cognition, but our society. As such, the primary focus of this work will be what I call complex creativity -- that is, novel and useful connections that are relationally complex.

A particularly interesting, useful, and theoretically rich example of complex creativity is creative analogical reasoning. An analogy is said to exist when the pattern of relations amongst one set of elements, situations or objects is shared with that of another set. Analogical reasoning has been said to be at the "core of cognition" (Hofstadter, 2001) and is thought by many to be *the* critical component of a cognitive toolkit that discriminates humans from other species (see Gentner & Smith, 2012), and as such, is an extremely important example of complex creativity. The comprehension of analogies falls under the purview of second-order relational reasoning -- that is, reasoning about the relations between relations. An increasing body of work looks at creativity in the context of analogical reasoning, as this type of reasoning has been shown to have great utility in a variety of domains related to creative output. Analogical reasoning has proven to be consequential for solving complex problems in real world settings (Thagard & Holyoak, 1995; Chan, Paletz, & Schunn, 2012), with distant analogies being particularly important to science, in that they are commonly used in the process of generating new scientific theories (Kuhn, 1962; Dunbar & Blanchette, 2001). For example, Holyoak and Thagard (1995) identify the earliest known major scientific analogy as having been developed in the era of Imperial Rome. Chrysippus of Soli (c. 240 B.C.), a Greek Stoic philosopher, identified the analogical relation rooted in the common behaviour of water waves and sound, shedding new light on the ways in which one could predict and understand the nature of acoustics based on existing understanding of the manner in which water behaves.

Analogies not only lead to new understanding at the collective level (i.e. scientific advancement) but also at the individual level as well (i.e. scientific education) (e.g. Dagher, 1995a; Dagher, 1995b; Cosgrove, 1995; Wong, 1993; Zook, 1991). For example, Joel Levy (2011) published *A Bee in a Cathedral And 99 Other Scientific Analogies*, a book in which more familiar notions about the world are mapped to unfamiliar concepts to yield new understanding. In the flagship example from which the title of the book is derived, Levy draws an analogy between the relative of size of a bee in a cathedral and that of the relative size of a nucleus in an atom. In calling attention to this underlying common relation, one is afforded new insight into the way to conceive of the composition of something not able to be observed organically based on a relation that can be easily visualized or imagined. Given the obvious benefits of understanding creative analogies, it becomes important to consider both states of mind, and individual dispositions, abilities, and traits that could lead to enhanced creative performance.

Stimuli and Task

Certain core components of the stimuli and task adopted in my dissertation are constant across the multiple experiments discussed here. Given the centrality of these conceptual and methodological details to the arguments outlined here, it is worthwhile to introduce these aspects, and the logic underlying their inclusion, prior to explicating the particulars of each respective experiment.

A long tradition of research in analogy (see Sternberg, 1977) requires participants to solve verbal analogies of the form A:B::C:D (i.e. A is to B as C is to D). Such 4-term pairs are thought to encapsulate much of the necessary conceptual depth and relational complexity required to mirror the types of reasoning one might go about in the real world, while also being relatively easier to experimentally explore than more complex and messy relations that one could potentially study. Our work draws on such stimuli and distinguishes analogies that are more or less creative by capitalizing on a distinction between analogies in which the A:B terms come from the same category, or domain, as the C:D terms, and those that do not. For example, a within-domain analogy, in which both relations are drawn from the same categories such as Lambchop is to Lamb as Porkchop is to Pig, is considered to be less creative than a cross-domain analogy such as Lambchop is to Lamb as Chapter is to Book (see Green, Fugelsang, Kraemer, Gray & Dunbar, 2010).

In all of the experiments outlined here, participants were presented with such 4-term analogy problems, half of which are cross-domain and half of which are within-domain, as well as filler non-analogy stimuli that serve as foils, which also systematically vary by domain. Although procedural details vary (experimental/instructional manipulations will be employed), participants in these experiments will invariably be asked to, as quickly as possible, identify whether the presented pairs are analogically related. As a means of avoiding item-level effects as a consequence of idiosyncrasies in the stimuli, common A:B pairs were used here, and in the other experiments, for cross-domain, within-domain, and invalid analogies (half were cross-domain, half were within-domain). In other words, for any given A:B pair, there were three C:D pairs; a cross-domain valid analogy, a within-domain valid analogy, and an invalid analogy.

The categorical distinction between cross and within-domain pairs is formalized by semantic distance values obtained via latent semantic analysis (LSA: Landauer & Dumais 1997; Landauer, Foltz, & Laham, 1998) for each item. LSA essentially describes how distantly related concepts or relations are in semantic space, providing a useful means of describing creativity that is grounded in models of the way that knowledge is encoded. More technically, the LSA application

> calculates the similarity between the contextual-usage meanings of words as measured by the cosine of the included angle between vectors assigned to those words within a very high-dimensional ‘‘semantic space,’’ comprising extensive corpa of English text. A vector is added for multiword inputs such as the word pairs constituting our analogy stimuli. (Green, Kraemer, Fugelsang, Gray & Dunbar, 2010, p. 71).

Norming, done by a panel of 84 independent raters (see Green, Fugelsang, Kraemer, Gray & Dunbar, 2010), indicated greater than 90% agreement as to the validity (i.e. is this a valid analogy?) and domain classification (i.e. are these word pairs from the same domain?) providing support that the semantic distance ratings effectively relate to human subjective judgment and index what they are meant to. The words were also equated for a number of other dimensions, including word length, word frequency, and concreteness. Another advantage of these stimuli, beyond being very well-controlled, is that they have been extensively studied in the context of neuroimaging studies (Bunge et al., 2005; Green, Fugelsang, Kraemer, Shamosh & Dunbar, 2006; Green et al., 2010; Green, Fugelsang, Kraemer, Gray & Dunbar, 2012), and as such, we can relate the behavioural results here to the burgeoning evidence pertaining to the neural correlates with relative confidence.

By clearly delineating non-creative from creative analogical connections, one can, in a controlled fashion, explore the cognitive factors underlying such reasoning in relation to the relative creativity of these dichotomous types of analogies. Through the imposition of constraints more typically associated with reasoning tasks, rather than focusing primarily on divergent open-ended responses, one can get a more refined sense of how the creative relations were identified, as only certain conceptual combinations will yield insight into the underlying common relation shared by the constituent pairs. Although ostensibly an identification task, such a paradigm does index creative generation, as correct identification of a creative analogy is contingent upon the generation of the covert relational mappings that form the basis of the analogical relation (see Green et al., 2012). In other words, although not mirroring some standard creative generation paradigms, this task still has a generative component in that participants must *create* the appropriate common underlying relation that binds the A:B and C:D pairs. Support for the notion that such a task is suitable for gauging creative generation comes from evidence that the task of generating solutions to open-ended analogies and the task of identifying them draw on a largely synonymous set of neural regions, with both eliciting unique activation as a function of semantic distance parametrically (Green, Fugelsang, Kraemer, Gray, & Dunbar, 2010, 2012)

The selected stimuli are well-aligned with several key concepts discussed in analogical reasoning research (italicized terms and quotes drawn from Gentner & Smith, 2013, p. 130). All items used have *structural consistency*, “the property of having a clear set of matches between two analogs” (i.e. A:B::C:D structure), thus providing some modicum of experimental control that serves to simplify the cognitive processes under study. All valid analogies in the set are defined by *relational similarity*, that is, “likeness based on relations common to both domains or situations (whether or not the objects in the two systems resemble each other)”, whereas the non-analogies are defined by the absence of this likeness of relations. The distinction between cross and within-domain pairs effectively systematically varies *surface similarity*, the “likeness based only on similar objects and background context between two domains/situations” for both analogy and non-analogy pairs, precluding successful reasoning on the basis of category information alone. Importantly, whereas cross-domain analogies only have *relational similarity* but not *surface similarity*, within-domain analogies feature both *relational similarity* and *surface similarity*.

Although obviously not entirely representative of the creative process as it unfolds when scientists connect the unconnected or artists fuse previously unrelated styles in a novel way, such a task carries on the general tradition in psychological science of reducing the noisiness and variability in many of the mental phenomena we hope to understand through laboratory controls and simplification of otherwise very complex and disorderly situations (e.g. Ebbinghaus, 1885). More specifically, our work is congruent with the creative cognition approach (Ward, Smith & Finke, 1999). This approach presumes that ordinary mental processes underlie creative thinking, and like any other cognitive phenomena, creativity is considered amenable to empirical investigation in the laboratory.

Rationale and Predictions

I have reviewed here a diverse collection of research and theory pertaining to diverse facets of psychology in order to characterize a contemporary problem plaguing the creativity literature (i.e. does executive/Type 2 processing help or hinder the creative process?), a paradigm in which to attempt to answer this question (i.e. creative analogical reasoning task) and a potential theoretical vehicle (i.e. DPTs) by which to resolve this conundrum and through which psychological science can drive the study of creativity to greater heights.

A motivating factor for the choice of problem to study, paradigm to use, and the theoretical perspective adopted is that an abundance of evidence exists that allows a priori predictions regarding the experiments at hand. Specifically, I predict that identifying creative cross-domain analogies will require greater analytic thought than the identification of non-creative within-domain analogies, thus supporting characterizations of relatively more executive processing yielding relatively greater creative output. As I noted above, there are many conflicting reports regarding the role of Type 2 processing in creativity. Accordingly, rather than merely point to the creativity studies that support my theoretical predictions (and ignore those that go against it), I will instead selectively review a novel combination of evidence from memory and reasoning research to support my prediction. That is to say, I will inform my predictions regarding complex creativity on the basis of work not traditionally from the domain of creativity, as the waters of creativity seem too muddy to glean a clear view of what lies below to give an unbiased estimation of what to expect.

Mind, Memory, and Making Connections

An important aspect of understanding the way in which one fuses concepts on the basis of underlying common relations comes from a characterization of the nature of semantic memory. Semantic memory is described as our long-term inventory of knowledge about the world (Tulving, 1972), including information about categories, features, and the complex inter-relations that exist between them (Murphy & Medin, 1985). Important developments in recent years regarding the structure (see McRae & Jones, 2013, for a review) and neurobiology of semantic memory (see Binder & Desai, 2011, for a review) have illuminated a rich, inter-connected network that underlies the representation of knowledge integral to nearly all psychological phenomena. When one activates a concept in long-term memory, emotional, sensory and motor regions that correspond to the features of that concept become active, as do what Binder and Desai (2011) call ‘convergence zones’; regions in which these modality-specific systems come together to enable the sorts of higher-order, abstract, supra-modal representations that enable cognitive feats of the sort that humans alone seem to enjoy. Such a characterization is supported by the plausibility and utility of recent neurocomputational simulations that rely on semantic pointers, which are defined as activity patterns of spiking neuron populations that function as condensed representations via the binding of distributed patterns of activation (see Eliasmith, 2013).

Such work seems to at least begin to offer an account for the fusion of features that comprise individual concepts, but much more remains to be known about the way that meaningful connections between such representations are made. Some behavioural and neuroscientific evidence does exist on the nature of relations between concepts in semantic memory despite years of such relations often being treated as tacit connections between conceptual nodes in a network (see Spellman, Holyoak & Morrison, 2001). It is becoming clear that relations are not mere passive conduits for activation, but instead are meaningful components of semantic organization themselves. For example, it has been demonstrated that causal relations are distinct from more general associative relations both behaviourally (Fenker, Waldmann & Holyoak, 2005) and neurologically (Satpute et al., 2005) and it has been advocated that further research explore the unique representational structures of the many diverse relations that exist between concepts in semantic memory (see McRae, Khalkhali & Hare, 2012).

Although arguments that semantic relations are a type of important structured concept are gaining traction, it is also clear that relational information does not spread in semantic networks in a way analogous to that seen by object concepts, or other more singular representations. For example, conceptual/semantic priming (e.g. Neely, 1977), the classic finding of facilitated processing of one concept following prior exposure to a related concept, unfolds in a ballistic and effortless fashion via spreading activation mechanisms. Relational, or analogical priming (e.g. presentation of Bear-Cave facilitating subsequent processing of Bird-Nest), on the other hand, does not occur in such a way, instead relying on an appropriate strategic set (Spellman, Holyoak, & Morrison, 2001). Specifically, participants must note and use the semantic relations in order to see any evidence of analogical priming and, as such, is thought to occur due to a mixture of controlled and automatic processes/factors. Put simply, priming based on first-order surface similarity seems to unfold autonomously, relative to second-order relational priming, which seems to require executive engagement of WM systems. Given this, it seems unlikely to me that relational connections, of the sort defined as creative within the chosen analogical reasoning paradigm, will emerge spontaneously via the autonomous operation of Type 1 processing, as the conceptual connection provided by congruence between categories (i.e. within-domain analogies) should instead be the information that spreads relatively more automatically, relegating relational information to the realm of the overridden.

Such a picture of the nature of the underlying representations being accessed is easily tied to the broader sphere of analogical reasoning research. The processes that underlie analogical reasoning are well studied, especially the mapping process thought to occur when reasoners find relational correspondences between potentially superficially dissimilar objects (e.g. Gick & Holyoak, 1980; Gentner, 1983; Hummel & Holyoak. 1997). It is clear that the process of identifying common relational structure is aided by surface similarity of the sort described earlier, and exemplified by our within-domain analogy items. A series of clever priming experiments has shown that for within-domain analogical reasoning, category information is automatically activated when identifying analogies, despite this information not being integral to judgment (i.e. analogical judgment need only consider relational, not surface similarity) but relational information is not automatically activated when judging the same stimuli for category information (Green, Fugelsang & Dunbar, 2006; Green, Fugelsang, Kraemer & Dunbar, 2008). Given that Spellman, Holyoak & Morrison (2001) only observed analogical priming when participants noted and made use of the relations between word pairs, it seems reasonable that this dissociation reflects the notion that unlike category information, which can spread autonomously, conscious attention is needed to activate relational information. In other words, Type 1 processing seems more amenable to facilitating the identification of surface similarity rather than relational similarity, and accordingly suggests that cross-domain analogies, in which there is incongruence in relational and surface similarity, should be more reliant upon Type 2 processing. One must proactively inhibit or retroactively override the automatic response generated as a consequence of superficial similarity in order to arrive at the requisite, relationally relevant response.

A final piece of the puzzle for my predictions herein pertains to DPTs of cognition, and the type of processing thought most often engaged. Evans and Stanovich (2013) advocate a default-interventionist form of DPTs, in which it is presumed that humans are cognitive misers, who tend to only sparingly engage analytic reasoning, and it is this theoretical perspective that I adopt here. In their words: “rapid autonomous processes (Type 1) are assumed to yield default responses unless intervened on by distinctive higher order reasoning processes (Type 2)” (Evans & Stanovich, 2013, p. 223). Such a perspective is supported by decades of reasoning and decision-making work focused on the ways in which human reasoners often fall short of optimality through their decision to allow Type 1 processing to guide most choices and solve most problems (see Kahneman, 2011). A classic finding is that people tend to substitute easier questions in lieu of more difficult ones. In the current context, given that category information (i.e. surface similarity) is relatively more easily processed than relational information (i.e. relational similarity), it seems that one should predict that a cognitive miser would be more inclined to rely on the former, as it would come to mind more easily, leading to lessened identification of deeper meaningful relations between the constituent pairs.

In order to accomplish the stated aim of utilizing a DPT perspective to better understand complex creativity, I will describe studies that in turn vary the conditions of the general paradigm described above to promote or discourage analytic thinking (Experiments 1 & 2), explicitly cue people to think analytically (Experiment 3), explicitly cue people to think both analytically or intuitively while measuring long-term individual differences in analytic thinking style (Experiment 4), and finally, consider individual differences in analyticity in a broader array of tasks thought to index diverse aspects of creativity (Experiment 5). This dissertation is a selective sample of studies from a broader program of research. Many of the findings have been subject to replication and extension in other work. After reviewing the included studies, I will then attempt to analyze and re-combine the evidence pertaining to executive intervention in creativity to provide a clearer picture of the cognitive underpinnings of complex creativity and suggest how we may cultivate it.

Experiment 1

In Experiment 1, I aimed to test my central prediction that creative cross-domain analogical reasoning would be relatively more dependent upon Type 2 processing than less creative within-domain analogical reasoning. To do so, I used a rather heavy-handed experimental manipulation designed to limit the ability of participants to engage in WM dependent processing while attempting to ascertain whether the presented items did indeed form an analogical relation and looked at the relative accuracy of the different stimulus types.

In previous work using these stimuli (e.g. Green et al., 2012), all 4 components of the analogies were presented simultaneously and remained on screen together until response and performance was uniformly high (Overall Accuracy = 93.21%; participants were also cued to think a certain way on some trials, but that is not of interest yet). Furthermore, norming studies obtained 90+% agreement as to the classification of these analogies suggesting that participants can extract relational information from these stimuli when presented simultaneously and participants were not advised to go as quickly as possible while still being accurate. In the current study, the A:B pair appeared for a brief period of time (1000 ms) before it was replaced by the C:D pair, which remained on screen until response (i.e. stimulus onset asynchrony of 1000 ms). Critically, such a manipulation limits participants' ability to simultaneously view the A:B and C:D pairs while assessing whether an analogical relation exists between them. I predict that forcing one to hold the A:B pair in WM will limit the ability to identify the cross-domain analogies, as under my view, Type 2 processing, which is WM dependent, is critical for correct identification of the underlying common relation. In other words, the structures and processes that subserve holding the A:B term in WM will be shared with those structures and processes that are used to determine whether the A:B and C:D pairs are analogously related. Accordingly, I predict that performance will be markedly worse than in previous experiments (e.g. Green et al., 2012) and, in conjunction with my speeded instructions, might potentially prove to be very disruptive to this process.

Importantly, if creative analogical reasoning is more dependent upon Type 2 processing, this hypothesized decrement to performance as a function of the presentation parameters should be more pronounced for cross-domain than within-domain analogies. My logic for this prediction is rooted in the fact that the congruent surface and relational similarity in within-domain analogies will allow participants to find the common underlying relation between the representations in a relatively more intuitive fashion. Conversely, because the relations comprising cross-domain analogies do not share surface similarity, more in-depth (and WM demanding) processing should be required to correctly identify an analogy. Likewise, I anticipate that accuracy in rejecting non-analogies will be lower for the within-domain pairs, as the surface similarity should lead participants to more often mistakenly presume an analogical relation in such a design. Another way to frame the same prediction is that the further semantic distance on cross- relative to within-domain analogies takes more effort to traverse, and requires more WM dependent resources. For the non-analogies, the closer proximity in semantic space for within-domain analogies should make them relatively more difficult to correctly reject than cross-domain analogies. Put another way, because the constituent pairs of within-domain non-analogies are more likely to share features and semantic space at the representational level than those composing cross-domain non-analogies, a sense of relatedness will be experienced despite no underlying analogical relations, which should serve to make correctly ascertaining that no analogy exists more difficult. In cases of true analogies, the representational overlap should facilitate acceptance and in non-analogies this same shared semantic space should make rejection relatively more difficult. To put these predictions into statistical terms, I anticipate a significant interaction between Domain and Validity, such that under these conditions within-domain analogies will be easier to identify than cross-domain analogies, but within-domain non-analogies will be less often correctly rejected than are cross-domain non-analogies.

A more general prediction, common to all of the speeded analogical reasoning tasks employed here, is that within-domain analogies should take less time to identify than cross-domain analogies, for the same reasons listed above.

Experiment 1 Method

Participants

42 undergraduate students (29 females, M_{age} = 20.4 years, SD = 1.36) participated in this experiment in exchange for course credit. One participant was removed for responding ‘yes’ on all trials. No special criterion for participation was required beyond normal or corrected to normal vision and fluency in English. This study, and all the others reported in this thesis, was reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo.

Materials/Procedure

Participants were presented with 120 four-word sets of the form A:B::C:D (40 each of within and cross-domain analogies and 20 within and cross-domain non analogy pairs) and were asked to judge if an analogical relation existed between the word pairs (see Appendix A for a complete list of stimuli). Order of item presentation was randomized. Importantly, examples of each stimulus type and the correct response were shown in instructions to ensure that all participants understood the nature of the task (i.e. that an analogy is not determined by surface similarity but rather depends on a common underlying relation between the word pairs). Participants were told to make their judgments (yes or no), via key-press (‘c’ for yes, ‘n’ for no), as quickly as possible while still being accurate. A blank screen appeared for 500 ms (i.e. 500 ms inter-trial interval; I.T.I.), followed by a central fixation for 500 ms. The A:B pair was then centrally presented for 1000 ms before being replaced by the C:D pair, which remained on screen until response.

Experiment 1 Results

Any trials that were more than 3 standard deviations above a participant’s mean response time (RT) for a given stimulus type, or trials less than 200 ms, were considered an outlier and excluded from further analysis, resulting in the removal of less than 1% of trials. Unless otherwise stated, RT refers to correct trials only.

Figure 1 presents the mean accuracy data as a function of Domain and Validity, and Figure 2 presents the analogous RT data. A 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) Analysis of Variance (ANOVA) on the accuracy data revealed a main effect of Domain (F (40) = 36.30, p < .001, $\eta_p{}^2$ = .48), no main effect of Validity (F < 1), and a significant Domain × Validity interaction (F (40) = 80.59, p < .001, $\eta_p{}^2$ = .67). All ANOVAs are reported in full in Appendix B. More specifically, as anticipated, the presentation manipulation massively and selectively disrupted performance in identifying cross-domain analogies (Mean accuracy = 52.6%, SD = 20.5) relative to within-domain analogies (Mean accuracy = 89.3%, SD = 10.0), t (41) = 11.28, *SEM* = 3.15, p < .001. Also as predicted, ability to reject non-analogies was much worse for within-domain items (Mean accuracy = 64.0%, SD = 21.1) than for cross-domain analogies (Mean accuracy = 80.2%, SD = 20.9), t (41) = 4.44, *SEM* = 3.56, p < .001.

Experiment 1 Accuracy

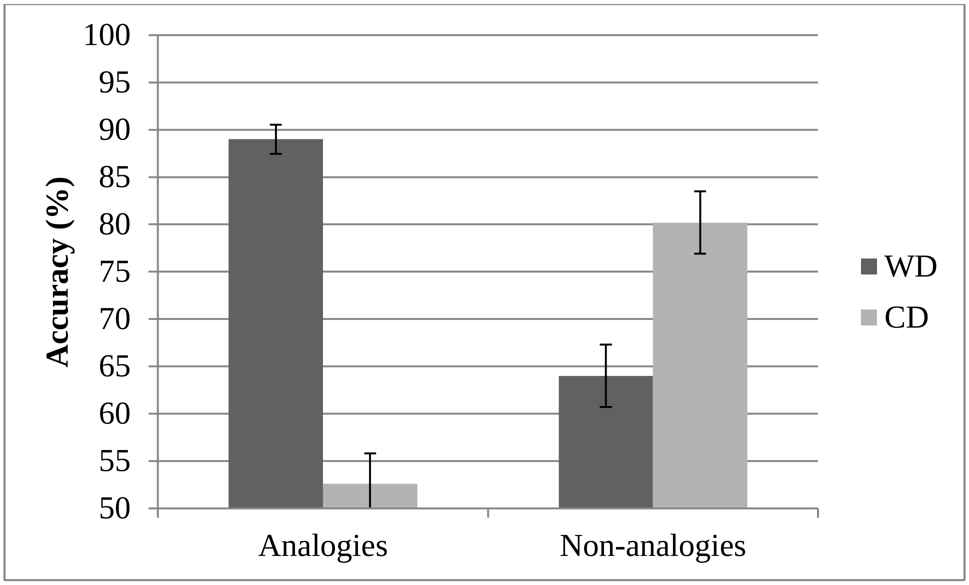

Figure 1. Accuracy as a function of Domain and Validity. The error bars for this figure (and for all remaining figures) represent the standard error for each condition. In this figure (and for all remaining figures) WD = Within-domain, CD = Cross-domain.

Experiment 1 RT

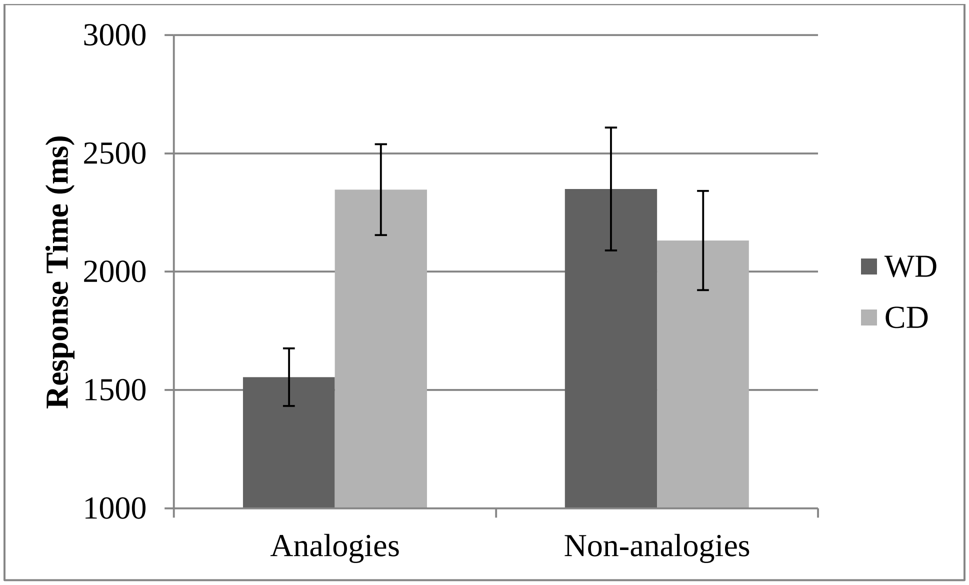

Figure 2. RT as a function of Domain and Validity.

In an analysis analogous to that conducted on the accuracy data, a 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) ANOVA on the RT data revealed a main effect of Domain (F (40) = 15.38, p < .001, $\eta_p^2 = .28$), a main effect of Validity (F (40) = 5.89, p < .05, $\eta_p^2 = .13$), and a significant Domain × Validity interaction (F (40) = 20.10, p < .001, $\eta_p^2 = .33$). RT differences were found in the anticipated direction as a function of domain for valid analogies, with within-domain analogies (Mean RT = 1554 ms, SD = 776) being correctly identified much faster than cross-domain analogies (Mean RT = 2347 ms, SD = 1228), t (41) = 8.20, *SEM* = 94.6, $p < .001$. Correctly rejecting cross-domain non-analogies took less time (Mean RT = 2132 ms, SD = 1343) than correctly rejecting within-domain non-analogies (Mean RT = 2347 ms, SD = 1228), though this difference was not statistically significant, t (41) = 1.32, *SEM* = 164.5, $p = .19$.

Experiment 1 Discussion

Experiment 1 has several findings that are novel and inform the nature of the underlying processes and representations of interest when discussing complex creativity in analogical reasoning. It was found that within-domain analogies were answered much more accurately than cross-domain analogies despite faster overall RTs. We take this as preliminary evidence that cross-domain analogies require more Type 2 processing to comprehend. Although I anticipated this general pattern of results, the impact of the presentation parameters upon creative cross-domain analogical reasoning was even greater than I would have predicted. Many participants were extremely poor at identifying the requisite common relation to understand the cross-domain analogies, despite relative preservation of the ability to identify within-domain analogies. Interestingly, there were large individual differences in the extent of disruption, in that there was a huge range in performance. Some participants were only successful in correctly identifying about one-third of the cross-domain analogies, whereas others were able to identify a majority of these items correctly. Although I cannot speak to the reason behind these differences here, this point will be discussed further in later portions of this thesis when I directly explore the locus of such individual differences in performance. These experimental conditions also led to a large number of errors in identifying non-analogies as valid analogies, specifically in cases in which the constituent pairs were from the same domain. This effect was more pronounced for within-domain non-analogies, further suggesting that when analytic thinking is limited, so is the ability to correctly infer relational information.

Together, these results support my assumption that surface similarity is more amenable to being understood via autonomous Type 1 processing than is relational similarity, and suggest that creative cross-domain analogical reasoning is relatively more contingent upon Type 2 processing, loading on WM dependent resources to a greater extent than the matched within-domain stimuli. It seems clear that relations spanning a greater semantic distance require relatively more executive engagement to connect in a meaningful way, providing a first hint that such complex creativity is reflective of a reasoned, rather than intuitive, connection.

Experiment 2

In Experiment 1, via a manipulation to the presentation parameters that limited the ability to engage Type 2 processing, I selectively impeded the ability of participants to generate the underlying relational structure, thus limiting their ability to make semantically distant connections. In Experiment 2, I modified the presentation parameters again, in order to show that the disparity between our reported accuracy and that observed in other published reports (i.e. Green et al., 2012) was indeed a result of the inability of participants to only view the constituent relations sequentially, and not simultaneously, thus limiting the extent to which Type 2 was directed to ascertaining the underlying relation. The aim of this experiment is, as such, quite simple. Here, I simply structured the experiment to mirror the presentation parameters of 1, with a few exceptions that should increase the extent to which analytic Type 2 processing can be engaged toward identifying relational matches. Specifically, I had participants view the A:B pair in isolation for the same duration as in Experiment 1, but rather than replace the A:B pair, the C:D pair appeared beside, such that participants could now view both of the pairs simultaneously. In an additional, again heavy-handed, effort to induce greater analytic thinking, participants could not make their judgment until they had viewed the pairs together for at least two seconds.

Although I expect improvements over Experiment 1 in cross-domain analogical reasoning, I still expect the general pattern of lowered accuracy and longer RTs for cross-domain, relative to within-domain analogies, which will be taken as further support for the stated predictions.

Experiment 2 Method

Participants

42 undergraduate students (26 females, M_{age} = 20.8 years, SD = 1.18) participated in this experiment in exchange for course credit. No special criterion for participation was required beyond normal or corrected to normal vision and fluency in English.

Materials/Procedure

All aspects of the materials and procedure of Experiment 1 were preserved with the following exceptions. After the blank screen (ITI), a red fixation cross appeared and remained on screen. The A:B pair appeared to the left of fixation for 1000 ms. After that time elapsed, the C:D pair appeared to the right of fixation, and after 2000 ms of simultaneous presentation, the fixation cross changed from red to green. During instructions (which were otherwise identical to Experiment 1) participants were told they could respond only after the fixation cross changed to green. Reported RTs are the time taken from the onset of the C:D pair until response (i.e. these values include the two second period before response was allowed, to better align with the measurement of RT in Experiment 1 and better reflect the time spent processing the pairs).

Experiment 2 Results

Any trials that were more than 3 standard deviations above a participants mean RT for a given stimulus type were deemed an outlier and excluded from further analysis, resulting in the removal of less than 1% of trials.

Figure 3 presents the mean accuracy data as a function of Domain and Validity, and Figure 4 presents the analogous RT data. A 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) ANOVA on the accuracy data revealed a main effect of Domain (F (41) = 112.42, p < .001, η_p^2 = .73), a main effect of Validity (F (41) = 8.3, p < .01, η_p^2 = .17), and a significant Domain × Validity interaction (F (41) = 96.05, p < .001, η_p^2 = .70). As expected, performance in identifying cross-domain analogies was again far inferior (Mean accuracy =

64.6%, SD = 15.5) to performance in identifying within-domain analogies (Mean accuracy = 93.3%, SD = 4.6), *t* (41) = 12.44, *SEM* = 2.31, *p* < .001. Also as predicted, accuracy in identifying non-analogies was worse for within-domain items (Mean accuracy = 82.2%, SD = 12.7) than for cross-domain non-analogies (Mean accuracy = 85.9%, SD = 8.9), *t* (41) = 2.16, *SEM* = 1.71, *p* < .05.

In an analysis analogous to that conducted on the accuracy data, a 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) ANOVA on the RT data revealed a main effect of Domain (*F* (41) = 56.53, p < .001, η_p^2 = .58), a marginal effect of Validity (*F* (41) =

3.27, p = .08, η_p^2 = .07), and a significant Domain × Validity interaction (*F* (41) = 17.12, p < .001, η_p^2 = .30). RT differences were found in the anticipated direction again as well, with within-domain analogies (Mean RT = 2687 ms, SD = 435) being correctly identified faster than cross-domain analogies (Mean RT =3369 ms, SD = 890), *t* (41) = 7.54, *SEM* = 90.5, *p* < .001. Correctly rejecting cross-domain non-analogies took significantly less time (Mean RT = 3127 ms, SD = 1343) than correctly rejecting within-domain non-analogies (Mean RT = 3127 ms, SD = 1058), *t* (41) = 2.16, *SEM* = 77.1, *p* < .05.

Experiment 2 Discussion and Experiment 1 and 2 Comparisons

As expected, we again saw superior performance as a function of domain, whereby the less creative within-domain analogies were more successfully identified, relative to the cross-domain analogies. There was again an effect of domain for non-analogies as well, with cross-domain non-analogies being easier to reject than within-domain analogies. We also replicated our expected RT results, specifically, the primary prediction that cross-domain analogies will take relatively more time to understand due to the incongruence between surface and relational similarity and the greater semantic distance.

In order to understand the implications of the work described thus far, it is useful to contrast performance in Experiments 1 and 2. There was a large difference in accuracy across experiments for cross-domain analogies (12%; Experiment 1 mean accuracy = 52.6% vs. Experiment 2 mean accuracy = 64.6%), but there was also a difference in performance on within-domain analogies across experiments (4.3%; Experiment 1 mean accuracy = 89.0% vs. Experiment 2 mean accuracy = 93.3%). The smaller difference in the latter stimulus type suggests that the impact of having a lessened capacity for the use of Type 2 processing selectively influenced cross-domain analogical reasoning performance. However, in order to properly make such a claim, it is important to identify whether the conditions of Experiment 1 (parameters relatively less conducive to engaging Type 2 processing) selectively hindered cross-domain analogy identification, relative to within-domain analogy identification (parameters relatively more conducive to engaging Type 2 processing) when compared to Experiment 2, or if there was simply a global difference in performance between the two experiments as a function of the differences in design. Evidence for such a selective influence account would come from the presence of an Experiment × Domain interaction. If no such interaction exists, one could argue that the differences in parameters generally decreased performance in any sort of reasoning. As such, I conducted a 2 (Experiment: Experiment 1, Experiment 2) × 2 (Domain: Cross-domain, Within-domain) mixed ANOVA and found main effects of both Experiment (F (1, 81) = 11.66, $p < .01$, $\eta_p^2 = .13$), and Domain (F (1, 81) = 285.26, $p < .001$, $\eta_p^2 = .78$). Critically, there was indeed a significant Experiment × Domain interaction (F (41) = 4.01, $p < .05$, $\eta_p^2 = .05$), supporting the suggestion that parameters meant to reduce Type 2 processing selectively hindered performance on creative cross-domain analogies, relative to within-domain analogies. In other words, although the parameters of Experiment 1 reduced performance in identifying both types of analogies relative to Experiment 2, this decrement was especially large for cross-domain analogies.

It is important to note, though, that depending on one's perspective, there are several factors that might preclude my analyzing Experiments 1 and 2 in such a way. For one, they were not run as such, and were completed in different terms. Secondly, there are large differences in the variance between these task variants that would violate some assumptions of the ANOVA. However, given the roughly equal sample size and the a priori interest in contrasting performance, I made comparisons that converge with the analysis conducted above which should quell any concerns of more conservative statisticians. Specifically, I elected to contrast performance in each stimulus sub-type as a function of variant, to illuminate the extent to which each sub-type was affected by the relative changes in condition. Importantly, these analyses can be attuned to address the heterogeneous variance (Levene's Test for Equality of Variances was significant for all four comparisons; performance on Experiment 1 was much more variable) through the Welch-Satterwaite method, which increases the conservatism of the test by adjusting the degrees of freedom as a function of the relative inequality of variance. Thus, the subsequent analyses will feature these adjusted degrees of freedom and should afford some insight into the relative differences across tasks while avoiding contention about the suitability of the previously reported ANOVA.

Though there was a difference in cross-domain non-analogy performance as a function of task, with accuracy on Experiment 1 (Mean accuracy = 80.2%, SD = 20.9) being lower than that seen in Experiment 2 (Mean accuracy = 85.9%, SD = 8.9), t (53.743) = 1.61, SEM = 3.54, $p >$

.05, this difference was statistically not significant. For within-domain analogies there was a significant, but relatively slight difference between performance in Experiment 1 (Mean accuracy = 89.0%, SD = 20.9) compared to Experiment 2 (Mean accuracy = 93.3%, SD = 4.6), t (56.073) = 2.49, *SEM* = 1.71, $p < .05$. For the two stimulus types in which the surface similarity conflicted with the relational information (i.e. the semantically distant analogies and the semantically near non-analogies), however, a marked difference in accuracy was evident. The ability to correctly reject the within-domain non-analogies was significantly hindered in the sequential presentation conditions in Experiment 1 (Mean accuracy = 64.0%, SD = 4.6) relative to the simultaneous presentation conditions in Experiment 2 (Mean accuracy = 82.2%, SD = 12.7), t (65.524) = 4.76, *SEM* = 3.83, $p < .01$. Similarly, the ability to correctly find the relational connection in cross-domain analogies was severely hindered in Experiment 1 (Mean accuracy = 52.6%, SD = 20.5) relative to Experiment 2 (Mean accuracy = 64.6%, SD = 15.5), t (74.329) = 3.00, *SEM* = 4.00, $p < .01$. Additionally, I ran two one-sample *t*-tests to determine whether performance for cross-domain analogies was greater than chance (i.e. 50%) in these two variants. In Experiment 2, participants did perform significantly better than would be expected by chance, t (41) = 6.12, $p < .001$, but performance in Experiment 1 was not different than what would be expected if participants were simply guessing, $t < 1$, strongly supporting my supposition that sequential presentation severely limited the WM resources that are required for the cross-domain analogies and underscoring the necessity of executive involvement in the extraction of underlying relational information. This pattern of results strongly supports a view in which the ability to span the semantic distance required to link the constituent pairs is strongly hindered when WM resources are dedicated to holding the A:B pair constant, supporting my hypothesis that Type 2 thinking is integral to creative analogical reasoning. It also suggests that closer proximity in semantic space can mislead one to identify a non-existent relation.

If it were the case that the manipulation employed in Experiment 1, which was designed to limit the amount of Type 2 processing, simply hindered the ability to do any type of analogical reasoning, one would have expected similarly sized decrements in within-domain analogies. The notion that the cause of the sharp drop in performance is less Type 2 processing is supported by the following pattern. In Experiment 1 there were positive correlations between accuracy in identifying cross-domain analogies and RT for correct, $r(40) = .34$, $p < .05$, and incorrect trials of that type, $r(41) = .62$, $p < .001$. Such relations were not significant for Experiment 2, in which all participants were forced, for at least several seconds, to view the pairs simultaneously, thus reducing variance in individual differences in Type 2 engagement; $r(40) = -.23$, $p = .15$ and $r(41) = .17$, $p = .28$, for the relation between accuracy and correct and incorrect trial RTs respectively. I take this to suggest that those who did the best in Experiment 1 were those who were both willing and able to maintain the A:B pair and map the relational correspondences. Those who went quickly and relied on the autonomous, Type 1 stream of processing for response performed relatively poorly. No such correlation existed for the relation between RT and accuracy for within-domain analogies and RT on correct and incorrect trials of that type (p's of .67 and .81 respectively), again qualifying that the need for Type 2 processing is not general to this sort of reasoning, but specific to the semantically distant cross-domain analogical reasoning.

Comparing my results to Green et al.'s (2012) results is also supportive of my interpretation, as the accuracy in cross-domain analogical reasoning was much, much poorer (52.6% & 64.6%) than their observed accuracy (90+%), whereas our average accuracy for within-domain analogical reasoning was similar (both approximately 90%). The primary difference between our tasks, beyond the presentation manipulations and a cuing procedure used by Green et al. (2012) that I will discuss in the next section, is that participants in my sample were instructed to go “as quickly as possible while still being accurate” whereas no such admonishment was made to their participants. Green et al.’s (2012) participants took, on average, approximately 5500 ms to correctly identify cross-domain analogy trials, whereas my participants took only 2347 ms in Experiment 1 and 3369 ms in Experiment 2. Presumably, in those extra few seconds, participants were analytically mapping the relational correspondences via WM dependent processes, leading to the much better accuracy. Recall too, that in norming studies, participants nearly unanimously agree as to the validity classification of these stimuli, meaning it is not the case that these relations are impossible to understand -- rather, so long as you can and do engage Type 2 processing sufficiently, you will find the common underlying relation. Taken as a whole, these experiments support the notion that creative cross-domain analogies require relatively more Type 2 processing, and show the utility of the general paradigm, and set the stage for further experimentation.

Experiment 3

In Experiments 1 and 2, I took a classically cognitive psychological approach by modulating performance in the task at hand by manipulating the presentation parameters within the study. Specifically, I controlled the extent to which participants could engage Type 2 processing, and analyzed which sub-types of the stimuli used were relatively more adversely affected by these manipulations. This investigation was illuminating in regards to the types of processing connected to within and cross-domain analogies respectively, with the results clearly suggesting that creative connections of the sort of interest here are dependent upon the engagement of Type 2 processing, relative to items that have the same relational structure but are more semantically near and bound by surface similarity. Although quite helpful in understanding the types of underlying processes that subserve such reasoning, it is at best indirect in terms of helping us go about cultivating creativity. That is, although the former experiments give us some clues as to what processes underlie complex creativity and the sorts of conditions that preclude this ability, I have yet to say anything about how best to encourage or enable people to more effectively identify such connections. The purpose of Experiment 3 is to explore whether one can cue creativity, in a moment-to-moment basis. Such an investigation will both add to the conceptual understanding of the cognitive processes that potentiate complex creativity, and perhaps begin to allow intervention aimed at enhancing the ability to identify relationally complex creative connections.

The logic of Experiment 3 is quite simple. Under a default-interventionist DPT perspective, people tend not to routinely engage such processing unless required and rather rely on the output provided by autonomous Type 1 processes. In the context of the speeded analogical reasoning task employed here, there are several aspects of the setting which lend themselves to not engaging Type 2 processing over and above the experimental manipulations, including the standard instruction to “go as quickly as possible while still being accurate”, the number of trials, and the general testing environment. Given this, as well as the findings of Experiments 1 and 2, which suggest that an integral part of identifying cross-domain analogies is the engagement of Type 2 processing, it seems that an instructional manipulation might be quite effective. Specifically, I am curious as to what the consequence would be of an instruction to think more deeply and engage Type 2 processing? Given that the situational and instructional set seem to favour autonomous responding, I wondered whether admonishing participants to think more analytically about certain items would induce greater ability in identifying cross-domain analogies. In other words, I aim to test whether one can be instructed to more often engage Type 2 processing as a means of improving performance.

A recent study already cited here (Green et al., 2012), provides a useful template for testing this idea. These authors used the precise stimuli used here and directly explored whether intra-experimental cues could modulate performance in making creative connections. Participants engaged in the analogical identification task used here (all 4 terms presented simultaneously), but on half of the trials (randomly inter-mixed, not blocked) a cue indicated that they “should think more creatively”. They found that the cue to think more creatively did enhance performance on cross-domain analogical reasoning. Importantly, this increase was not due to a more liberal response criterion (i.e. the creative cue did not lead to greater endorsement of non-analogies as valid) suggesting that participants were indeed seeing connections they otherwise would not. Despite demonstrating than an explicit cue could be effective at enhancing creativity, these authors said little about why such a cue might have been effective at a cognitive processing level. Given the previously discussed experiments and the findings that support a view in which relatively greater Type 2 processing is beneficial to the identification of cross-domain analogies, I wondered whether inducing participants to more analytically decompose the relations (i.e. engage in relatively more Type 2 processing) would improve identification rates. Such an interpretation is consistent with Green et al.'s (2012) finding that along with an increase in accuracy as a function of the cue, participants had longer RTs on cue trials compared to non-cue trials. If participants were responding relatively more intuitively or heuristically (i.e. via relatively more Type 1 processing) in an effort to be more creative, one might expect faster RTs on cue trials.

Although it is valuable to know that such creativity can be modulated at the state-level, especially via a manipulation as simple as advising one to think more creatively, for such interventions or instructions to have a broader meaningful impact, it is necessary to understand what the mechanisms are that underlie such a benefit. As such, the focus of this experiment is to discern whether a cue to think more analytically can enhance performance. If a cue of this sort could effectively enhance cross-domain analogical reasoning, this would constitute a possible means by which to enhance creativity in a manner that is inspired by low-level mechanistic evidence regarding the underlying cognitive processes involved. If the increased involvement of Type 2 processing as a function of the cue is of decrement to the processes that subserve the understanding of cross-domain analogies, then participants should perform more poorly on cue trials, relative to no cue trials. If the relative degree of Type 1 vs. Type 2 processing is unimportant, or insensitive to pointed instruction, such a cue should be of no consequence.

Experiment 3 Methods

Participants

63 undergraduate students (44 females, M_{age} = 20.4 years, SD = 1.40) participated in this experiment in exchange for course credit. No special criterion for participation was required beyond normal or corrected to normal vision and fluency in English.

Materials/Procedure

The stimuli and general instructions from Experiments 1 and 2 remained the same, though the sequence of trial presentation was such that following fixation, the four terms for each trial appeared on screen together and remained there until response, rather than a sequential presentation as done before. Additionally, on half of the trials, participants were instructed to “think more analytically” (this was counterbalanced such that equal numbers of each stimulus sub-type received a cue or no cue. The nature/implementation of such a cue was modelled directly after the procedure of Green et al. (2012) with color serving as the means by which to alert participants as to the manner in which they should engage each trial. Specifically, on half of the trials, the four word sets were purple and on the other half were green. Participants were told: “When the words appear in green, think more analytically about whether the four-word set constitutes a valid analogy.” The only change here in the nature of the cue and the procedure from Green et al. (2012) is the substitution of the word “analytically” for the word “creatively”. It is also important to recognize that participants were not advised to think in a particular way on no cue trials, rather being left to adopt the processing style of their preference.

Experiment 3 Results

Any trials that were more than 3 standard deviations above a participant’s mean RT for a given stimulus and cue type were deemed an outlier and excluded from further analysis, resulting in the removal of less than 1% of trials.

Figure 5 presents the mean accuracy data as a function of Domain, Validity, and Cue, and Figure 6 presents the analogous RT data. A 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) × 2 (Cue: Analytic cue, No cue) ANOVA on the accuracy data revealed a main effect of Domain (F (62) = 92.76, p < .001, $\eta_p{}^2$ = .60), no main effect of Validity (F <1), and no main effect of Cue (F <1). There was a significant Domain × Validity interaction (F (62) = 70.11, p < .001, $\eta_p{}^2$ = .53), and a marginal Validity × Cue interaction, (F (62) = 3.12, p = .08, $\eta_p{}^2$ = .05). The Domain × Cue interaction, and the three-way interaction were both not significant (F <1 and F =1.87, respectively). Direct comparisons of each stimulus sub-type as a function of cue reveal no significant effects, though there was a slight trend toward greater identification of cross-domain analogies in the cue condition (Mean = 72.67, SD = 15.8) relative to the no cue condition (Mean = 70.87, SD = 19.0), t (62) = 1.15, *SEM* = 1.55, p = .25, and performance in rejecting the cross-domain analogies was marginally worse in the cue condition than in the no cue condition t (62) = 1.80, *SEM* = 2.19, p = .08.

Again, the same analysis conducted on the accuracy data was performed on the RT data. The 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) × 2 (Cue: Analytic cue, No cue) ANOVA yielded a main effect of Domain (F (62) = 56.70, p < .001, $\eta_p{}^2$ = .48), a main effect of Validity (F (62) = 22.15, p < .001, $\eta_p{}^2$ = .26), and no main effect of Cue (F <1). There was a significant Domain × Validity interaction (F (62) = 70.11, p < .001, $\eta_p{}^2$ = .53), and a Validity × Cue interaction, (F (62) = 70.11, p < .001, $\eta_p{}^2$ = .53). Though the Domain × Cue interaction, and the three-way interaction were both not significant (both *Fs* <1), the Domain × Validity interaction, (F (62) = 41.38, p < .001, $\eta_p{}^2$ = .40), and Validity × Cue, (F (62) = 41.38, p < .001, $\eta_p{}^2$ = .40), interactions were significant. Direct comparisons of each stimulus sub-type as a function of cue revealed that for both within- and cross-domain analogies, there was no

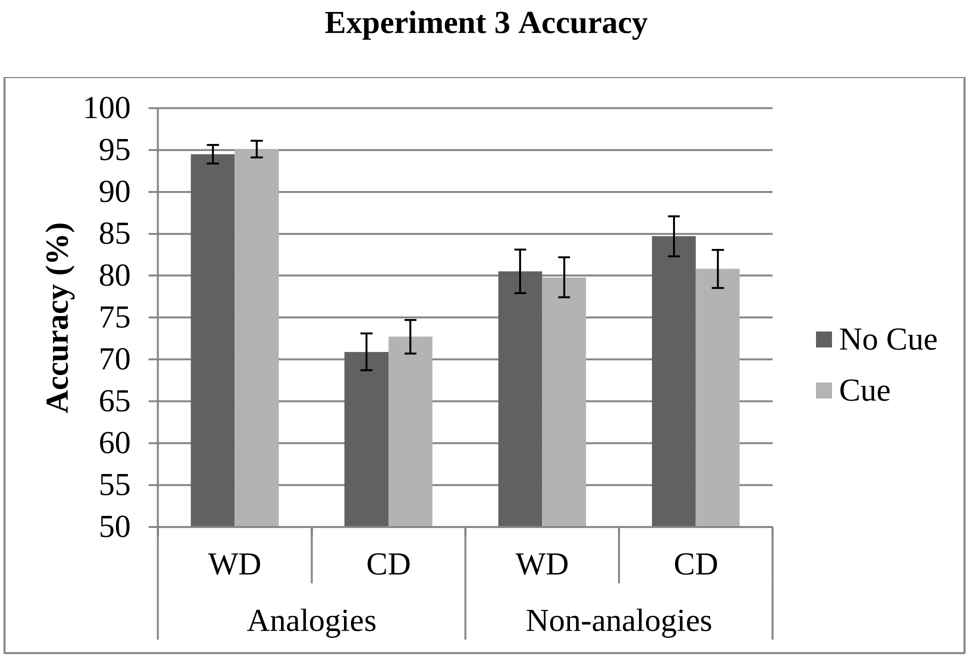

Figure 5. Accuracy as a function of Domain, Validity, and Cue.

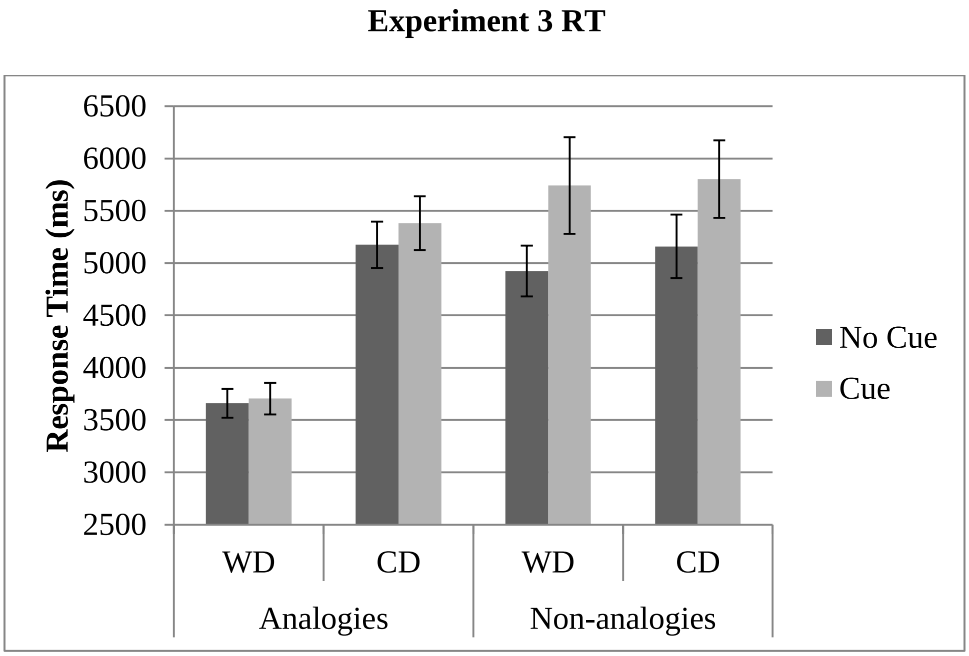

Figure 6. Accuracy as a function of Domain, Validity, and Cue.

significant increase in reaction time, *t* < 1 and *t* (62) = 1.53, *SEM* = 133, *p* = .13, respectively. There was a slight trend toward longer RTs on cue trials for both types (mean increases of 46 and 204 ms respectively) but there was great variability in the size of this RT difference as a function of cue (SDs of 687 and 1057 ms respectively). On non-analogy trials, participants did take significantly longer to respond on cue trials for both within- and cross-domain non-analogies (mean increases of 818 and 644 ms respectively), *t* (62) = 2.84, *SEM* = 288, *p* < .01 and *t* (62) = 2.67, *SEM* = 241, *p* = .01.

Experiment 3 Discussion

My attempt to mimic the effects of Green et al.'s (2012) cue to think more creatively was unsuccessful. These results were not in accord with my hypothesis that being told to "think creatively" was leading to greater engagement of Type 2 processing in their sample. There was no increase in the number of cross-domain analogies correctly identified on cue trials, relative to no cue trials, and we also did not see an increase in RT for cue relative to non-cue trials for this stimuli type, as observed by Green et al. (2012). Also, unlike Green et al. (2012), we saw a trend (though not statistically significant) whereby participants erroneously endorsed more cross-domain non-analogies as valid when told to think more analytically. The incongruence between our hypothesized results and what was found by Green et al. (2012) seem puzzling in the context of the previous experiments I report here. Specifically, if it is the case that Type 2 processing is critical to identifying cross-domain analogies, as evidenced by the effect of the manipulations we made, then why did telling participants to "think more analytically" on some trials not afford participants an advantage? Does this mean that I should abandon my predictions and theoretical position? I believe not for the following reasons.

For one, it is worth considering the relative size of the cuing effect elicited by Green et al. (2012). In their experiment, accuracy on cross-domain analogies for no cue trials was 91.66%, compared to 94.53% for cue trials, resulting in a benefit of 2.87%. In my experiment, accuracy on cross-domain analogies for no cue trials was 70.87%, compared to 72.66% for cue trials, resulting in a benefit of 1.79%. Translating these percentage increases into the actual benefit into the number of cross-domain analogies identified, participants in Green et al.'s (2012) experiment answered, on average, approximately 0.57 more analogies in the cue than in the no cue condition (there were 20 cue trials and 20 no cue trials for this stimulus type), and in my experiment, participants solved approximately 0.36 more. This means that relative to our data, participants in their experiment solved 0.11 more cross-domain analogies in the cue condition. Given the lessened variability (compared to performance in Green et al.'s (2012) experiment, my experiment had much lower accuracy and more variability), and the slightly larger increase, their experiment found a statistically significant cuing effect, whereas mine did not. Thus, although Green et al.'s (2012) "data [do] indicate that an explicit cue to think creatively was able to effectively augment reasoning for semantically distant analogies" (p. 602), as there was a statistically significant effect, it is sufficiently small that in conjunction with our results, I am, at this juncture, reticent to believe that explicit cuing of this sort is sufficiently impactful to meaningfully facilitate processing in more ecologically valid settings. Green et al. (2012) acknowledge that their effect is a small one, pointing to the ceiling effect caused by the use of gifted students, and ponder whether other populations that exhibit lower overall performance would receive greater benefit from the cue. Our data revealed that this was not the case, at least with this sample, as despite our overall accuracy being significantly lower, we did not see a relative increase in the size of the cuing effect on the stimuli of primary interest.

So, although the results demonstrated that the cue to “think more analytically” was statistically ineffective at enhancing performance, this experiment was not a waste as knowing this is valuable for understanding the underlying processes that allow such abilities. This data set also had another piece that I think consequential for the matters at hand, as further inspection of the pattern of results across cue types hints at a factor consequential to cross-domain analogical reasoning ability. I analyzed the relation between performance on cue and no cue trials for all stimulus types at the individual level and found positive correlations for all cells. In other words, I looked to see how strongly related an individual’s performance was on cue trials to no cue trials. Strikingly, a correlation of $r(61) = .71$, $p < .001$, was observed for performance on cross-domain analogy cue trials and no cue trials. Given this strong relation, and the relatively minimal effect of the cue, it seems reasonable to presume that stable individual differences (i.e. the trait level) in the ability to make such connections are of greater consequence than are any benefits afforded by explicit cues to think a certain way (i.e. state level).

Thus, one means of understanding the null results in this experiment, that is strongly grounded in reasoning research and DPTs, is that long-term dispositions in the extent to which participants engage in Type 2 processing is driving much of the difference in performance, and is sufficiently influential so as to hinder our ability to directly modify processing style on demand via an explicit cue. Given that we know meaningful individual differences exist in the relative proclivity to engage in Type 2 processing (e.g. Stanovich, 2009), and that there was great variability in the effect of the cue, it stands to reason that these individual differences should interact with explicit cues to engage in a particular sort of processing. Another potential source of variability is the manner in which people of varying cognitive styles respond to instructions to think a certain way. This is especially true given the previous design, as the baseline no cue condition contained no hint as to how one should respond on those trials.

Given the known individual differences in the extent to which one thinks analytically, the null results of Experiment 2, the strong correlation between individual performance on cue and no cue trials, and the myriad possibilities for how such individual differences will interact with cuing instructions, an important part of understanding how to cue creative thinking comes from qualifying this relation. As such, Experiment 4 will again have participants receive a cue to think a certain way, and I will collect information pertaining to participants' long term dispositions to engage in relatively more or less Type 1 and Type 2 thinking.

Experiment 4

Stanovich (1999; 2004) and other dual-process theorists, distinguish between the *willingness* (i.e. thinking disposition; cognitive style) and *ability* (i.e. intelligence; cognitive ability) to engage Type 2 processes. Importantly, individual differences in the dispositional use of Type 2 processing predict rational performance over and above individual differences in cognitive ability (Stanovich & West, 2000; Toplak, West, & Stanovich, 2011), and it is such differences that are of focus in the remaining experiments. Recall that Type 1 processing is considered autonomous and, as a consequence, the default mode of processing (Evans & Stanovich, 2013). Thus, individual differences in the dispositional use of Type 2 processing (i.e. cognitive style) are thought to exist on a spectrum such that those *more* willing to engage Type 2 reasoning are therefore *less* likely to be influenced by Type 1 processes whereas those who are *less* willing to engage Type 2 reasoning are therefore *more* likely to be influenced by Type 1 processes.

In the context of the current experiment, we were interested in indexing this individual difference and exploring its effects upon explicit cues to think certain ways. Several possibilities exist. For example, it might be the case that cuing a relatively non-analytic thinker to think analytically could be detrimental to reasoning as they might waste valuable WM dependent resources, integral to Type 2 processing, in conscious attempts to alter their cognitive style, or meta-monitoring of their ability to follow the admonishment to think analytically. Conversely, less analytic thinkers might experience relatively greater benefit than others who tend to already engage in relatively more analytic thought, as these participants might already be at ceiling. Little work in the reasoning tradition has employed such direct cues to think a certain way in a speeded task of the sort employed here, and as such, the current experiment is important not only for understanding the creative analogical reasoning of primary interest, but generally informs research on thinking styles and their ability to be modified in an explicit way on a trial-to-trial basis.

Experiment 4 Method

Participants

76 undergraduate students (59 females, M_{age} = 20.3 years, SD = 3.19) participated in this experiment in exchange for course credit. No special criterion for participation was required beyond normal or corrected to normal vision and fluency in English.

Materials/Procedure

The cued analogical reasoning task was nearly identical to that used in Experiment 2, with the exception that rather than only have a cue on half of the trials, all trials were cued; however, the nature of the cue changed. Now, participants were told: “When the words appear in green, think more analytically about whether the four-word set constitutes a valid analogy. When the words appear in purple, think more intuitively about whether the four-word set constitutes a valid analogy.” By introducing such an instructional set, I improve upon both Green et al.’s (2012) and my own previous (Experiment 3) attempts to cue creativity in several ways. For one, rather than leave it to the participants to decide what it means to “think more creatively”, I instead cue them to think particular ways on every trial in hopes of more specifically being able to bind the effects of the cue to underlying cognitive processing mechanisms or styles. It might be the case that some participants think more analytically (i.e. more frequently engaging Type 2 processing) when prompted to think more creatively, whereas others might try thinking more intuitively (i.e. less frequently engaging Type 2 processing), making the locus of any improvements difficult to ascertain. As such, having contrasting cues used on every trial provides a more clear demarcation between trial types than that afforded by a cue vs. no cue comparison, and hopefully will provide slightly more uniformity in the manner in which participants respond to the cue.

In order to glean insight into individual differences in cognitive style, upon completing the analogical reasoning task, participants completed the Rational Experiential Inventory (REI; Pacini & Epstein, 1999). The REI is a self-report index that is comprised of two sub-scales each comprised of 20 questions. The Need for Cognition scale (NFC) indexes the extent to which an individual enjoys and engages in effortful or analytic thinking. The Faith in Intuition scale (FI), indexes the extent to which one is prone to trust one’s first impulses (see Appendix C for the full scale). Although such a scale has a slightly different decomposition (i.e. distinctions amongst the analytic and experiential systems) than that of the DPTs discussed, it, in essence, is thought to index the same types of dispositions.

Experiment 4 Results

Again, any trials that were more than 3 standard deviations above a participant’s mean RT for a given stimulus and cue type were deemed an outlier and excluded from further analysis, resulting in the removal of less than 1% of trials.

Before considering the effects of the cue as a consequence of individual differences, I will analyze the cued analogical reasoning task in isolation. Figure 7 presents the mean accuracy data as a function of Domain, Validity, and Cue, and Figure 8 presents the analogous RT data. A 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) × 2 (Cue: Analytic cue, Intuitive cue) ANOVA on the accuracy data revealed a main effect of Domain (F (75) = 123.98, $p < .001$, $\eta_p^2 = .62$), a main effect of Validity (F (75) = 6.30, $p < .05$, $\eta_p^2 = .08$), and a marginal

Experiment 4 Accuracy

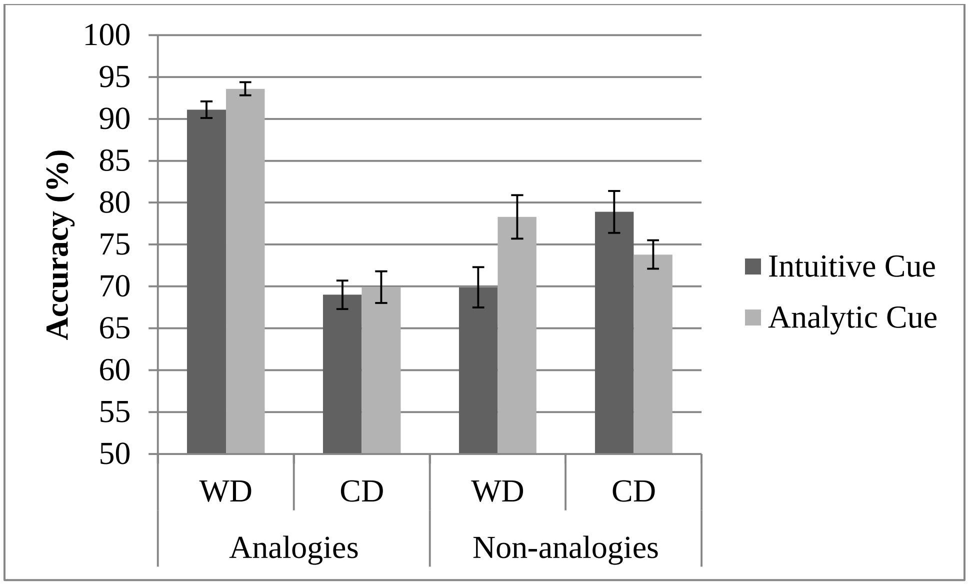

Figure 7. Accuracy as a function of Domain, Validity, and Cue.

Experiment 4 RT

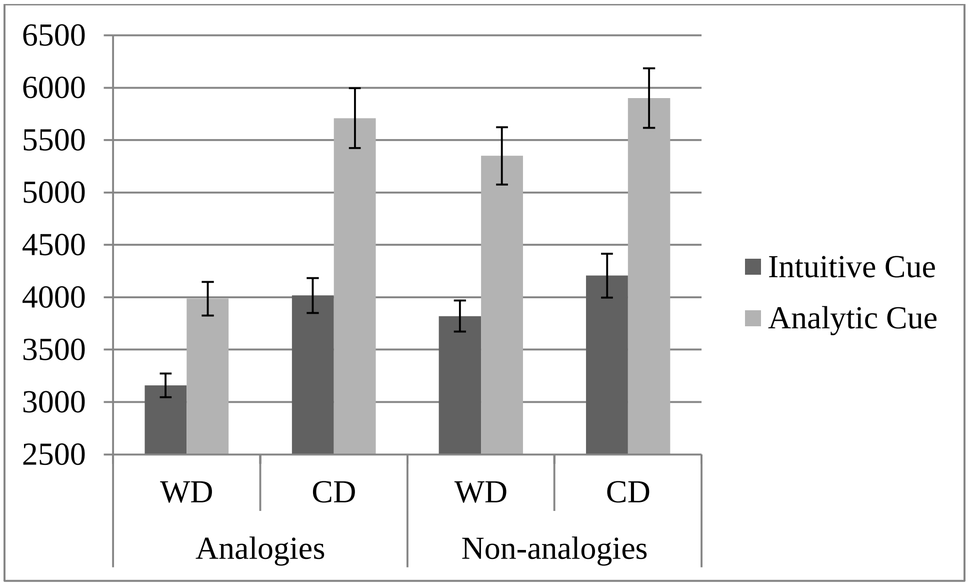

Figure 8. RT as a function of Domain, Validity, and Cue.

main effect of Cue (*F* (75) = 3.18, $p = .08$, $\eta_p^2 = .04$). The Validity × Cue interaction was not significant (F<1). The Domain × Validity, (*F* (62) = 119.62, $p < .001$, $\eta_p^2 = .62$), and Domain × Cue, (*F* (62) = 26.27, $p < .001$, $\eta_p^2 = .26$), interactions were significant, as was the three-way interaction (*F* (62) = 8.78, $p < .01$, $\eta_p^2 = .11$). Direct comparisons of each stimulus sub-type as a function of cue reveal the pattern underlying these effects. For within-domain analogies performance was lower on intuitive cue trials (Mean = 91.1%, SD = 8.3) than analytic cue trials (Mean = 93.6%, SD = 7.3), *t* (75) = 2.69, *SEM* = .93, $p < .01$. A similar advantage was found for within-domain non-analogies, with performance again lower on intuitive cue trials (Mean = 69.9%, SD = 21.1) than analytic cue trials (Mean = 78.3%, SD = 8.3), *t* (75) = 3.60, *SEM* = 2.3, $p < .01$. For cross-domain non-analogy trials, the inverse pattern was found, with performance on intuitive cue trials (Mean = 78.9%, SD = 22.0) being significantly worse than on analytic cue trials (Mean = 73.8%, SD = 15.1), *t* (75) = -2.63, *SEM* = 1.94, $p < .01$. Interestingly, the stimulus sub-type of most interest to the current investigation (i.e. true cross domain analogies) was the only one not to show any difference, with mean accuracy for analytic (Mean = 69.9%, SD = 16.6) and intuitive cue trials (Mean = 69.0%, SD = 15.1) being almost identical ($t<1$). I shall return to explore this finding in more detail later in this section.

Before diving further into these results, and qualifying them in the context of our individual differences measure, I will report the analogous analysis conducted on the RT data. A 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) × 2 (Cue: Analytic cue, Intuitive cue) ANOVA revealed significant main effects of Domain (*F* (75) = 124.33, $p < .001$, $\eta_p^2 = .62$), Validity (*F* (75) = 26.2, p < .001, $\eta_p^2 = .26$), and Cue (*F* (75) = 45.06, $p < .001$, $\eta_p^2 = .38$). All possible interactions were also significant: Domain × Validity, (*F* (75) = 24.29, $p < .001$, $\eta_p^2 = .25$); Domain × Cue, (*F* (75) = 9.68, $p < .01$, $\eta_p^2 = .11$); Validity × Cue, (*F* (75) =

5.13, $p < .05$, $\eta_p^2 = .06$); and Domain × Validity × Cue, (F (75) = 4.74, $p < .05$, $\eta_p^2 = .06$). Although such a pattern seems complicated, the essential facts can be quite succinctly summated as follows. For all stimulus types, analytic cue trials had longer RTs than intuitive cue trials (as evidenced by the main effect of cue). Cross-domain analogies and both non-analogy types had relatively similar increases (all three between 1500-1700 ms) with within-domain analogies, which also had the lowest overall RT, unsurprisingly having a smaller increase on analytic relative to intuitive cue trials (828 ms). Importantly, cross-domain analogies took longer to identify than within-domain analogies at both cue types, consistent with earlier findings.

In terms of individual differences measures, I correlated performance on all trial types and found that FI was not correlated with accuracy for any type. NFC was positively related to accuracy in rejecting, for both cue types, within-domain non-analogies, r (75) = .30, $p < .01$ for intuitive cues and r (75) =.33, $p < .01$ for analytic cues, and in rejecting cross-domain non-analogies, r (75) = .39, $p < .01$ for intuitive cues and $r = .22$, $p = .06$ for analytic cues. NFC was unrelated to success in identification of analogies for either stimulus under either cuing instruction.

I was surprised by two main results, given my theoretical predictions, and some of the data I had collected earlier. Firstly, I had made an a priori prediction that performance in the identification of cross-domain analogies would be superior for the analytic cue trials, relative to the intuitive cue trials. Secondly, I had also predicted that performance on cross-domain analogies would be predicted by the REI. Specifically, I had reasoned that those who are more willing to think analytically (i.e. greater disposition to engage Type 2 processing) and less likely to rely on intuitions (i.e. less reliance on Type 1 processing) would be more likely to correctly identify cross-domain analogies. Given these failures in supporting my hypothesis, I conducted several follow-up analyses to explore whether there was any evidence that would speak to the broader questions at hand.

Importantly, inspired by Cognitive-Experiential Self-Theory (CEST; Epstein, 1973), the two subscales that together comprise the REI are purported to index subtly distinct dimensions pertaining to the issues at hand, through asking questions thought to relate to rational and experiential systems. The NFC is thought to capture variation in thinking style in regards to the extent to which one has rational ability (e.g. "ability to think logically and analytically) and the extent to which they engage that ability (e.g. "reliance on and enjoyment of thinking in an analytical, logical manner"). The FI indexes variation in the extent to which one has ability in inferring experiential states (e.g. "ability with respect to one's intuitive impressions and feelings") and the extent to which such an experiential system is engaged (e.g. "reliance on and enjoyment of feelings and intuitions in making decisions"). Such a distinction suggests that more nuanced characterizations of our reasoners might illuminate more interesting relations between thinking style and the ability to solve analogies. These subscales are theoretically intended to be independent, and this is borne out by the lack of a correlation, or even trend, in our sample (r = .005, p = .96). As such, I decided to conduct a median split on participants as a function of both subscales and explored the effects of a cue at this more nuanced level. For NFC, a split results in a distinction between reflective and non-reflective participants, and for FI, a split results in a distinction between intuitive and non-intuitive. The combinations afforded by this provide an interesting means of describing 4 subtypes of reasoners in our sample: those that are *non-reflective and intuitive*, those that are *non-reflective and non-intuitive*, those that are *reflective and intuitive*, and those that are *reflective and non-intuitive*.

To explore whether such groupings provide further insight into the processes of interest for the identification of true analogies, I conducted a 2 (Domain: Cross-domain, Within-domain) × 2 (Cue: Analytic cue, Intuitive cue) × 2 (Reflectiveness: Non-reflective, Reflective) × 2 (Intuitiveness: Non-intuitive, Intuitive) ANOVA. The presence of a massive main effect of domain (F (1, 72) = 274.16, p < .001, $\eta_p^2 = .79$) and a four-way interaction (F (72) = 11.33, p < .01, $\eta_p^2 = .14$) provided impetus to de-compose and run two three-way ANOVAs for each domain. For within-domain analogies, there was a main effect of the cue (F (1, 72) = 4.74, p < .05, $\eta_p^2 = .06$), with the analytic cue yielding slightly better performance than the intuitive cue but no significant interactions (all *Fs* < 1). For cross-domain analogies, however, there was no main effect of cue ($F < 1$), but a significant three-way interaction (F (1, 72) = 9.72, p < .01, $\eta_p^2 =$ .12). To further understand the pattern responsible for this interaction, I then split the file as a function of Reflectiveness and ran two separate 2 (Cue: Analytic cue, Intuitive cue) × 2 (Intuitiveness: Non-intuitive, Intuitive) ANOVAs, which were quite illuminating. For non-reflective participants there was no main effect of Cue, no main effect of Intuitiveness, and no interaction (all *Fs* < 1). For reflective participants, however, there was no main effect of cue ($F <$ 1) but a significant interaction (F (1, 36) = 11.76, p < .01, $\eta_p^2 = .25$). This interaction suggests that the effect of reflectiveness was modulated by whether or not one was intuitive. To quantify these patterns in actual performance and to understand this last interaction, I conducted paired sample t-tests between intuitive and analytic cue instructions for each of the 4 sub-groups discussed above. As is obvious from the ANOVA above, there was no significant difference in accuracy for cross-domain analogies as a function of cue for non-reflective intuitive or non-intuitive participants (both *t*’s< 1). For reflective participants, a very interesting pattern emerged as a function of intuitiveness that explains the aforementioned interaction. Intuitive reflective participants performed better on cross-domain analogy trials when they were cued to think intuitively (Mean accuracy = 67.9%, SD = 18.6) than when they were cued to think analytically (Mean accuracy = 61.7%, SD = 16.7), *t* (17) = 2.29, *SEM* = 2.74, *p* < .05. Conversely, non-intuitive reflective participants performed better on cross-domain analogy trials when they were cued to think analytically (Mean accuracy = 79.0%, SD = 15.1) than when they were cued to think intuitively (Mean accuracy = 68.9%, SD = 13.5), *t* (41) = 2.66, *SEM* = 3.79, *p* < .05. See Figure 9 for a graphical depiction of these results.

Experiment 4 Accuracy by group

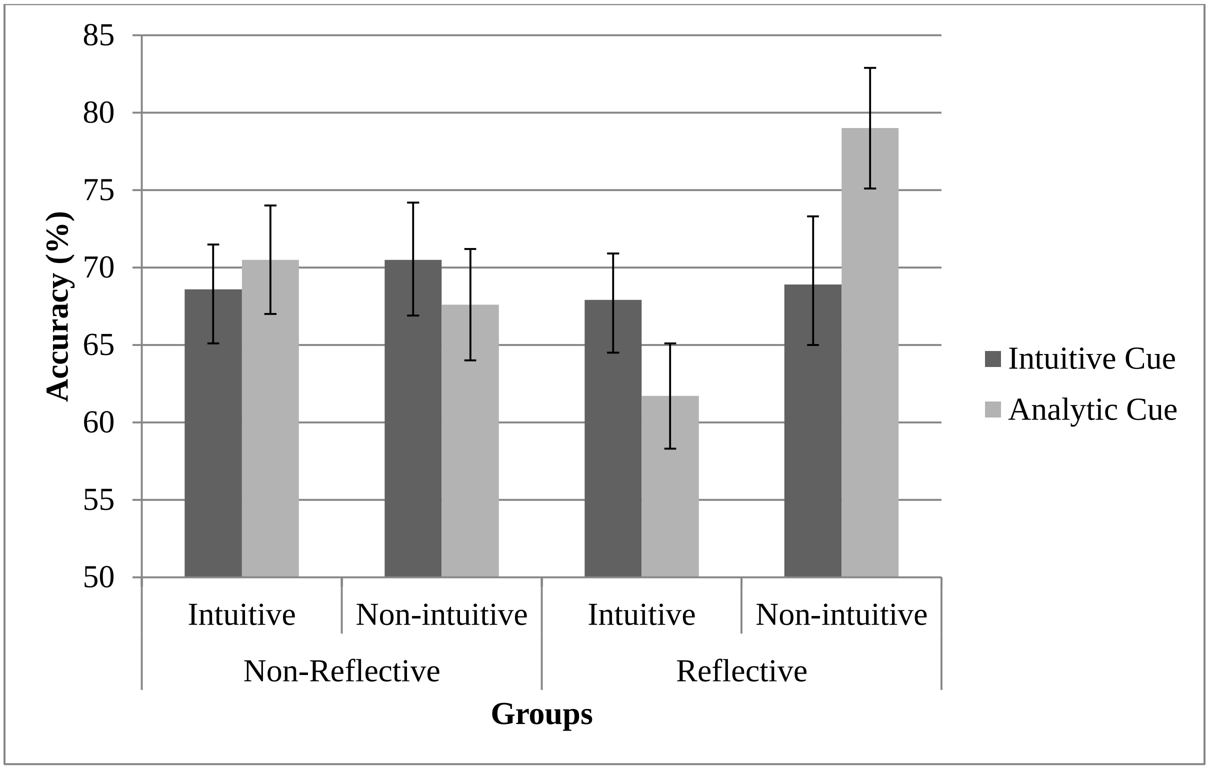

Figure 9. Accuracy as a function of Cue for each of the four sub-groups created by splitting file on NFC and FI .

Experiment 4 Discussion

There are several findings of theoretical interest, varying in complexity. Most simply, we replicate the very robust result that cross-domain analogies take longer to identify than within-domain analogies. The main effect of cue revealed that the additional instructions to think intuitively, rather than no cue at all (as in Experiment 3), cleaned up the variability in response to the cue to think analytically, as in this experiment all cells showed a mean increase in RT for the analytic relative to intuitive cue. This suggests we likely were effective in inducing the two different types of processing styles that we had hoped to at the outset, strengthening confidence that our cue instructions did induce the desired mindset and making this study amenable to understanding the pertinent questions. Such a result is suggestive that similar cues in future experiments should provide directives for all trials, rather than only cuing half the trials, as it is difficult to know what sort of processing a baseline no cue trial is reflecting, making interpretation of results more difficult.

This study also supported the view that experimental manipulations should be accompanied by individual differences measures whenever possible. Here, if I had not included a questionnaire gauging thinking dispositions, I would not have illuminated some nuanced and informative results. The decomposition of the impact of the cue as a function of reflectiveness and intuitiveness showed that the cues to think analytically and intuitively had divergent effects for certain sub-sets of the sample. One take-away from such a result is that interventions to enhance creativity should take into account individual differences in thinking style, as it seems that what is effective for one may not be for another. Some (e.g. Howard-Jones, 2002) have suggested that interventions aimed at enhancing creativity should focus on encouraging people to think a way that is not their typical ‘style’. Specifically, it was suggested that getting more analytic thinkers to think more associatively might be helpful, and encouraging more associative thinkers to think more analytically might be helpful. My results show this was not the case, and that cues that were congruent with one's thinking style were effective. Although there was congruence between the benefit of moment-to-moment cues and longer term dispositions (i.e. non-intuitive reflective thinkers did better when told to think analytically, and intuitive reflective thinkers did better when told to think intuitively). It is important to emphasize, though, that the highest performance on cross-domain analogies came from non-intuitive reflective individuals on the analytic cue, with this group having the highest overall (i.e. irrespective of cue) accuracy as well. It would seem that on these types of trials, these participants are engaging the most Type 2 processing we have seen, and this is resulting in the highest performance yet. This is entirely consistent with the view articulated here and suggestive that cultivation of complex creativity might benefit from longer term efforts to instill analytic cognitive styles.

More generally, the finding that intuitive reflective participants had lowered performance makes sense, as the information that would come intuitively to mind would be lack of surface similarity (i.e. these pairs are semantically distant), which would cue the participant to assume there is no common underlying relation and incorrectly respond no. Non-intuitive reflective participants are presumably less influenced by the autonomous stream of information that automatically activates the idea that the two things at hand are not related and are accordingly more successful at finding relational connections. Recent work has related such thinking dispositions to conflict detection, with more analytic participants being more sensitive to conflict (Pennycook, Koehler & Fugelsang, 2012). It might be the case that although the non-intuitive non-reflective participants are less influenced by the relatively smaller semantic distance, they might not be any less sensitive to this incongruence. In other words, they might experience the same activation, but actively be inhibiting the response based on similarity in order to respond relationally, a point to which I will return in the discussion. As for the finding that intuitive reflective thinkers actually experienced a decrement in performance when told to think analytically, it might be the case that the meta-level cognitive monitoring required to shift one's thinking style actually in effect served as a dual-task manipulation. That is, the effort required to consciously be more analytic might require the very resources required for the analogical mapping process.

It seems clear from the basis of the results of Experiment 4 that individual differences in disposition to engage Type 2 processing are consequential in determining one's ability to generate the mappings required to identify cross-domain analogical reasoning. It also seems clear that these differences interact with cues to think a particular way. As with any good study though, the results raise more questions than they provide answers, and in Experiment 5, I will explore a few of the many lingering questions I have about the processes at play.

Experiment 5

Experiment 5 sought to expand the extent to which I could understand the relation between the individual differences factors that predict performance in the context of complex creativity. To do so, there were several changes to the procedure used in Experiment 4, as well as several expansions to the scope and breadth of my investigation. These modifications importantly afford novel insights above and beyond that offered by my previous experimental explorations and serve as the culmination of my goal to understand complex creativity (or a small part of it at least). I will review the nature of these changes and expansions next, and relate them to the broader question of what allows us to make creative connections.

For one, I wanted to explore the role of thinking dispositions, such as that measured by the REI in Experiment 4, in the absence of trial-by-trial cues. Given that thinking dispositions are by their very definition reflective of a tendency to approach problems in a certain way, it seems important to allow participants freedom in how to respond to better understand the question I aim to address. By removing the cue, we should see relatively more ‘natural’ responding that is more reflective of the manner in which they might organically approach a problem, which in turn might illuminate inter-relations otherwise hidden by the imposition of the cue. A critic might say that this is still an artificial speeded task, but it is important to recall that these same stimuli are identified correctly with a high degree of uniformity but in the context of my experiments there was a large amount of individual differences, specifically within the cross-domain analogies, which are of primary interest. As such, I would argue that preservation of this element is important for illuminating individual differences of the sort I am interested in.

Also, although self-report measures have utility, they bring certain problems (e.g. see Paulhus & Vazire, 2007). People are generally notoriously bad at assessing the nature of their own abilities, traits, and behaviours, and even misrepresent that which they could accurately report. For example, some participants will aim to respond in a socially desirable way, or engage in other strategic efforts to present themselves in a particular way. More specifically, it has been argued that indexing the extent to which one is prone to engage analytic processing is more effectively done through the use of performance measures that require the engagement of Type 2 thinking to solve (Toplak, West, & Stanovich, 2011). In this paper, the authors advocate the use of the Cognitive Reflection Test (CRT; Frederick, 2005) as a means of indexing thinking styles. The CRT consists of three items with open ended responses and is a widely used task thought to index analytic thinking (Toplak, West, & Stanovich, 2011). The questions are quasi-mathematical in form and designed so as to engender a strong intuitive response. To answer correctly, one is thought to need to question and override the Type 1 response in favour of more analytic, Type 2 processing. Consider the following example:

> A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?

The response of $.10 comes to mind quickly, presumably due to the segmentation of the given values into even units, but further reflection reveals this to be erroneous. As the math involved is quite basic, incorrect responses are thought to be primarily a consequence of a failure to engage analytic processing, rather than a deficiency in ability to actually do the requisite operation. Toplak, West and Stanovich (2011, p. 1284) identify the CRT as a

> particularly potent measure of miserly tendencies because of its logic of construction: It is a performance measure rather than a self-report measure. That is, it is not a questionnaire measure on which people indicate their preferences for engagement—for example, as the need-for-cognition scale does (Cacioppo, Petty, Feinstein,& Jarvis, 1996). Instead, the tendency to accept heuristically triggered responses is measured in a real performance context where participants are searching for an accurate solution. The

> CRT measures miserliness in action, so to speak. It is a direct measure of miserly processing rather than an indirect self-report indicator.

Given the arguments of these authors, and the demonstrated utility in the use of the same and similar measures in other contexts (e.g. Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012; Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2014a; Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2014b), Experiment 5, in addition to the REI, incorporated performance based measures (including the CRT) that are thought to also index individual differences in the relative degree of Type 2 engagement. The addition of performance based measures allows both a more objective means of assessing the relative engagement of Type 2 processing as well as providing an opportunity to determine whether the self-report and performance based measures cohere in predicting creative performance, allowing a chance for convergent validity.

As a means of expanding the scope of the study further, I also included two brief cognitive ability indices (i.e. vocabulary/numeracy tasks) to measure individual differences in knowledge. Stanovich (2009) distinguishes between the willingness and ability to engage Type 2 processing, and these measures are thought to relate more to the ability, than the willingness that is of primary focus. Their inclusion is motivated by several things. For one, by including measures thought to index more general cognitive ability, we can explore whether our cognitive style measures are independent contributors. As cognitive ability and a more analytic cognitive style are correlated, it is important to ascertain whether the disposition to engage more Type 2 processing is indeed required. These questions, although having normatively correct answers, do not feature a misleading intuitive response such as that in the cognitive style tasks used here. Furthermore, it seems that a larger base of knowledge is important for tasks in which one must bring together elements represented in distal semantic space. Given that semantic memory is akin to a network of connections, having more concepts and richer inter-connections might prove critical to understanding more complex creative relations amongst sets of relations.

A final addition here was that of additional creativity tasks. Semantic distance of the sort studied here is only one sub-type of creative thought that is of interest to psychologists. Accordingly, it is important to both explore the relation between individual differences regarding thinking style and other types of creativity and to understand whether the analogical reasoning task reported here relates to other tasks thought to index the same over-arching construct. In addition to tasks that index very distinct aspects of creativity (i.e. cognitive flexibility, fluency, originality), I also incorporated another task thought to require the integration of disparate concepts as a means of understanding whether our results are an idiosyncratic consequence of the analogy task, or if they inform a more general cognitive ability to connect semantically distant concepts. Given the consensus regarding the extant confusion characterizing the field of creativity research (see Hennessey & Amabile, 2010), it is important to more fully qualify the commonalities and differences between the processes and traits that afford success in diverse facets of creativity.

As discussed in the introduction, creativity researchers are divided as to the relative utility of engaging executive processing in the creative process and it is this question that is of primary importance here. Importantly, those championing the view that relatively less controlled processing is helpful do not deny its role altogether. As such, the question is not whether creative thought involves some degree of controlled processing. The question, rather, is whether relatively more or less intervention of such processing is beneficial to creativity. For example, Wiley & Jarosz (2012) assert that creative problem solving requires a mixture of “non-goal-directed processes and more controlled, attention-demanding processes” (p. 260). Moreover, they state that individual differences in the ability to shift between these two modes of thought may be useful in understanding creativity, but that “there is not yet a definitive paradigm that allows for the measurement of individual differences along these lines” and overtly state that there is a “need for a dual-process model of problem solving that incorporates both analytic and nonanalytic processes” (p. 261).

We agree with Wiley & Jarosz (2012) that such individual differences hold promise, but disagree that there exists no suitable paradigm for measuring such differences, as DPTs incorporate individual differences in analytic thinking disposition. Under this formulation, Type 2 processing relates directly to the relative reliance on intuitive “non-goal directed processes” as they are necessarily modulated by the explicit engagement of “controlled, attention demanding processes” (using Wiley et al.’s terminology).

In Experiment 5, we use individual differences measures indexing cognitive ability and cognitive style to predict creative performance, as indexed by a number of diverse tasks that reflect the multi-faceted nature of the construct of creativity. Our aim is to illuminate whether relatively *more* or *less* analytic thinking is beneficial to the creative process and attempt to understand the interplay between distinct types of thinking in creativity, formalizing previous suggestions that the study of creativity could benefit from a DPT perspective (see Allen & Thomas, 2011) and more strongly situating my state level results with evidence regarding the traits that afford success in such tasks. If higher cognitive ability and a more analytic cognitive style are associated with increased creativity, it would suggest a greater benefit of executive processing than would be predicted by some accounts of creativity (e.g. Wiley & Jarosz, 2012). In contrast, if lower cognitive ability and a less analytic cognitive style is associated with increased creativity, it would suggest a greater benefit of non-goal directed, potentially unconscious processing than would be predicted by some accounts of creativity (e.g. Beaty & Silvia, 2012). Given the logic outlined in the introduction, and the findings discussed thus far, I would predict that complex creativity tasks, such as that exemplified by the cross-domain analogies will be positively related to a dispositional tendency to more often engage Type 2 processing. Given the results of the previous experiments in this study, as well as the logic outlined in the introduction regarding the nature of knowledge representation and the default-interventionist DPT framework, I hypothesize that tasks indexing the ability to make remote connections will benefit from relatively more Type 2 processing, but am less certain about what to expect with the other tasks.

Experiment 5 Method

Participants

One-hundred two University of Waterloo undergraduates (66 females, $M_{\text{age}} = 20.01$ years, SD = 3.11) participated in a two-part study for course credit. No special criterion for participation was required beyond normal or corrected to normal vision and fluency in English.

Design

The experiment consisted of several tasks and one questionnaire. The individual difference cognitive measures were included as part of a larger online study. Participants who completed these measures online were eligible to come into the lab and complete the creativity tasks, as well as a self-report questionnaire on thinking dispositions. All in-lab tasks were computerized and implemented via E-prime. Task order was randomized with the exception of the analogy task, which was always first. Further details for each task follow.

Materials/Procedure

Cognitive Tasks/Questionnaires. See Appendix D for ACS and CA measures. To index the extent to which participants varied in analytic cognitive style (ACS), that is, the willingness/tendency to think analytically, participants completed the Cognitive Reflection Test (CRT; Frederick, 2005) and a Base-rate conflict task (Pennycook et al., 2012).

The CRT is discussed above and as such is not described further here, though all three items can be found. The base-rate task employed here is similar in logic and makes use of the idea that successful judgments often necessitate consideration of several different, and often competing, sources of information. By intentionally creating incongruence in these sources, we can make inferences about the types of processing that relate to the given choice. Specifically, we asked participants to decide category membership in situations in which the base-rate information and personality description were in conflict. In other words, we presented the relative chance that an individual in our sample would be from either of two given categories alongside a description of their personality that fits better with the less likely of those two choices. Consider the following example (from De Neys & Glumicic, 2008):

> In a study 1000 people were tested. Among the participants there were 995 nurses and 5 doctors. Paul is a randomly chosen participant of this study. Paul is 34 years old. He lives in a beautiful home in a posh suburb. He is well spoken and very interested in politics. He invests a lot of time in his career.
>
> Is Paul more likely to be a nurse or a doctor?

People often ‘neglect’ or underweight the fact that there is an extremely high chance that Paul, or any other person from this sample, is a nurse (i.e. base-rate probability = 99.5%) in the face of the more intuitive personality description that it conflicts with. As such, the relative distribution of base-rate versus personality-based choices on this task is considered a means of indexing the extent to which an individual is willing to engage analytic processing. There were 18 items in total: six neutral (no personality descriptions, six congruent (base-rate and personality match), and six incongruent problems such as that outlined above. Our primary dependent measure for this task was the proportion of incongruent problems correctly solved.

Importantly, in both tasks, an intuitive (Type 1) response is cued that requires Type 2 processing to override. Overall performance reflects the relative reliance on both Type 1 and Type 2 processes such that those who are more analytic are necessarily less intuitive, and vice versa. Thus, variations in performance on such tasks that cue misleading intuitive responses reflect individual differences in deployment of both analytic and nonanalytic processes. In order to create a composite ACS score, the percentage correct for the CRT and incongruent base-rate problems were averaged.

An important issue to address is that although the CRT and Base-rate task are primarily thought to be indexing ACS, recent investigations have confirmed that performance on both tasks is predicted by measures of cognitive ability as well (Base-rate problems: Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2014a; CRT: Toplak, West & Stanovich, 2011). As such, these tasks are not “pure” measures of the willingness to think analytically but also, to some degree, are reflective of an individual’s analytic ability. However, as noted above, that performance on these problems is relatively low, despite the simple computations required, indicates a stronger relative role for cognitive style than cognitive ability (see Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2014b for a similar discussion).

The Rational Experiential Inventory (Pacini & Epstein, 1999) was again used as a self-report index, as it is related to our performance-based ACS tasks. Fourteen participants did not complete the REI.

To measure cognitive ability (CA), participants completed a widely used Numeracy task (Schwartz et al., 1998) and the Wordsum (see Huang & Hauser, 2010), a verbal intelligence measure shown to correlate well with full scale intelligence measures (Malhorta, Krosnick, & Haertwl, 2007). The Numeracy task consists of three questions thought to index basic understanding of concepts pertaining to probability and basic numerical knowledge. The Wordsum is a 12 item vocabulary test in which participants are shown a target word, and given five other words, one of which is close in meaning to the given word. Participants are simply asked to identify the word that is closest in meaning to the target word or to indicate that they do not know the meaning of the word. Together, these short tasks comprise an index of broad cognitive abilities and have demonstrated predictive validity in previous work (e.g. Pennycook et al., 2012; Pennycook et al., 2014a). In order to create a composite CA score, the percentage correct from the Numeracy task and the Wordsum were averaged.

Creativity Tasks. See Appendix E for creativity measure items. Four tasks were employed to index different facets of creativity. To measure cognitive flexibility, participants completed the Category-Inclusiveness Task (CIT; Isen & Duabman, 1984). In this task, participants are presented with exemplars and asked to indicate the extent to which the given item belongs in the category to which it belonged. Here, participants were presented with a total of 36 exemplars from four categories (furniture, vehicle, vegetable, and clothing), with each category consisting of three weak, moderate, and strong exemplars. The presentation of words in each category was blocked and the order of blocks was randomized, as were the exemplars within the block, with the caveat that a strong exemplar was always first (as in Isen & Daubman, 1984 and Slepian & Ambady, 2012). The primary dependent variable is the ratings of belonging for weak exemplars of a given category. Those who, on average, assign higher ratings to weak exemplars are purported to be more flexible and are thought to conceive of entities in an atypical manner.

To measure fluency and originality, participants completed the Alternate Uses Task (AUT; Guilford, 1967). The dependent measures for our study were fluency (i.e. the number of items generated) and originality (i.e. the extent to which the provided use is deemed divergent from the intended uses of that object, as assessed by three independent raters on a scale from 1 (*not at all*) to 7 (*very*). In our study, participants were asked to generate as many possible creative uses for a newspaper as they could within one minute (Guilford, 1967; Slepian & Ambady, 2012)

To assess the ability to make remote connections, two tasks were used. The first, the Remote Associates Test (RAT; Mednick, 1962), presents three words that are ostensibly unrelated (e.g. SORE, SHOULDER, SWEAT) and participants are asked to generate a common associate that forms a compound with all three of the given words (e.g. COLD). No time limit was imposed, contrary to what has been done in some investigations (see Dorfman, Shames, & Kihlstrom, 1996; Slepian, Weisbuch, Rutchick, Newman, & Ambady, 2010; Slepian & Ambady, 2012) as allowing participants to decide how long to think about the problems should allow greater variance in the extent of Type 2 processing, an issue central to our investigation. The 15 three-word triads, originally drawn from Bowden and Jung-Beeman (2003) and more recently used by Slepian and Ambady, (2012), were rated in previous investigations as being moderately difficult and were presented in random order on screen. Participants typed their responses, but if they could not generate the answer, they were asked to type “no” to move on to the next trial.

The final creativity measure was the same speeded analogical reasoning task used throughout this thesis. Presentation parameters were such that a blank screen appeared for 500 ms, followed by a fixation cross for 500 ms in isolation before being joined by the two word pairs, to the left and right of fixation. This procedure is nearly identical to that used in Experiments 2 and 3, without the explicit cue.

Experiment 5 Results

Cognitive tasks. Performance on the cognitive tasks was as follows: CRT, Mean accuracy = 41.2%, SD = 37.9; Base rate Incongruent problems, Mean accuracy = 30.2%, SD = 32.5; Wordsum, Mean accuracy = 58.2%, SD = 20.6; Numeracy, Mean accuracy = 74.5%, SD = 29.7.

Remote connections. Embedded within the broader correlation design, the analogy task features the same experimental component (i.e. the distinction between within and cross-domain analogies) as earlier experiments. Figure 10 presents the mean accuracy data as a function of Domain, Validity, and Cue, and Figure 11 presents the analogous RT data. A 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) ANOVA on the accuracy data revealed a main effect of Domain, F (1, 101) = 203.58, $p < .001$, $\eta_p^2 = .67$, a main effect of Validity F (1, 101) = 13.44, $p < .001$, $\eta_p^2 = .12$, and a significant Domain × Validity interaction F (1, 101) = 162.04, $p < .001$, $\eta_p^2 = .67$. Specifically, performance for within domain analogies (Mean accuracy = 93.8%, SD = 6.3) was far superior (and less variable) than that for cross-domain analogies (Mean accuracy = 63.7%, SD = 18.8), $t = 17.47$, *SEM* = 1.72, $p < .0001$. Again, performance for cross-domain non-analogies (Mean accuracy = 87.75%, SD = 13.0) was superior to that for within-domain non-analogies (Mean accuracy = 81.0%, SD = 17.5), $t = 4.22$, *SEM* = 1.60, $p < .001$.

An analogous 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) ANOVA on the RT data revealed a main effect of Domain, F (1, 101) = 195.03, $p < .001$, $\eta_p^2 =$ .66, a main effect of Validity F (1, 101) = 8.12, $p < .01$, $\eta_p^2 = .07$, and a significant Domain ×

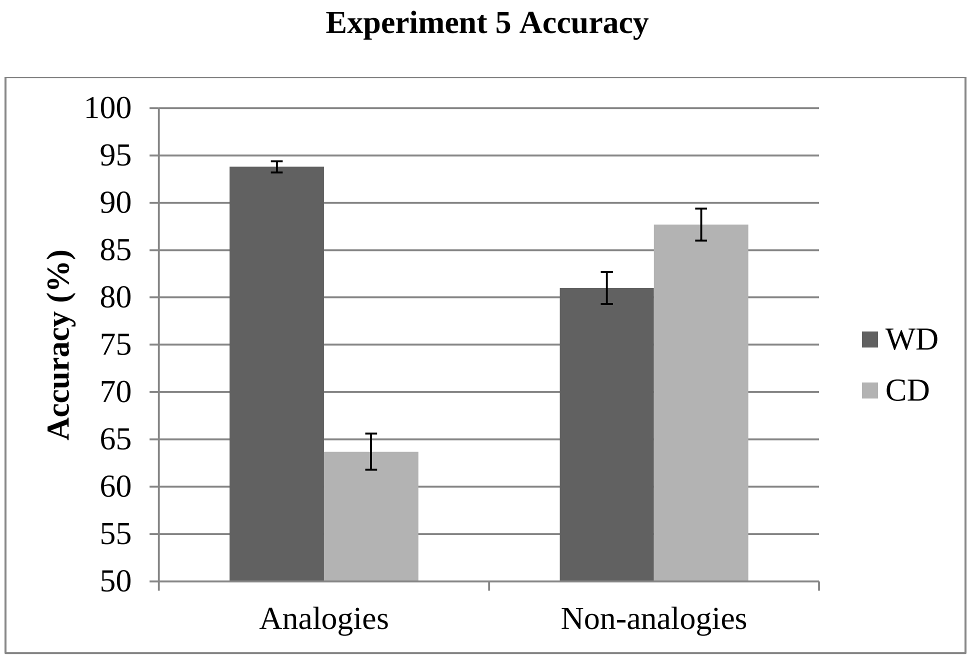

Figure 10. Accuracy as a function of Domain and Validity.

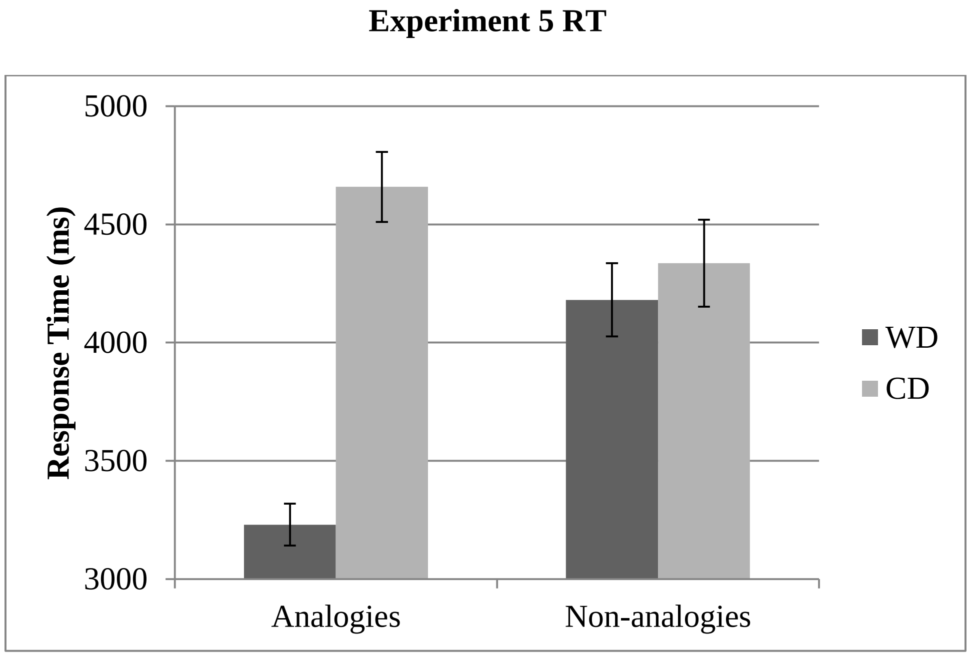

Figure 11. RT as a function of Domain and Validity.

Validity interaction *F* (1, 101) = 78.5, $p < .001$, $\eta_p^2 = .44$. For non-analogies, participants took slightly longer to respond correctly to cross-domain items (Mean RT = 4336 ms, SD = 1852) than within-domain items (Mean RT = 4181 ms, SD = 1563), but this difference was not significant, $t = 1.56$, *SEM* = 99.42, $p = .12$. Again, a significant RT difference was found as a function of domain for true analogies, with within-domain analogies (Mean RT = 3230 ms, SD = 891) being correctly identified much faster than cross-domain analogies (Mean RT = 4659 ms, SD = 1495), $t = 17.23$, *SEM* = 82.92, $p < .0001$. As within-domain analogies were yet again answered more accurately despite faster overall RTs, it seems clear that cross-domain analogies require more analytic thinking to solve. We take the robustness of this result as further support that Type 2 thinking is relatively more strongly involved in the ability to identify creative, cross-domain analogies than in within-domain analogies.

Consistent with the intra-experimental results are positive relations between performance in cross-domain analogical reasoning and ACS, CA, and NFC, but not FI (see Table 1 for correlation table and Appendix F for more complete table). Importantly, correct rejection of non-analogies was not negatively related to ACS and CA, suggesting that the benefit in identifying cross-domain analogies was due to a heightened ability to see a connection and not a result of a more liberal response criterion (i.e. a general tendency to say yes).

Performance on the RAT (Mean accuracy = 37.6%, SD = 21.4) was also positively associated with ACS, CA, and NFC, but not FI, further supporting a view in which the ability to make remote connections is aided by relatively more engagement of Type 2 processing. Those higher in CA presumably have greater ability to generate a solution to these problems as a function of greater familiarity with language and the constituent terms of the problem.

Experiment 5 Inter-correlations

	1	2	3	4	5	6	7	8	9	10	11	12
Analytic Thinking												
1. Cognitive Ability	-											
2. Analytic Cognitive Style	**.53**	-										
3. Need for Cognition	**.42**	**.47**	-									
4. Faith in Intuition	-.17	**-.24**	-.20	-								
Creativity												
5. Cross Domain Analogies	**.49**	**.44**	**.36**	-.01	-							
6. Within Domain Analogies	**.31**	.14	.12	.11	**.38**	-						
7. Cross Domain Non-Analogies	.16	**.23**	.01	**-.22**	-.18	.19	-					
8. Within Domain Non-Analogies	**.44**	**.45**	**.32**	-.05	**.34**	**.22**	**.47**	-				
9. Remote Associates Test	**.38**	**.32**	**.22**	.03	**.48**	**.35**	.12	**.44**	-			
10. Alternate Uses Task - Originality	**.28**	.14	.14	-.03	**.20**	**.20**	.14	**.21**	**.34**	-		
11. Alternate Uses Task - Fluency	-.01	.07	.05	-.04	-.01	-.08	-.05	-.04	.12	-.13	-	
12. Category-Inclusiveness Task	.06	.11	-.01	.06	.12	.12	.18	.08	-.11	-.09	-.06	-

Table 1. Pearson product-moment correlations among cognitive variables and creativity tasks. Coefficients in bold are significant, $p < .05$.

Fluency and Originality. Fluency (Mean number of items generated = 8.2, SD = 3.4) did not differ as a function of any of the cognitive tasks. Originality ratings (Mean rating = 2.4, SD = .73) were related to CA, however. Given this, it seems that those with greater CA more efficiently retrieved creative uses from semantic space. The lack of strong relation between Originality and ACS (*p* = .16) suggests that individual differences in thinking style may be less likely to emerge in constrained time periods with clear instructions to generate ideas.

Cognitive flexibility. There was no relation between cognitive flexibility (Mean rating for weak exemplars = 4.4, SD = 1.3) and the ACS or CA measures. Presumably, given the lack of a correct answer in such a rating task, engagement of Type 2 processing is unlikely to yield an answer divergent from the default response produced by Type 1 processing in any systematic way (i.e. further analysis could lead one to either view an item as more or less representative of a category). In other words, tasks such as the CIT that rely on an affective judgment (Isen & Daubman, 1984), but do not have a correct answer, may not be systematically related to reasoning ability or style.

Complex creativity. An important ancillary issue is the extent to which the creativity measures cohere. Based on the inter-correlations between our tasks, a nuanced look at the over-arching construct of creativity is warranted. Analogical reasoning and RAT performance most strongly related to our reasoning measures (see Table 2 for summary of these key correlations), and to each other, $r(101) = .48$, $p < .001$, suggesting they together represent a type of complex creativity. A common element between analogical reasoning and the RAT is that of unification of concepts spanning large semantic distance in a coherent manner -- a reasoned connection. In both the RAT and creative analogical reasoning, one must be able to maintain and manipulate relations between activated concepts to assess the connection between disparate elements. We created a complex creativity composite score by averaging percentage accuracy for RAT and cross-domain analogy problems. This score was positively related to ACS and CA, *r*(101) = .44, *p* < .001 and *r*(101) = .50, *p* < .001 respectively, as well as NFC , *r*(87) = .34, *p* = .001, but not FI, *r*(87) = .02, *p* = .88. Regression analyses revealed that ACS and CA together accounted for approximately 29% of the variance in complex creativity scores, with both emerging as independent predictors *B* = .14, *t* = 2.39, SE = .06, *p* = .019 and *B* = .33, *t* = 3.76, SE = .09, *p* < .001, respectively (see Table 3 for regression table).

Experiment 5 Key correlations

Creativity Index	CA	ACS	NFC
CD analogies	0.49**	0.44**	0.36**
RAT	0.38**	0.32**	0.22*

Table 2. Pearson product-moment correlations amongst ACS, CA, CD analogy accuracy, and RAT accuracy. Coefficients with ** are significant, *p* < .01, Coefficients with * are significant, *p* < .05.

Experiment 5 Complex Creativity Regression Table

	Unstandardized Coefficients		Standardized Coefficients		
	B	**Std. Error**	**β**	***t***	**Sig.**
ACS	.140	.059	.239	2.388	.019
CA	.333	.089	.376	3.760	.000

Table 3. Regression table for analysis of relation between ACS, CA (predictors) and Complex Creativity Composite scores (dependent variable).

Experiment 5 Discussion

Creative performance on only some of the tasks employed here was related to the willingness and ability to engage Type 2 processing, a finding that speaks both to the relation of these tasks to ACS and CA as well as the diversity of the tasks thought to index the same over-arching construct of creativity. The most relationally complex of the creativity tasks, in particular, were strongly positively correlated with ACS and CA, suggesting that the process of connecting remotely associated items in semantic space is related to more efficient and frequent engagement of an analytic reasoning system.

Although the primary research question revolved around the relation between thinking dispositions and creativity, an interesting ancillary source of information here is the correlations, or lack thereof in some cases, amongst the diverse creativity tasks in Experiment 5. There was relatively little connection between some of the tasks. For example, not only were cognitive flexibility and fluency unrelated to our reasoning measures, they were both also unrelated to any of the other creativity tasks. Interestingly, originality ratings related to both cross-domain analogical reasoning and RAT performance. One way to conceptualize the commonality is that generating original uses requires spanning of larger semantic space, with less original uses being closer in semantic space to the given object’s typical use. Although this connection exists, there was no relation between originality and ACS measures (as there was with the tasks comprising our complex creativity composite). One reason for this dissociation might be that there is not the same type of underlying relational complexity. Such an interpretation predicts that first order semantically distant connections likely do not require as much Type 2 processing as do more relationally complex ones.

Another interesting result is that NFC did not predict performance in identifying cross-domain analogies in the previous experiment in which participants were cued on each trial to think a certain way; here, though, we did see a significant correlation between NFC and the measures meant to index complex creativity. Such a result suggests that attempts to relate thinking style and performance on creative tasks might be best undertaken in more open-ended formats. It is quite possible that if the speeded instructions were removed from the analogical reasoning tasks that the effects here might be even larger.

As a whole, the correlational and experimental results of this study together support the predictions I established at the outset of this thesis, and have made the findings more specific by distinguishing complex creativity from other indices. Given that I have now explicated all of the results of my experiments and have a more full idea of the processes at play, rather than continue my discussion here only about Experiment 5, I will move to the General Discussion to more fully characterize what I believe to be the cognitive underpinnings of complex creativity at multiple levels of analysis, yielding a relatively complete model of such creativity and some suggestions for how to foster future innovation.

General Discussion

The creativity literature has been described by experts as “both daunting and exciting” (Hennessy & Amabile, 2010, p. 570). I agree with this characterization: it is daunting because there are many unconnected results that together comprise a vast literature, and it is exciting because this lack of cohesion means the field is ripe for a perspective that can tie together these disparate threads into a more cohesive inter-woven fabric of findings. In the aim of providing such a perspective, I have argued that the application of a DPT model of reasoning (Stanovich & Evans, 2013) could help resolve some of the extant issues in this area, and conducted several studies to explore the utility of such an approach in accounting for variance in the ability to make creative connections at both the state and trait levels.

Highlighted Findings

In the context of state-level factors, I explored whether inducing (i.e. via experimental manipulation) or cuing (i.e. via instructional manipulation) relatively more or less intuitive/analytic thinking enhances or reduces creative performance (see Experiments 1, 2, 3 and 4). I found that making it more difficult to engage Type 2 processing selectively impaired the ability to identify cross-domain analogies. Especially strong evidence for this came from Experiment 1, when the parameters were most challenging, as participants’ performance was no different than that expected by random responding on the creative cross-domain analogies. In Experiment 2, participants performed better when they could view all four items simultaneously, but there was still marked differences in performance between cross and within-domain analogies such that cross-domain accuracy was lower despite longer RTs. This general pattern was preserved across the studies and is a robust demonstration of the strong role that semantic distance plays in analogical reasoning, and underscores that the manipulations used in these experiments did not indiscriminately deter reasoning in general, but rather, quite specifically, the ability to identify the cross-domain analogies. The instruction to respond as quickly and accurately as possible hindered performance, further underscoring the important role of semantic distance in finding common underlying relations. In Experiment 3, counter to expectation, I found that a cue to think analytically did little to improve performance on cross-domain analogies, which, coupled with consistently large variance across individuals in performance, led me to consider longer term disposition (i.e. individual differences) in the context of cuing. Accordingly, in Experiment 4 I measured thinking styles and cued participants to think analytically or intuitively on each trial and found that although there was no main effect of the cue for cross-domain analogies, short term instructions to think a certain way interacted with longer term dispositions in processing style. Most interestingly, on cross-domain analogies, reflective thinkers who were relatively more intuitive performed better when told to think intuitively than when told to think analytically, whereas those who were reflective but less intuitive performed better when told to think analytically than when told to think intuitively. This suggested that one must consider longer term disposition when attempting to augment creativity in the short term. The highest accuracy for the creative items were on analytic cue trials for the non-intuitive reflective participants, again underscoring the importance of Type 2 processing for understanding such analogies. In Experiment 5, I explored the roles of individual differences in cognitive ability and analytic cognitive style (as in Stanovich, 2009) and included other indices of creative ability to broaden the scope of my investigation. I found that those more willing and/or able to engage Type 2 processing were more likely to successfully make creative connections in tasks requiring the unification of disparate elements and the novelty of generated items, but not in some other indices of creativity, namely, cognitive flexibility and fluency.

Taken together, these results support and qualify my supposition that one must engage executive, WM demanding Type 2 processing to engage in complex creativity. In what follows, I more fully explore these results in the context of the broader reasoning and creativity literatures, and formulate a more complete account of the manner in which humans make complex creative connections.

More or Less Executive Engagement

Taken together, the studies in this thesis strongly suggest that more frequent engagement of Type 2 processing is helpful in making creative connections, shedding light on a disputed issue in the creativity literature. The extent to which Type 2 processing is engaged varies as a function of contextual and situational determinants as well as longer term dispositions. As such, a consideration of this interplay can be used to both describe differences in the way an individual engages WM dependent resources under different conditions and individual differences in ACS. In all of the studies conducted here, complex creativity seemed to benefit from relatively more involvement of Type 2 processing at both the state and trait levels. In other words, both situations that more often prompt one to engage in Type 2 processing and having a general disposition to do so more often converge from the state and trait levels to support the idea that more, not less, intervention is helpful for complex creativity. Interestingly, these results were qualified further by the lack of a relation between certain other creativity tasks.

The results regarding complex creativity here are highly consistent with an array of evidence implicating executive processes in creativity (Nussbaum & Silvia, 2011; Beaty & Silvia, 2012; Atchley, Strayer & Atchley, 2012; Benedek, Franz, Heene & Neubauer, 2012). For example, recent experimental work finds a role for analytic processing in the solving of compound remote associates. In one such study, it was found that articulatory suppression (i.e.

repeating digits) impeded insight problem solving on difficult problems, whereas talking aloud (i.e. verbalizing one's thoughts about the task and inner-thoughts) facilitated performance (Ball & Stevens, 2009). In related research, Chein and Weisberg (2014) found that individual differences in attention and verbal WM at the state level aided the solving of such problems. These, and our own, findings support the view that the same cognitive mechanisms that subserve other types of non-creative problem solving underlie creative problem solving (i.e. business-as-usual theory) rather than one in which creativity and insight are a result of spreading activation mechanisms that operate below the level of awareness (i.e. special-process theory).

My work is also consistent with findings relating to the temporal course of creative generation. The serial order effect, a well replicated and relatively old finding in creativity research (Christensen, Guilford, & Wilson, 1957), refers to the fact that in generative tasks more creative responses typically come later in the response period. In other words, people generate more creative responses as time goes on, or, even more simply, ideas grow better with the passage of time. Traditional accounts attributed this result to spreading activation, whereby more proximal associates (i.e. closer in semantic distance) come to mind first, but with increased time on task, activation spreads to more distal associates, resulting in more creative responses. Such an account considers the primary determinant of creativity to be non-controlled associative thinking. Recent research, however, has eschewed the associative explanation and forwarded an executive based account in which top down thinking and guided search can afford creative ideas (Beaty & Silvia, 2012). These researchers showed that as intelligence increased, the serial order effect diminished. Amongst the most intelligent of their sample, order was inconsequential, and their earliest ideas were as creative as their later ones. Such a result suggests that one need not rely on the passive spread of activation to find relations amongst items in memory. Rather, one can strategically intervene via top down control and executive processes to find one’s way to more creative ideas. Although less relationally complex than the analogies and RAT, work in this vein provides a useful way to think about what it is that is accomplished through executive intervention in creative thinking and suggests that controlled processes can systematically explore semantic space in novel ways.

In integrating some of these notions Beaty, Silvia, Nusbaum, Jauk, and Benedek (2014) describe their controlled attention theory of creativity and cite more work relating fluid intelligence (Gf; Beaty & Silvia, 2012, 2013; Benedek, Franz, Heene, & Neubauer, 2012; Jauk, Benedek, & Neubauer, 2014; Silvia & Beaty, 2012) and working memory capacity (de Dreu, Nijstad, Bass, Wolsink, & Roskes, 2012; Lee & Therriault, 2013; Süß, Oberauer, Wittmann, Wilhelm, & Schulze, 2002) to creativity. In this paper, the authors looked to reconcile the discussed divide between those that think creativity is associative or executive. They related verbal fluency task performance (meant to index associative processes) and measures of executive attention and found support for both as predictors of the creative quality of divergent thinking responses in the AUT. Future work would be well served to explore whether associative factors of the sort used there hold any predictive value in complex creativity. Given my results and interpretation, I would predict executive factors to be relatively more influential and associative factors relatively less important in complex creativity than in other creativity tasks.

In relevant theoretical work, Nijstad, de Dreu, Rietzschel, and Baas (2010) describe the dual-pathway model of creativity which presumes that two distinct routes can lead one to creative thoughts. The persistence pathway entails in-depth analysis of a relatively constrained semantic space, which can lead one to find fruitful avenues by which to connect disparate elements. The flexibility pathway entails sampling from diverse categories, with frequent vacillation of focus between them, in hopes of fostering a creative connection. Nijstad et al. (2010) presume that both modes entail executive control, in that the search through semantic space is controlled and strategic. This description is befitting of the general tendency found here for those who most frequently intervene upon the autonomous stream of processing with analytic thought, are the most likely to forge creative connections. Although both pathways are tied to Type 2 processing, with the authors even stating that their theory does not apply to cases of spontaneously generated creative output, they differ in the nature of the role of such processing. The flexibility pathway entails sampling from intentionally diverse categories and styles of problem solving, trying many novel approaches in hopes of making remote connections. The persistence pathway involves a greater degree of executive control as it involves a more strategic approach in which people engage in a much more focused search through a relatively smaller semantic space. A systematic search for semantic connections is another way of putting this. It seems the former relates to relatively more time spent allowing autonomous Type 1 processing to unfold before engaging Type 2 processing, whereas the latter entails more maintenance of Type 2 processing over time. Interestingly, these authors posit that one can move back and forth between these modes, in effect describing variability in the sampling of the autonomous stream in WM. Sowden, Pringle and Gabora (2014) describe the flexibility pathway as being more strongly related to originality but identify ambiguity about how the persistence pathway leads to such originality as a shortcoming of their model. I would argue, on the basis of the results here, that a fruitful means of further understanding the nature of the persistence pathway would be to explore it in the context of complex creativity of the sort used here. A role for a focused search through semantic space seems to converge with the notion that people need to analytically identify common relations with Type 2 thinking, as the autonomous Type 1 stream is unable to pass such information automatically.

Another theoretical model that speaks to the extent of executive engagement in creative thinking comes from Finke, Ward and Smith (1992). Their Geneplore model draws a distinction between generation and exploration. This model is supportive of the work found here, as it presumes that reasoners take the path of least resistance (see also Ward & Kolomyts, 2010). By this, the authors mean that people, when generating ideas, draw on similar domains to constrain the process. The example used to explicate this idea by Sowden, Pringle and Gabora (2014), drawn from Ward (1994), is that of people ascribing aliens similar appendages as that found amongst creatures on Earth, rather than developing completely novel anatomy. Such a conceptualization is conducive with our broad theoretical framework and data. Theoretically, this account fits a default-interventionist DPT view, as it seems that people tend to naturally traverse relatively smaller semantic distances, thus limiting the use of the more demanding processes needed to draw from more distal domains. Empirically, my finding that participants tend to intuitively extract surface similarity, rather than relational information, is congruent with their general view and I would predict that instances of more open-ended analogy generation (i.e. given A:B, must produce C:D) might provide even stronger evidence for my claims, as less reflective participants would presumably be much less likely to spontaneously come up with cross-domain analogies given their cognitive miserliness.

Mechanisms and Models

Although the relative utility of frequent engagement of such processing for complex creativity seems clear from my investigation, I have yet to fully unpack the sorts of sub-processes that are likely to be involved when such Type 2 processing is engaged and more fully explicate what is likely occurring at a mechanistic level. What exactly is occurring during this interjection of Type 2 processing that is affording insight into the relational connections between semantically distant relations? One can view the relatively infrequent decoupling from the autonomous stream via Type 2 processing as a selective sampling and fusion of the internal and external information that is being continuingly processed autonomously. Such a view in which autonomous processes are responsible for activating collections of concepts which are then scrutinized in a more analytic fashion is reminiscent of other models of creativity that describe various stages.

As noted in the introduction, I am by no means the first to characterize creativity as benefitting from the interplay between distinct cognitive modes, processes or stages. Wallas' (1926) description of the creative process as being composed of stages was massively influential, with many similar models appearing over the intervening decades of research. Recently, Allen and Thomas (2011) systematically explored each stage of the creative process in terms of whether it seemed to be more related to Type 1 or Type 2 processing. Most simply, their conceptualization seems to capitalize on a distinction between the generative and evaluative components of the creative process, with Type 1 processes presumed to underlie the generation of ideas, which are then subject to conscious scrutiny via Type 2 thinking though they do recognize that both types of processes likely are active in all stages. However, these authors did not collect empirical evidence to support their suppositions, and as such, have little to say about the precise nature of this interactive relation beyond that both are active, relatively more or less, at all stages. Allen and Thomas (2011) warn that one should be careful mapping large stages (i.e. longer temporal windows) of the creative process to one or the other type of processing in such a way as to imply that generation is solely dependent on Type 1 and evaluation is solely dependent on Type 2. Doing so is likely too simplistic as humans assuredly vacillate between types of processing frequently and in short time frames, meaning that a conceptualization of quick vacillations between processing types could be helpful in describing sub-stages to the more traditional stages associated with the creative process. The fact that we were able to find differences as a function of ACS in speeded tasks such as those employed here is suggestive that such qualitative shifts between Type 1 and 2 processing are amenable to exploration within each of the stages discussed in stage models such as that put forth by Wallas (1926).

Similar notions to that put forth by Allen and Thomas (2011) were posited by Basadaur, Graen, and Green (1982), through their description of the stages of problem finding, problem solving, and solution implementation when explicating their idea of ideation-evaluation cycles. In their theory, depending on the stage one is in during the creative process, one might engage in relatively more or less ideation or evaluation -- that is, more or less time can be spent generating ideas or assessing their utility, depending on the current task demands. This theory is not geared toward understanding the mechanistic underpinnings of such shifts or the ways in which individuals might differ in the relative contributions of each type of process, though it is useful to map more basic processing mechanisms to higher level observations such as these.

An older view, one that is more grounded in the types of low-level cognitive processes of the sort of interest here, is the famous “Blind-Variation-and-Selective-Retention” model (Campbell, 1960), which eventually was evolved by Simonton (1999, 2010, 2013) into the Darwinian theory of creativity. Such models analogize the evolution of ideas as being akin to that accomplished by species. They describe the generative aspects of the creative process as reflecting random (i.e. blind) combinations of ideas which then are assessed for utility, with the best (or most fit, in Darwinian terms) being kept for use (i.e. selectively retained). Such models, though having intuitive appeal, have been criticized on both theoretical grounds, and for not matching emergent empirical evidence.

Reasoned Connections: Relational Complexity and Creativity

My view differs from these existing models or accounts in an important way. My work addresses and more fully incorporates work on the nature of relational representation in semantic memory and in so doing accounts for the notion that some creative ideas are more complex than others, which could potentially explain the deep division on whether executive engagement is beneficial or not. To illustrate the utility in making such a distinction, I will contrast what I will call first-order creative connections and complex creativity. First-order creative connections refer to two concepts being connected across a relatively large semantic space and are typical of what is commonly indexed in some divergent thinking tasks. For example, in coming up with a less frequent category exemplar, one is making a relatively more remote connection between the over-arching category (e.g. bird) and a given item (e.g. emu) than when generating a more frequent exemplar (e.g. robin). Although creative, there is little in the way of relational complexity. Contrast this example with the complex cross-domain analogical reasoning of interest here. One must find a connection between two relations through identification of a common underlying relation. Here, it is not the case that one must reach a concept on the edges of the defining features of a category, but rather, one must find the common relational path connecting two sets of elements in relatively very distant semantic space. In such a case I would suggest the complex creative ideas are not generated autonomously and subsequently assessed in a controlled fashion as one might see in a first-order creative connection. To illustrate the subtle distinction between these types of creative connections, I will explain and expand upon an existing model of the way in which remote concepts are activated in memory by focusing on what could be occurring in complex creative connections.

Gabora (2010) has explicated a detailed model of the way that more creative ideas become active that relies on the concept of contextual focus. Contextual focus refers to the ability to shift between two modes of thought, associative and analytic, through the focusing/de-focusing of attention. Such an interpretation is amenable to understanding through the old analogy of attention as a spotlight. Although an imperfect representation of the precise manifestation of memory in such reasoning (the spotlight analogy is more often and more accurately linked to visual and spatial attention, rather than an internal search through semantic space), such an analogy is useful as a thinking tool, so long as one does not take it too far (see Harrison & Treagust, 2006 for more on the use of analogies in teaching and learning). When engaged in focused thought, the spotlight of attention is narrow and intensely centered upon a relatively smaller neural region (i.e. a relatively smaller region of neurons is activated), resulting in relatively mundane and uncreative thought. When engaging in the less focused associative thinking, the spotlight of attention becomes more diffuse, illuminating otherwise unseen representational features (i.e. a relatively larger region of neurons is activated). Her conceptualization is entirely congruent with the manner in which the neurobiological investigations discussed earlier presume that our knowledge is represented (e.g. Binder & Desai, 2011). Specifically, Gabora (2010) discusses memory as content addressable; “there is a systematic relationship between the state of an input and the place it gets encoded” (p. 5), which directly relates to the notion that representations are coded in terms of the emotional, sensory, and motor regions that are active when these representations are experienced, and that these regions become re-activated when one recalls such a representation (e.g. Schachter et al., 2012;

Skinner, Manios, Fugelsang, & Fernandes, in press). Such a view presumes that things closer in semantic (and thus neural) space rely on similar and overlapping neural signatures. Most simply, given this overlap, a defocused state of attention affords recruitment of otherwise inactive representations that correspond to atypical or abstract features of the problem or task, and a return to focused attention allows one to hone in on the relevant information within these representations for the idea.

I believe such a conceptualization to likely be effective for characterizing cognitive flexibility and other divergent thinking. To use the example above, allowing a relaxation of the spotlight of attention could allow the more semantically distant exemplar of emu to become active when trying to think of a bird, when a more focused search might only yield the relatively common robin. However, such a model seems incomplete in its ability to explain very distantly related concepts only bridged by relational information, as the spotlight of attention cannot become wide enough to encompass such semantically distant relations.

Consider the following example of a cross-domain analogy drawn from the stimuli I used here: Star is to Constellation as Goose is to Flock. Given the organization of semantic memory, it seems unlikely that a relaxation of focus could activate a broad enough neural space to capture the requisite representational concepts and elements simultaneously given their extremely distinct underlying features and the accordingly vast semantic distance between the pairs. To again invoke the spotlight analogy: the spotlight cannot be broadened sufficiently to illuminate such distant areas. Also, as discussed earlier, we know from analogical priming studies that the activation of relational information required for understanding such analogies is not analogous to the spread of activation associated with the ballistic activation of related concepts (Spellman, Holyoak & Morrison, 2001) and this is suggestive that controlled processes are required for such a process. Accordingly, unlike first-order creative connections in which ideas are automatically generated and then analytically assessed, I argue that the idea truly becomes formed only when one selectively co-activates several concepts and their relations simultaneously or perhaps in rapid succession, such that the requisite elements are held active via WM demanding resources and Type 2 processing. Only when this otherwise diffuse activation distributed throughout the semantic system is held in focus via Type 2 processing is the idea truly 'generated'. As such, in cases of complex creativity, I would argue that such a model would require incorporation of a mechanism dedicated to allowing multiple spotlights to be active simultaneously or in quick enough succession for decomposition rather than a simple broadening of a singular metaphorical spotlight. As I will discuss soon, there is evidence that frontal regions of the brain may play an important role in such a process.

The Role of WM

I have argued that it is not the case, at least with complex creativity, that one generates connections between distally related elements via Type 1 processing, and then proceeds afterwards to assess the veracity of this relation, but rather, that the comparison of features and relations in consciousness via Type 2 processing yields novel ways of viewing the relational structure between elements. As you will recall, the defining feature of Type 2 processing is the engagement of WM processes, and given the central role of such processing systems in my arguments, understanding the nature of working memory is critical to understanding the relation between creativity and analyticity. Modern models of WM are not considered as being comprised of a single store or conceived as a unitary construct (see, e.g. Unsworth & Engle, 2007; Shipstead, Lindsey, Marshall & Engle, 2014). Rather, WM is divided between Primary and Secondary WM components. Primary WM relates to an ability to store/maintain entities in consciousness for subsequent use and is most often what one thinks of when the term WM is used. Secondary WM, on the other in contrast, refers to one's ability to retrieve information from long-term memory and bring it to conscious awareness. One plausible means by which complex creative connections could arise, then, would be the maintenance of one set of relations in primary WM, followed by the access of the relations from a distinct domain via secondary WM. The underlying relational content would then be forged in the fires of focus to arrive at a new conception. Less hyperbolically, once the elements of the candidate analogy are simultaneously held in WM, one can assess common relations. It seems that some sort of psychological processes must be at play which allows this less well travelled path to be walked and that WM processes are most certainly at play. Such a view is quite reminiscent of Hofstadter's (2001) characterization of the mechanisms underlying analogical reasoning, which he sees as the "lifeblood" of human thinking, though it is more strongly grounded in modern advances in cognitive psychology. According to him, thinking and analogy depend upon "the transfer of tightly packed mental chunks from the dormant area of long-term memory into the active area of short-term memory, and on their being unpacked on arrival, and then scrutinized" (p. 142).

It seems likely that secondary WM might be the especially crucial cog in the wheel of complex creativity, as the ability to hold active items from long-term memory to relate with environmental stimuli, or other recently activated long term memories, seems an absolutely essential component of forging complexly related new ideas. Perhaps one reason for mixed results in many creativity experiments is the use of Primary WM dependent measures that don't actually index the more crucial Secondary WM. This seems a likely possibility as WM theorists use a very intensive array of tasks, and subsequently employ advanced statistical analysis to generate indices of such subtle components of the WM system (see Redick, Broadway, Meier, Kuriakose, Unsworth, Kane, & Engle, 2012). Such an approach, although more amenable to understanding sub-components of the WM system, is much more time consuming to use relative to more traditional span tasks. Given that much of contemporary creativity research is more strongly rooted in social than cognitive psychological frameworks, I believe it important that cognitive psychologists advocate the fusion between more mechanistically based models of basic cognitive systems and higher order cognition to ensure accurate understanding of the role of WM in complex creativity.

The paths to new connections

In creative problem solving, “dominant solutions or most obvious solution paths will lead to initial failure” (Wiley & Jarosz., 2012, p. 259) and as such, associative connections that were forged due to frequent pairings are unlikely to be divergent, leaving the question of how one arrives at the correct concepts to be compared. I would suggest that this is facilitated by two primary processes that relate to what information enters/remains in WM: inhibition and overriding. Creativity has long been connected to inhibition (e.g. see Beaty & Silvia, 2012) such that more obvious answers must be inhibited in order to ascertain a novel one. For example, in the case of cross-domain analogies, one must inhibit the intuition that such semantically distant pairs are unrelated in order to find the creative connection. The other process, overriding, has strong roots in both the reasoning and creativity literatures. In reasoning, the response provided via Type 1 processing comes to mind quickly and often must be overridden in order to arrive at a normatively correct response. This is precisely the sort of process thought to be indexed in problems such as those within the CRT. A strong intuitive response in situations that could afford a more creative and meaningful relation connection would be first order relational information, such as that exemplified by domain information in assessing analogical relations.

The intuitive sense that pairs drawn from disparate domains are not related, if not initially inhibited, must be assessed and overridden to assess the second order relational information. In creativity research, the oft-described evaluative process (e.g. Wallas, 1926) seems to mirror the type of reflection often described in reasoning research. In both, one assesses the contents of autonomously generated input in a deliberative manner via WM dependent Type 2 processing.

Importantly, my characterization of creativity is not incompatible with evidence that relinquishment of such Type 2 processing can still yield creative output (e.g. Aiello et al., 2012; Jarosz et al., 2012) if creativity is conceptualized as a destination (i.e. output) that can be reached via multiple paths (i.e. types of processing), with some paths being more fruitful than others. To illustrate this point, I return to Mednick's (1962) classic paper. In articulating the different means by which one could achieve a creative solution, Mednick described creativity by serendipity: "The requisite associative elements may be evoked contiguously by the contiguous environmental appearance (usually an accidental contiguity) of stimuli which elicit these associative elements" (p. 221). Though he was referring to the presence of associative elements in the external world, I believe that internal semantic space can be conceptualized in a similar way. Given that relational, or analogical, priming does not occur in the ballistic, automatic fashion that concept priming does (with conscious attention to the relations a requisite for facilitation; Spellman, Holyoak & Morrison, 2001), it seems unlikely that relationally complex creative ideas will frequently emerge spontaneously. Rather, executive intervention potentiates new connections amongst distal concepts that would otherwise remain unearthed. So, despite insight and moments of sudden illumination being real and interesting phenomena, our results would suggest that identifying connections across great semantic distance more often comes via intervening upon autonomous processes with more analytic reasoning.

Neuroscientific and Neurocomputational Models/Evidence

Neuroscientific evidence dedicated to exploring the neural regions that subserve the identification and generation of semantically distant analogies provides plausible ways that complex creativity occurs at the neural level, and is convergent with the theories and evidence discussed to this point. Specifically, much evidence supports the view that creative analogical reasoning relies heavily on frontal regions of the brain, specifically the frontopolar cortex (Bunge et al., 2005; Green, Fugelsang, Kraemer, Shamosh & Dunbar, 2006; Green et al., 2010; Green, Kraemer, Fugelsang, Gray & Dunbar, 2012). As semantic distance between the constituent pairs of the analogy parametrically increased, so does activation of this region. This well-replicated finding is presumed to occur as a function of the role of these regions in the relational integration required for understanding the complex creative connections, with more activation required for more semantically distant elements. More generally, Ramnani and Owen (2004) proposed a model of the cognitive-anatomical architecture of prefrontal function and organization, which identifies the frontopolar cortex as being crucial for the integration of items represented in distal cortical space, suggesting these results may well extend to other instances of complex creativity, such as the RAT, suggesting a future avenue for empirical inquiry. In addition, neuropsychological work with frontotemporal dementia patients has shown that creative ability is contingent upon involvement of frontopolar cortex (de Souza et al., 2010), providing convergent support for the conclusions of such neuroimaging results. Green et al. (2006, p. 134), in summarizing the key role of such regions in creative thinking, eloquently argue that:

> highly developed frontal lobes–frontopolar cortex in particular–make the human brain unique in terms of its structure. It is perhaps not coincidental that the most advanced reaches of the evolved human brain should mediate function at the most advanced reaches of human cognition.

Recent work has also illuminated a complex and widespread neural network thought to comprise the mental workspace which subserves the maintenance and manipulation of concepts and images thought integral for creative thinking (Shlegel et al., 2013). In describing the regions responsible for manipulation and combination of visual images, four core regions were identified that vary in activation as a function of whether one is maintaining or manipulating concepts: dorsolateral pre-frontal cortex, posterior parietal cortex, posterior precuneus, and occipital cortex. Further exploration into the commonalities between these regions and those that underlie the ability to combine verbal concepts should further illuminate the sorts of networks that support advanced creative cognition. In this vein, Schelegel et al. (2013) state that although they only looked at visual representations, they presume “that this network is part of a more general workspace in the human brain in which core conscious processes in frontal and parietal areas recruit specialized sub-domains for specific mental operations” (p. 5) and this issue awaits empirical investigation. Future work should also explore the relative temporal onset of regions in the mental workspace (Schlegel et al., 2013) in different types of creative thinking, as advocated by Kounios and Beaman (2014) while varying the relational complexity of the creative connections forged. Dietrich (2004) has taken important steps in articulating such a view, by describing different types of creative insight and the neural underpinnings of such processes. It seems likely that the frontal cortex could be actively engaged to systematically search through memory in cases where a person is actively seeking a creative solution (such as that described by Nijstad et al. in the persistence pathway). In moments of insight or less consciously sought after creative connections, it could be that a threshold of shared activation between disparate elements in distributed semantic space is reached, forcing online the frontal networks responsible for the maintenance and manipulation of such concepts. A recent meta-analysis of the neuroscientific data pertaining to analogy and metaphor strongly suggests that there is no singular region of the brain that constitutes a creativity module and it is concluded that in order to glean the cortical underpinnings of creative thought, a nuanced approach that considers component processes, task demands, and diverse types of creativity tasks is necessary (see Vartanian, 2012).

An important direction for future research in this area will be the neuroscientific exploration of the manner in which frontal regions interact with relatively ancient structures related to affective reactivity and emotion. An interesting and understudied parallel exists in the reasoning and creativity literatures that could help guide this process. In problem solving of the sort often used in creativity research, a moment of insight or illumination is often described, wherein one experiences the sudden appearance of a solution in consciousness. It is as if the activation pattern associated with the solution induces an affective "feeling of rightness" such that currently active representations that were, until that moment, below the threshold of awareness, are cast into the spotlight of WM and Type 2 processing is engaged. In reasoning research, it has been shown that an affective "Feeling of Rightness" (FOR) determines whether one engages Type 2 processing, such that a higher FOR when trying to answer a question leads to less engagement of Type 2 processing (Thompson, Prowse Turner, Pennycook, 2011). Generally, such work points to the role of affective information guiding analytic processes but little can be said more specifically until further exploration has ensued. As such, an important question, one that I am currently developing behavioural experiments to answer, regards the extent to which a relation exists between feelings of insight and FOR. One quite interesting possibility is that such feelings are highly correlated such that individual differences in one predict differences in the other, with both in turn having an influence on reasoning, creative or not. Neuroscientific study of connectivity between frontal and affective regions should help further understand any such relation. In general, a stronger unification between DPT and creativity should more fully account for the role of such affective responses in cognition, and help specify their role in diverse scenarios.

Another interesting avenue for future research is further fusing of such neuroscientific work with neurocomputational simulations of such biological processes. This approach has proven effective and become more influential in recent years as advances in computing power have enabled computational modelling of hither-to too complex phenomena (e.g. Eliasmith, 2013). Thagard (in press) identifies the key to creative insights to be the competition between and binding of semantic pointers, which he describes as high-level neural representations that are a function of the combination of lower-level neural representations (see Eliasmith, 2013 for more in-depth treatment of semantic pointers). Such a conceptualization maps well to the neural account described by Gabora (2010) and is consistent with the notion that distributed semantic memory representations are combined to arrive at new and creative ideas. Future work should formally fuse Thagard's (in press) work on creativity with DPT views on creativity and reasoning.

Similarly, Holyoak and Thagard's (1989) notion of parallel constraint satisfaction seems to be an important idea for understanding how complex creative connections can be made. In models of thinking that utilize this framework, thinkers must engage in the simultaneous satisfaction of numerous constraints. In first-order creative connections, one is merely constrained such that a generated item is novel but sufficiently related to the original item to still be task-appropriate. In complex creativity, however, more constraints must be made. Holyoak and Thagard (1989) described constraint satisfaction as being an integral component of analogical mapping, and implemented a computational model (Analogical Constraint Mapping

Engine; ACME), that took into account structural, semantic, and pragmatic constraints and these authors have connected such processes to meaningful instances of real world creativity (Holyoak & Thagard, 1995). This model was eventually supplanted by the LISA model (Learning and Inference with Schemas and Analogies; see Hummel & Holyoak, 1997), which has been useful in understanding the role of the frontal lobes in analogical reasoning, for example (Morrison, Krawczyk, Holyoak, Hummel, Chow, Miller, & Knowlton, 2004). Other complex creativity, such as that seen in the RAT can be considered in similar ways, as one must satisfy constraints regarding the relative relations amongst more than a single pair of elements and likely could be modelled in a similar way.

Development of Creativity: Across the Lifespan and Within our Species

Our finding that creative analogical reasoning performance is reliant upon Type 2 processing is consistent with research centered on a developmental milestone dubbed the relational shift (see Gentner, 1988). It has been shown that when faced with conflicting object (surface similarity) and relational congruency (relational similarity), younger children are strongly biased to base judgments on the more basic surface similarity level. With age, however, children undergo a shift in which they transition from this more superficial reasoning into a mode more intensively concerned with relations. Several accounts of this shift have been offered. Gentner and colleagues credit this shift to a growth in the base of relational knowledge from which children can draw to base their decisions (see Gentner & Smith, 2012). In other words, the increased repertoire of relations affords new means of understanding connections. Halford (1993) believes the source of this shift is a maturational increase in processing capacity. This view is predicated on the supposition that relational processing is more resource demanding than matching items on the basis of surface or object level features, and as students develop greater informational processing capacity, they less often rely on the less taxing of the two tactics. Richland, Morrison, and Holyoak (2006), in addition to these factors, identify inhibitory control as another critical component in the shift. Under this view, the ability to suppress or inhibit the lower level similarity information comes with age, accounting for the transition. I believe that all three of these accounts are consistent with the findings herein, as they generally all relate to the dimensions of cognitive ability and cognitive style discussed extensively above. In all cases, the ability or willingness to engage Type 2 thinking (my terminology, not that of the authors) seems critical. Richland and Gentner's positions can be conceptualized as reflecting growth in knowledge and skill, and Halford's view is reminiscent of the type of suppression and overriding that characterizes the intervention of Type 2 processing in favour of relying on the autonomous stream of processing, which is often insufficient for the comprehension of relational information. Interesting and important future research could relate this shift to the ability to solve complex creativity problems such as the RAT. My account would predict that the onset of the relational shift would coincide with advances in the ability to generate solutions to such problems. My view would also predict this shift to correlate with advances in more general reasoning ability and increases in the tendency to engage in the cognitive decoupling characteristic of an analytic cognitive style. Developmental research could modify the CRT and other similar measures to gauge such advances in analytic thinking and relate this to other intellectual achievements across developmental time.

Moving beyond the lifespan of any individual, there is research linking the onset of creative output in our species and cognition. Specifically, the outpouring of creative output in the Paleolithic period has been linked to the development of reasoning abilities largely synonymous with those associated with Type 2 processing (Gabora & Kaufman, 2010). This change is argued to involve: “the onset of symbolic thinking, cognitive fluidity, and the capacity to shift between convergent and divergent or explicit and implicit modes of thought. Also, the emergence of meta-cognition enabled our ancestors to reflect on and even override their own nature” (Gabora & Kaufman, 2010, p. 293). Interestingly, this behavioural shift did not coincide with anatomical changes, suggesting, as we do at a more micro-level, that creativity is related to not just ability, but willingness to engage in particular types of processing. Put another way, it was not a change in the structure of our brains that afforded the massive advances in the way we solved problems in the world, but rather the way we used that brain. Such a characterization is clearly congruent with the conceptualization of the types of cognitive processes involved in complex creativity and conjures a view that compels us to capitalize upon these cognitive gifts bestowed over evolutionary time. One interesting possibility is that enhancement of Secondary WM abilities helped bring on a new era of creativity. Although difficult to understand the mechanistic nature of such ancient advances, the fact that such theory converges with the developmental, experimental, correlational, and neuroscientific evidence allows greater confidence in the nature of such claims and evidence.

Enhancing Creativity

An important issue addressed in this dissertation is the extent to which we can augment creativity. I attempted, via several cues, to enhance the ability to make creative connections but was largely unsuccessful. Green et al. (2012) did find significant effects of cuing participants to think more creatively but as discussed earlier, the impact of their intervention was sufficiently small that it is far from obvious that such strategies will yield creative solutions in more ecologically valid settings. Given the pattern of results here, I would argue that the most effective means of enhancing ability in complex creativity will come from interventions aimed at longer term thinking dispositions. It seems clear from the results here that telling people to "think more analytically" is relatively ineffective, and as such, we must instead focus on instilling analytic approaches to thinking over the longer term.

In terms of our finding that instruction type and longer term disposition interacted, it is worthwhile to consider Howard-Jones' (2002) Dual State Model. This model describes shifting between associative and analytic modes of thought as integral to creative thought. It is interesting to note that although this model is very similar to the ideas I put forth here, Howard-Jones (2002) seems to focus on the opposite emphasis when it comes to promoting creative output. In particular, this author, similar to Wiley and Jarosz (2012), focuses on fixation as being a primary obstacle to creative generation. That is to say, people need help disengaging from the analytic stream to allow the associative stream to engage its generative powers, and even prescribes means by which to encourage this shift. Such a notion that one must relinquish analyticity in favour of associative processing is very much at odds with the specific data here and generally with default-interventionist forms of DPTs. Given that most of our waking lives are spent processing information primarily via autonomous Type 1 processing, it seems counter-productive to admonish the relinquishment of Type 2 thinking as decades of reasoning research show that such processing is already used quite sparingly. As discussed, many existing models of creativity have identified that two types of thinking are implicated in the creative process, but little has been said about the optimal distribution of engagement of either type of processing. Here, I not only argue that creative thinking is dependent upon two types of processing, but find evidence that relatively more Type 2 processing is beneficial for certain sorts of creative thinking.

Gabora (2010) similarly seems to focus more strongly on the manner in which a de-focusing of attention results in creativity. For example, she describes the way that de-focusing attention recruits neuronal activation of cliques that would be unavailable: “if one were in an everyday relatively convergent mode of thought, but would be included if one were in an associative mode of thought” (p. 8). My work, on the other hand, suggests that the focusing of attention (specifically, the assessment of relational information in WM) is critical in complex creativity and questions the idea that analytic modes of thought are “everyday”. Given that default-interventionist DPTs presume that most people are cognitive misers, who only as sparingly as needed engage Type 2 processing, it seems to me that imploring one to more often disengage focus is less likely to be the key to creativity as this is the most frequently engaged sort of process. A way of reconciling this issue is recognizing that although my focus is upon the need for engaging Type 2 processing, this does not mean that Type 1 processing is not integral to the process, but simply that this is actually the natural “everyday” mode of processing. Another way of synthesizing this work would be to qualify whether the creativity at hand is relationally constrained as it must be in complex creativity. Gabora’s (2010) view might require qualification to accommodate second, rather than first-order relational information, given the already discussed nature of relational priming (Spellman, Holyoak, & Morrison, 2001).

Further to this point, under the DPT discussed earlier, relaxed, associative, Type 1 processing constitutes the normal mode of operation for humans and working memory dependent analytic thinking is engaged much more infrequently. Given the ubiquity of Type 1 processing in cognition, evidence that such thinking is related to creativity at the state level should not be surprising, as it is implicated in *all* thought. In other words, I do not posit that Type 1 processing is unrelated to creative thinking, but simply that it bears no *special* relation to creative thinking. I argue that although Type 1 processing is necessarily implicated in advanced thought, Type 2 processing is the catalytic factor. Importantly, as already noted, an interpretation of the sort laid out in this dissertation still accommodates the notion, as evidenced by a large number of studies (e.g. Wiley & Jarosz, 2012), that too much interjection of Type 2 processing can hinder the creative process, though I do not think it important for measures to promote innovation and creative thought. Again, under a default-interventionist DPT framework, it is presumed that humans use Type 2 processing relatively sparingly, so in most instances, the use of executive processes would not be harmful in more ecological settings as the natural rate of interjection is lower than that required to disrupt the spread of activation to the point of decrement. Of all the scenarios where such a situation might emerge, one of the most likely seems, to me, a psychological experiment where one is presented a quite obviously difficult problem, as is often used in insight and creativity studies. One is motivated to consider and solve the problem in a short temporal window. One is likely to remain in an intensely focused state for that brief interval, and as such show evidence of a narrowed search through semantic space. Such focused processing is sufficiently costly in time and energy that it is unlikely to persist in the long term, thus precluding a harmful effect in the larger scale. Indeed our evidence that across many trials, the ability to interject more frequently was positively related to performance, though this supposition would benefit from evidence from longer term studies of real world creativity.

That said, one particularly interesting area for future directions is individual differences in contextual focus, the relaxation of attention, cognitive dishibition and other factors related to the relinquishment of Type 2 processing (Eysenk, 1995; Martindale, 1999; Vartanian, 2009). Not only would further consideration of such factors more fully situate my work with the broader creativity literature, it provides interesting impetus for refinement of DPTs of cognition.

Specifically, Stanovich (2009), a leading proponent of DPTs has argued that few meaningful, continuous differences exist in the way that Type 1 processing operates across individuals but there is emerging evidence that this may not be entirely true. As already noted, Beaty, Silvia, Nusbaum, Jauk, and Benedek (2014) found support for the notion that differences in both executive and associative tendencies can account for variation in creative ability. Kaufman, DeYoung, Gray, Jiménez, Brown, and Mackintosh (2010) showed that implicit learning can be conceived as an ability that is independent of explicit learning, suggesting there may be utility in questioning strong claims that autonomous processing is largely uniform across individuals. As already suggested, I would predict executive factors to be relatively more influential and associative factors relatively less important in complex creativity than in other creativity tasks, but more empirical exploration is necessary. Further integration of creativity and reasoning research can be mutually informative, and could further qualify the nature of the interaction between Type 1 and 2 processing at both basic and specific levels.

Climate of creativity

The fact that executive processing seems critical for complex creativity is important for the way we consider the allocation of attention when reasoning. As noted, task level meta-cognitive monitoring of success on the problem at hand might deter these resources from being dedicated to actually focusing on the relevant task. The current concerns theory (Klinger, 1977) describes how mind wandering often leads one to think of things that are currently of concern to people in terms of their goals. In the case of creativity problems, it is quite conceivable for people to reflect on their progress, which hinders success through occupation of crucial cognitive resources required to actually solve the problem. In more ecological settings such a state of affairs seems to resemble the fixation plaguing some innovators. Poincaré (1913), for example, described futile attempts to solve a certain problem he intensely worked on, only to solve it when he left to take a vacation. Mozart was quoted as saying: “When I am traveling in a carriage, or walking after a good meal, or during the night when I cannot sleep, it is on such occasions that ideas flow best and most abundantly.” Explanations of such anecdotes have often pointed to the unconscious or associative implicit processing as the driving force for such ideas. However, an alternative means of interpreting such a trend is to assume that the reprieve afforded greater access to the executive resources formerly wasted on worrying about the problem, better preparing the mind to seize the otherwise unearthed common elements of a hitherto unsolved problem in WM (see Thagard in press, for a similar argument about incubation and semantic pointers).

An interesting convergence comes from the role of nature in cognition. Berman, Jonides, and Kaplan’s (2008) attention restoration theory posits that urban environments capture attention relatively more dramatically than natural environments. As such, time spent in nature allows restoration of directed-attention abilities, leading to cognitive benefits. Atchley, Strayer, and Atchley (2012) explored whether such executive restoration led to enhanced creativity by comparing RAT performance amongst a group about to embark on a nature hike, versus those who had already spent several days in the wilderness. They found a dramatic improvement in creative performance, suggesting that such restful periods in which one’s attentional reserves are replenished might be critical for creativity, and supporting my view regarding complex creativity.

The notion that recuperation/freeing of WM dependent executive resources enhance creativity has implications for the climate in which scientists and other innovators operate. It is commonly accepted that modern academicians are under intense pressure to produce at all costs.

For example, Peter Higgs, the physicist behind the Higgs boson particle stated that he would not get an academic job today and has a hard time imagining that he would have had enough peace and quiet in the present sort of climate to make the groundbreaking advances for which he became famous (Aitkenhead, 2013). With this kind of pressure, it seems that the concern of creating an idea could consume valuable cognitive resources that could otherwise be used to try and solve the problems they seek to study. In a similar vein, Wenger, Schneider, Carter, and White (1987) described the “paradoxical effects of thought suppression”, suggesting that trying to not think of something actually has the opposite effect whereby that which is attempted to be suppressed permeates one’s thoughts. Similarly, I wonder if the intense pressure to produce in science and innovation has a similar effect whereby a great desire to produce an innovation actually precludes creative thinking due to counter-productive meta-level monitoring of one’s progress, which comes at the cost of concerted creative thinking.

Research focused on cultivating creativity notes that one must not only have domain general abilities in problem solving but domain specific knowledge of the topics at hand (Mayer, 1983). Such a characterization is highly congruent with our findings that both ACS and CA predicted performance on complex creativity tasks. People had to have sufficient knowledge in order to have the requisite relational structure to connect in semantic memory, as well as the disposition to engage the necessary Type 2 processing to ensure one becomes conscious of this underlying connectivity. Such a conceptualization is also congruent with much more recent reviews of the efficacy of creativity training. Scott, Leritz and Mumford (2004) examined the factors that contribute to the effectiveness of creativity training programs and identified the relatively more successful programs as being those that focus on honing general cognitive skills in the context of domain appropriate problems. Interestingly, it has been suggested that neuroscientific work regarding the regions underlying creative thought can been used to suggest means by which to foster creativity (Vartanian, 2013). This author has argued that there are two particularly interesting ways that creativity can be enhanced. One is through heightening neural efficiency and fluid intelligence. Higher fluid intelligence is thought to entail greater efficiency in the deployment of cortical regions, and it is has been shown that behavioural interventions can enhance such efficiency, suggesting a means by which to be more creative. The other possibility is enhancing creativity through WM training. The notion that such training could lead to improvement is supported by both the evidence and theoretical orientation offered here, and future work would be well served to qualify the efficacy of such training regimens with pre-existing individual differences in not just WMC, but ACS and CA. It truly is an exciting time for such interventions, as creativity can now be understood from many distinct and complementary levels of analysis, including the neural.

"Giving away" creativity research

Mayer (1981) in *The Promise of Cognitive Psychology*, claimed that "as we learn more about the use of strategies in solving complex problems, we will be able to do a better job of teaching people to solve complex problems" (p. 104). Similarly, Scott, Leritz and Mumford (2004) state that "creativity training should be subject to revision and extension as we develop a better understanding of creative thought and better understanding of the approaches that might be used to enhance creative thought" (p. 383). In this thesis, I hope to have provided more solid footing by which to characterize the types of processing that allow one to make creative connections, and in turn, a stronger ability to enhance creativity throughout society. Mayer (1983) expressed dismay that most creativity training studies yielded little in the way of global skills that enhance creativity and can be learned independently of the actual content area.

However, my finding that greater engagement of Type 2 processing leads to greater ability in connecting semantically distant relations suggests a promising avenue in this end and converges with the work of Vartanian (2013). Furthermore, knowing that this disposition is correlated, but independent from more general fluid intelligence suggests that such a trait might well be able to be cultivated in the longer term.

An emerging trend in reasoning research, which relates to my admonishment to encourage analytic thinking to promote creativity, is the effort to share results and theory regarding the way our minds typically operate in order to help people become more effective information processors. For example, Lilienfield (2011) discusses “giving de-biasing away”. In this paper, he admonishes that reasoning researchers share the pertinent results which show how heuristics and the general disinclination to engage Type 2 processing damage our decision making ability in hopes of showing citizens means by which to avoid falling prey to the perils of such paltry use of our advanced cognition.

In terms of complex creativity, knowing that measures predicting reliance on such heuristics are negatively related to creative ability provides a framework by which to center educational programs on overriding initial autonomous intuitions to arrive at novel solutions. Recent work finds that explicit instruction on how to think more analytically coupled with practice doing so is effective in improving critical thinking (Heijltjes, Van Gog & Pass, 2014), suggesting that such longer term training and intervention could be fruitful. Such a combination of factors thought to enhance creativity leads one to question the relative value of work that focuses on more ephemeral inductions or admonishments to enhance creativity, as it seems society would benefit from longer term educational and cognitive training interventions. In general, a stronger unification of reasoning and creativity interventions and training will likely prove efficacious as my work suggests that long term cultivation of creative thinking will be more fruitful than efforts at short term induction of such thinking.

In sum, I would contend that the detrimental impact of executive thought in the creative process is overstated. We, as a society, should be weary of intentional attempts to shut the doors of analyticity in hopes of opening the window of creativity, for the biggest of ideas, those that are complex, comprised of deeply meaningfully inter-connected relations, and that are most crucial to the continued success of our species might not fit through that window when swept along by the wind of spreading activation. Instead, such multifarious combinations of concepts must be carefully carried in a controlled fashion through the door of analyticity.

Limitations and Future Directions

Throughout this thesis I have largely focused on what my investigation allows us to understand but have said less about what it cannot tell us. In what follows, I describe several limitations and constraints that are of interest in critically assessing this work (though I admittedly maintain an optimistic tenor in evaluating the implications of this work) and suggest areas of study for future research that would quell current concerns.

One obvious point of contention with my work methodologically is the choice of individual difference measures. I improved upon this from Experiment 4 to Experiment 5 by including performance-based measures in addition to a self-report questionnaire. However, this work was still limited in that the measures used were by no means exhaustive and often were quite simple, mostly due to practical constraints. It is quite impressive that such limited indices of processing types were able to so effectively account for variance and demonstrate the power of the DPT perspective. However, in an ideal world, such an investigation would have used full scale intelligence measures and more complete assessments of cognitive style, and even personality variables. Future work could systematically expand the scope of individual differences measures (and as such, also broaden the theoretical scope). To this end, I have collected data from around 100 participants in follow-up work (not included in this dissertation) while measuring more complete ACS and CA measures in an online task, the analogical reasoning task used here, the RAT, the Raven's Progressive Matrices, an automated WM span from Engle, and a questionnaire indexing visual imagery ability. This follow-up work should provide deeper insights into the complex pattern of inter-relations unearthed in my investigations within this dissertation. In addition, by measuring WM ability using a variety of measures, this follow-up work will provide a more direct test of the role of WM in complex creativity. Future work could use more precise cognitive indices of WM capacity, inhibition and other factors to more precisely understand the creative process, and even better understand what exactly leads one to more often and/or more effectively engage Type 2 processing.

Perhaps a more fundamental limitation of the current work is the very nature of the primary task used. The analogy task used here took an approach in which experimental control was prized over ecological validity. Such an approach has proven extremely useful throughout the history of psychological science; however, such control does come at a cost. Aspects of the over-arching processes at play when such reasoning operates outside of the confines of the experimental setting are unable to be understood due to the design. Here, through the use of a constrained task that isolated the factor of semantic distance while holding the structure of the analogies constant, I was able to shield my investigation from certain noisy processes, and was accordingly able to hone more specifically upon sub-processes of interest. To my disadvantage though, elimination of such variance precludes a broader view.

To address this limitation, future work could begin to expand the logic of this work to progressively more noisy settings. For example, other investigations have had participants generate the C:D terms rather than identify whether given items are analogies. I would be extremely interested to see future work that utilizes similar manipulations and individual difference measures to explore the attempted generation of within and cross-domain analogies. I predict an analogous set of results to my work would emerge. For example, under dual-task conditions one should have a harder time generating a cross-domain than within-domain analogy. A chronometric approach could reveal that it takes longer to generate cross than within-domain analogies. I would also predict that those higher in ACS could more effectively retrieve cross-domain analogies than those lower in ACS, given the mechanisms I discuss.

Although having participants generate the C:D terms incorporates other processes, one might still argue that this is too artificial to understand how analogy of the sort studied here operates ‘in the wild’. Future research could, however, explore such issues by investigating individual differences in analogy use in real world problem solving situations as a function of certain cognitive variables. Dunbar and Blanchette (2001) have employed a naturalistic approach to studying analogy, what they called *in vivo* methods, whereby they tracked the use of analogies in leading scientific laboratories. Such a method affords insight into the preponderance and utility of analogies in a real world dynamic environment. I would be very curious to know how differences in ACS and CA relate to how analogy is used both within and across individuals.

Even more ecological validity could come from expanding beyond observational methods in finite time periods, as in a laboratory method. Future research should more often engage in studies on problem solving over longer periods of time as a function of individual differences. An important avenue for such exploration could come from Smartphone technology's role in psychological research in that round the clock data can be collected (Miller, 2012). Billions of people worldwide now carry devices that could be used to index problem solving strategies. I would be very curious to understand how individual differences in ACS and CA relate to real world innovation. An especially interesting question in that vein regards the relation between dispositions to think analytically when reasoning and longer term perseverance and effort toward goals, and how these factors contribute to creativity. Galton (1892) long ago discussed the role of perseverance in attaining the heights of achievement and Duckworth, Peterson, Matthews, and Kelly (2007) have found grit, long term passion and perseverance toward a goal, to be influential in determining long term success and these factors are likely key to achieving an eminently important creative contribution to humanity. If we wish to reach our full creative and intellectual potential, as a society and as individuals, future work will be very well-served to make use of emerging technology that will afford us the chance to peer upon the characteristics of creative achievers in a manner unavailable to previous generations. Such potential for big data and long term tracking of outcomes, accompanied by advances in understanding the mechanistic underpinning of complex creativity will afford future researchers unprecedented insight into a systems view of creativity that incorporates the neurological, cognitive, personality, group, social environment, and cultural/societal correlates of creative thinking (see Hennessy & Amabile, 2010). In particular, I think that universities, research centres, innovation-oriented corporations and institutions, think tanks and other hubs of innovation should be the focus of efforts to track creativity amongst real world innovators through a systematic look at what potentiates creative output from diverse levels of analysis.

Conclusion

Although more research is focused upon creativity now than ever before, the field remains fragmented and lacks cohesion. When one does adopt a broader perspective, it becomes apparent that communication may not be the sole problem as the anecdotal, correlational, and experimental evidence regarding creativity presents a disjointed, and even seemingly contradictory, collection of findings. In this thesis I delineate complex creativity from other measures of creative thinking, providing a more qualified look at a complicated construct. By linking complex creative thinking to meta-theoretical frameworks in reasoning research that accommodate both notions of ability, as well as dispositional factors related to thinking style, I meld vestiges of classic work tying intellectual capacity and creativity (e.g. Galton, 1892) with that following Guilford's (1950) admonishments to study the aspects of the creative process that can be seen in isolation from intelligence.

Such a view synthesizes diverse findings and perspectives within creativity research under a broad and influential class of models. A major contribution of the current work is the emphasis placed on a mechanistic approach in which the cognitive and neural processes that underlie thinking and reasoning are applied to understanding the means by which a creative connection is forged. Such an approach grounds creativity in the broader cognitive and neuroscientific literature, allows the process to be characterized at a fine temporal resolution, and affords greater integration across domains of creativity research. Such a conceptualization is compatible with extant theoretical frameworks focused on the types of thinking in various stages of the creative process (Allen & Thomas, 2011), the interplay between associative and analytic thinking at the neural level (Gabora, 2010), the role of intelligence in creativity (Silvia & Beaty, 2012), theories that describe different paths to creativity (de Dreu, Nijstad, Baas, Wolsink & Roskes, 2012), the emergence of creative thinking in the human species (Gabora & Kaufman, 2010), eminent and real-world creativity (Holyoak & Thagard, 1995; Dunbar & Blanchette, 2001) and situates complex creativity alongside other types of cognition thought to be uniquely human (Penn, Holyoak, & Povinelli, 2008). Our capacity to hold, manipulate, and understand the complex inter-relations amongst distantly connected concepts sets us apart from other creatures and has allowed us to reason our way to new and useful means of understanding and changing the world around us (Ouspensky, 1950; Stanovich, 2004; Byrne, 2005).

Ouspensky (1950) observed that, "Man is a machine, but a very peculiar machine. He is a machine which, in right circumstances, and with right treatment, *can know that he is a machine*, and, having realized this, he may find the ways to cease to be a machine." It is important to understand the means by which we can intervene upon the way we think in a melioristic fashion to avoid only relying on automatic and associative thinking to produce powerful innovations. I have high hopes for humanity's capacity to do so, for "…what is really singular about humans [is that [we] gain control of [our] lives in a way unique among lifeforms on Earth—by rational self-determination" (Stanovich, 2004). It is my sincere hope that future work on creative cognition can continue to develop stronger understanding of the processes at play in such thought so as to allow our species to face the great challenges that await solution, but cannot be left too long, not merely by awaiting the emergence of a solution spontaneously in consciousness, but rather in a controlled and analytic manner through the utilization of our most advanced cognitive capabilities.

References

Aiello, D., Jarosz, A.F., Cushen, P.J., & Wiley, J. (2012). Firing the executive: When an analytic approach does and does not help problem solving. *Journal of Problem Solving*, *4*, Article 6.

Aitkenhead, D. (2013, December 6). Peter Higgs: I wouldn't be productive enough for today's academic system. *The Guardian*. Retrieved from: http://www.theguardian.com/science/2013/dec/06/peter-higgs-boson-academic-system

Allen, A.P. & Thomas, K.E. (2011). A dual process account of creative thinking. *Creativity Research Journal*, *23*, 109-118.

Ansburg, P.I. and Hill, K. (2003). Creative and analytic thinkers differ in their use of attentional resources. *Personality and Individual Differences, 34*, 1141-1152.

Atchley, R., Strayer , D., & Atchley, P. (2012). Creativity in the wild: Improving creative reasoning through immersion in natural settings. *PLoS ONE, 7*, 1-3.

Ausubel, D.P. (1964). Creativity, general creative abilities, and the creative individual, Psychology in the Schools, 1, pp. 344-347.

Ball, L., & Stevens, A. (2009). Evidence for a verbally-based analytic component to insight problem solving. In N. Taatgen & H. van Rijn (Eds.), *Proceedings of the 31st Annual Conference of the Cognitive Science Society* (pp. 1060–1065). Austin, TX: Cognitive Science Society.

Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W., Franklin, M. S., & Schooler, J. W. (2012). Inspired by distraction: Mind wandering facilitates creative incubation. *Psychological Science, 23*, 1117–1122.

Barr, N., Pennycook, G., Stolz, J. A., & Fugelsang, J. A. (2014). Reasoned connections: A dual-process perspective on creative thought. *Thinking & Reasoning*. Advance online publication. doi: 10.1080/13546783.2014.895915

Basadur, M. S., Graen, G., & Green, S. (1982). Training in creative problem solving: Effects on ideation and problem finding and solving in an industrial research organization. *Organizational Behavior and Human Performance, 30,* 41–70.

Batey, M., Chamorro-Premuzic, T. & Furnham, A.F. (2010). Intelligence and personality as predictors of divergent thinking: The role of general, fluid and crystallised intelligence. *Thinking Skills and Creativity, 4*, 1.

Batey, M., Furnham, A.F., & Safiullina, X. (2010). Intelligence, General Knowledge and Personality as Predictors of Creativity. *Learning and Individual Differences, 20,* 5.

Beaty, R.E., & Silvia, P.J. (2012). Why do ideas get more creative across time? An executive interpretation of the serial order effect in divergent thinking tasks. *Psychology of Aesthetics, Creativity, and the Arts, 6,* 309-319.

Beaty, R. E., & Silvia, P. J. (2013). Metaphorically speaking: Cognitive abilities and the production of figurative language. *Memory & Cognition*, 41, 255–267.

Benedek, M., Franz, F., Heene, M., & Neubauer, A. C. (2012). Differential effects of cognitive inhibition and intelligence on creativity. *Personality and Individual Differences*, *53*, 480–485.

Benedek, M., Beaty, R., Jauk, E., Koschutnig, K., Fink, A., Silvia, P. J.,& Neubauer, A. C. (2014). Creating metaphors: The neural basis of figurative language production. *NeuroImage*, 90, 99–106.

Benedek, M., & Neubauer, A. C. (2013). Revisiting Mednick's model on creativity-related differences in associative hierarchies: Evidence for a common path to uncommon thought. *Journal of Creative Behavior*, 47, 273–289.

Berman, M.G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science, 19,* 1207–1212.

Binder , J. R. & Desai, R. H. (2011). The neurobiology of semantic memory. *Trends in Cognitive Neuroscience, 15*, 527-536.

Bowden, E. M., & Jung-Beeman, M. (2003). Normative data for 144 compound remote associate problems. *Behavior Research Methods, Instruments, & Computers, 35,* 634–639.

Bowden, E. M., Jung-Beeman, M., Fleck, J., & Kounios, J. (2005). New approaches to demystifying insight. *Trends in Cognitive Sciences*, *9*, 322–328.

Bunge, S. A., Wendelken, C., Badre, D., & Wagner, A. D. (2005). Analogical reasoning and prefrontal cortex: Evidence for separable retrieval and integration mechanisms. *Cerebral Cortex, 15,* 239-249.

Byrne, R. M. J. (2005). *The rational imagination: How people create alternatives to reality*. Cambridge, MA: MIT Press.

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology*, *42*, 116-131.

Campbell, D. T. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Review*, *67*, 380–400.

Chan, J., Paletz, S. & Schunn, C.D. (2012). Analogy as a strategy for supporting complex problem solving under uncertainty. *Memory & Cognition*, *40,* 1352-1365.

Chein, J.M., & Weisberg, R.W. (2014). Working memory, insight, and restructuring in verbal problems: Analysis of compound remote associate problems. *Memory & Cognition, 42, 67-83.*

Christensen, P. R., Guilford, J. P., & Wilson, R. C. (1957). Relations of creative responses to working time and instructions. *Journal of Experimental Psychology, 53,* 82–88.

Cosgrove, M. (1995). A case study of science-in-the-making as students generate an analogy for electricity. *International Journal of Science Education, 17,* 295-310.

Dagher, Z. R. (1995a). Does the use of analogies contribute to conceptual change? *Science Education, 78,* 601-614.

Dagher, Z. R. (1995b). Analysis of analogies used by teachers. *Journal of Research in Science Education, 32,* 259-270.

de Dreu, C.K.W., Nijstad, B.A., Baas, M., Wolsink, I. & Roskes, M. (2012). Working memory benefits creative insight, musical improvisation and original ideation through maintained task-focused attention. *Personality and Social Psychology Bulletin, 38*, 656-669.

De Neys, W. & Glumicic, T. (2008). Conflict monitoring in dual process theories of thinking. *Cognition*, *106*, 1248-1299.

de Souza, L. C., Volle, E., Bertoux, M., Czernecki, V., Funkiewiez, A., &Levy, R. (2010). Poor creativity in frontotemporal dementia: A window into the neural bases of the creative mind. *Neuropsychologia, 48,* 3733–3742.

Dietrich , A. (2004). The cognitive neuroscience of creativity. *Psychonomic Bulletin & Review*, *11*, 1011-1026.

Dijksterhuis, A., & Meurs, T. (2006). Where creativity resides: The generative power of unconscious thought. *Consciousness and Cognition*, *15*, 135-146.

Dorfman, J., Shames, V. A., & Kihlstrom, J. F. (1996). Intuition, incubation,and insight: Implicit cognition in problem solving. In G. Underwood (Ed.), *Implicit cognition* (pp. 257–296). Oxford, England: Oxford University Press.

Duckworth, A.L., Peterson, C., Matthews, M.D. and Kelly, D.R. (2007). Grit: Perseverance and passion for long-term goals. *Journal of Personality and Social Psychology, 92,* 1087-1101.

Dunbar, K., & Blanchette, I. (2001). The in vivo/in vitro approach to cognition: The case of analogy. *Trends in Cognitive Sciences, 5,* 334–339.

Ebbinghaus, H. (1885). *Über das Gedchtnis. Untersuchungen zur experimentellen Psychologie*. Leipzig: Duncker & Humblot; the English edition is Ebbinghaus, H. (1913). *Memory. A Contribution to Experimental Psychology*. New York: Teachers College, Columbia University (Reprinted Bristol: Thoemmes Press, 1999).

Eliasmith, C. (2013). *How to build a brain: A neural architecture for biological cognition*. Oxford University Press.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, 11, 19-23.

Epstein, S. (1973). The self-concept revisited or a theory of a theory. *American Psychologist, 28*(5), 404-416.

Evans, J. B. T. (2008). Dual-processing accounts of reasoning, judgment, and social cognition. *Annual Review of Psychology, 59*, 255–278.

Evans, St. J. B. T., & Stanovich, K. E. (2013). Dual-process theories of higher cognition: Advancing the debate. *Perspectives in Psychological Science, 8,* 223-241.

Eysenck, H. J. (1995). *Genius: The natural history of creativity*. Cambridge, UK: Cambridge University Press.

Fenker, D., Waldmann, M., & Holyoak, K. (2005). Accessing causal relations in semantic memory. *Memory & Cognition, 33*, 1036-1046.

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). Creative cognition: Theory, research, and applications. Cambridge, MA: MIT Press.

Frankish, K., & Evans, J. St. B. T. (2009). The duality of mind: An historical perspective. In J. St. B. T. Evans & K. Frankish (Eds.), *In two minds: Dual processes and beyond* (pp. 1–30). Oxford, England: Oxford University Press.

Frederick, S. (2005). Cognitive reflection and decision making. *The Journal of Economic Perspectives*, *19*, 25–42.

Gabora, L. (2003). Contextual focus: A cognitive explanation for the cultural transition of the Middle/Upper Paleolithic. In (R. Alterman & D. Hirsch, Eds.) *Proceedings of the 25th Annual Meeting of the Cognitive Science Society* (pp. 432-437), Boston MA, July 31-August 2. Hillsdale NJ, Lawrence Erlbaum Associates.

Gabora, L. (2010). Revenge of the 'neurds': Characterizing creative thought in terms of the structure and dynamics of human memory. *Creativity Research Journal, 22*, 1-13.

Gabora, L. & Kaufman, S. (2010). Evolutionary perspectives on creativity. In (J. Kaufman & R. Sternberg, Eds.) *Cambridge Handbook of Creativity*. (pp. 279-300). Cambridge UK: Cambridge University Press.

Galton, F. (1892). *Heredity genius: An inquiry into its laws and consequences*. London: Macmillan.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7*, 155–170.

Gentner, D. (1988). Metaphor as structure mapping: The relational shift. *Child Development, 59*, 47–59.

Gentner, D., & Smith, L. A. (2013). Analogical learning and reasoning. In D. Reisberg (Ed.), *The Oxford handbook of Cognitive Psychology* (pp. 668-681). New York, NY: Oxford University Press.

Gick, M. L., & Holyoak, K. J. (1980). Analogical problem solving. *Cognitive Psychology*, *12*, 306–355.

Gilhooly, K. J., Fioratou, E., Anthony, S. H., & Wynn, V. (2007). Divergent thinking: Strategies and executive involvement in generating novel uses for familiar objects. *British Journal of Psychology*, *98*, 611–625.

Green, A., Cohen, M., Kim, J., & Gray, J. (2012). An explicit cue improves creative analogical reasoning. *Intelligence*, *40*, 598-603.

Green, A., Fugelsang, J., Kraemer, D., & Dunbar, K. (2008). The micro-category account of analogy. *Cognition*, *106*, 1004-1016.

Green, A., Fugelsang, J., Kraemer, D., Shamosh, N., & Dunbar, K. (2006). The dynamic role of prefrontal cortex in reasoning and abstract thought. *Brain Research, 1096*, 125-137.

Green, A. E., Kraemer, D. J. M., Fugelsang, J. A., Gray, J. R., & Dunbar, K. N. (2010). Connecting long distance: Semantic distance in analogical reasoning modulates frontopolar cortex activity. *Cerebral Cortex, 20*, 70–76.

Green, A. E., Fugelsang, J. A., Kraemer, D. J. M., Gray, J. R., & Dunbar, K. N. (2012). Neural correlates of creativity in analogical reasoning. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 38*, 264–272.

Gupta, N., Jang, Y., Mednick, S. C., & Huber, D. E. (2012). The road not taken: Creative solutions require avoidance of high-frequency responses. *Psychological Science*, 23, 288–294.

Guilford, J.P. (1950). Creativity. *American Psychologist, 5,* 444-454.

Halford, G. S. (1993). *Children's Understanding: The Development of Mental Models*. Hillsdale, NJ: Erlbaum.

Harrison, A., & Treagust, D. (2006). Teaching and learning with analogies—friend or foe. In P. Aubusson, A. Harrison, & D. Ritchie (Eds.), *Metaphor and analogy in science education* (pp. 11 – 24). Dordrecht, The Netherlands: Springer.

Heijlties, A., van Gog, T., & Paas, F. (2014). Improving student's critical thinking: Empirical support for explicit instructions combined with practice. *Applied Cognitive Psychology*, DOI: 10.1002/acp.3025

Hennessy B.A & Amabile, T.M. (2010). Creativity. *Annual Review of Psychology*, *61*, 569-598.

Holyoak, K. J., & Thagard, P. (1989). Analogical mapping by constraint satisfaction. *Cognitive Science,* 13, 295-355.

Holyoak, K. J. & Thagard, P. (1995). *Mental leaps: Analogy in creative thought.* Cambridge, MA: MIT Press.

Holyoak, K. J. (2012). Analogy and relational reasoning. In K. J. Holyoak & R. G. Morrison (Eds.), *The Oxford handbook of thinking and reasoning* (pp. 234–259). New York, NY: Oxford University Press.

Hofstadter, D. (2001). Analogy as the core of cognition. In D. Gentner, K.J. Holyoak, & B.N. Kokinov (Eds.), *The Analogical Mind: Perspectives from Cognitive Science* (pp. 499–538). Cambridge, MA: MIT Press/Bradford Book.

Howard-Jones, P. A. (2002). A dual-state model of creative cognition for supporting strategies that foster creativity in the classroom. *International Journal of Technology and Design Education, 12*, 215–226

Huang, M. H., & Hauser, R. M. (1998). Trends in Black–White test score differentials: II the WORDSUM vocabulary test. In U. Neisser (Ed.), *The rising curve: Long-term gains in IQ and related measures* (pp. 303–332). Washington, DC: American Psychological Association.

Hummel, J. E., & Holyoak, K. J. (1997). Distributed representations of structure: A theory of analogical access and mapping. *Psychological Review*, *104,* 427-466. Reprinted in T. A. Polk & C. M. Siefert (Eds.) (2002), Cognitive modeling. Cambridge, MA: MIT Press.

Isen, A. M., & Daubman, K. A. (1984). The influence of affect on categorization. *Journal of Personality and Social Psychology*, *47,* 1206–1217.

Jarosz, A. F., Colflesh, G. J. H., & Wiley, J. (2012). Uncorking the muse: Alcohol intoxication facilitates creative problem solving. *Consciousness and Cognition, 21,* 487–493.

Jauk, E., Benedek, M., & Neubauer, A. C. (2014). The road to creative achievement: A latent variable model of ability and personality predictors. *European Journal of Personality*, 28, 95–105.

Jiang, M., & Thagard, P. (forthcoming). Creative cognition in social innovation. *Creativity Research Journal*.

Kahneman, D. (2011). *Thinking, Fast and Slow*. New York: Farrar, Straus, and Giroux.

Kaufman, S.B., DeYoung, C.G., Gray, J.R., & Jimenez, L., Brown, J.B., & Mackintosh, N. (2010). Implicit learning as an ability. *Cognition, 116*, 321-340.

Kim, S., Hasher, L., & Zacks, R. T. (2007). Aging and a benefit of distractability. *Psychonomic Bulletin & Review*, 14, 301-305.

Klinger, E. (1977). *Meaning and void: Inner experience and the incentives in people's lives.* Minneapolis: University of Minnesota Press.

Kounios, J., Frymiare, J. L., Bowden, E. M., Fleck, J. I., Subramaniam, K., Parrish, T. B., & Jung-Beeman, M. (2006). The prepared mind: Neural activity prior to problem presentation predicts subsequent solution by sudden insight. *Psychological Science*, *17,* 882–890.

Kounios J. & Beaman M. (2014). The Cognitive Neuroscience of Insight. *Annual Review of Psychology, 65, 71-93.*

Kuhn, T. (1962). *The structure of scientific revolutions.* Chicago: University of Chicago Press.

Landauer, T. K., & Dumais, S. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction and representation of knowledge. *Psychological Review*, *104*, 211–240.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). Introduction to latent semantic analysis. *Discourse Processes*, 25, 259–284.

Lee, C. S., & Therriault, D. J. (2013). The cognitive underpinnings of creative thought: A latent variable analysis exploring the roles of intelligence and workingmemory in three creative thinking processes. *Intelligence, 41*, 306–320.

Levy, J. (2011). *A Bee in a Cathedral and 99 Other Scientific Analogies*. Richmond Hill, ON: Firefly Books.

Lilienfeld, S. O., Ammirati, R., & Landfield, K. (2009). Giving debiasing away: Can psychological research on correcting cognitive errors promote human welfare? *Perspectives on Psychological Science*, 4, 390-398.

Malhotra, N., J. A Krosnick, E. & Haertel. N.D. Latent Variable Analysis of the GSS Wordsum Vocabulary Test. *General Social Survey Methodological Report III.*

Marcy, R. T., & Mumford, M. D. (2007). Social Innovation: Enhancing creative performance through causal analysis. *Creativity Research Journal, 19*, 123-140.

Martindale, C. (1 999). Biological bases of creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 137-1 52). New York: Cambridge University Press

Mayer, R.E. (1981). *The promise of cognitive psychology*. San Francisco: W.H. Freeman and Company.

Mayer, R.E. (1983). *Thinking, problem solving, cognition*. New York: W.H. Freeman and Company.

McRae, K., & Jones, M. N. (2013). Semantic memory. In D. Reisberg (Ed.), *The Oxford Handbook of Cognitive Psychology* (pp. 206-219). Oxford, UK.

McRae, K., Khalkhali, S., & Hare, M. (2012). Semantic and associative relations: Examining a tenuous dichotomy. In V.F. Reyna, S. Chapman, M. Dougherty, & J. Confrey (Eds.), *The adolescent brain: Learning, reasoning, and decision making.* Washington, DC: American Psychological Association.

Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review, 69,* 220–232.

Miller, G. (2012). The Smartphone Psychology Manifesto. *Perspectives in Psychological Science, 7,* 221–237.

Morrison, R. G., Krawczyk, D. C., Holyoak, K. J., Hummel, J. E., Chow, T. W., Miller, B. L., & Knowlton, B. J. (2004). A neurocomputational model of analogical reasoning and its breakdown in Frontotemporal Lobar Degeneration. *Journal of Cognitive Neuroscience*, *16*, 260-271.

Mumford, M. D. (2002). Social innovation: Ten cases from Benjamin Franklin. *Creativity research journal, 14*, 253-266.

Mumford, M. D., Medeiros, K. E., & Partlow, P. J. (2012). Creative thinking: Processes, strategies, and knowledge. *Journal of Creative Behavior, 46*, 30-47.

Mumford, M.D. & Moertl, P. (2003). Cases of social innovation: Lessons from two innovations in the 20th century. *Creativity Research Journal*, (15(2-3)), 261-266.

Murphy, G. L. & Medin, D. L. (1985). *The role of theories in conceptual coherence*. *Psychological Review, 92*, 289-316.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, *106*, 226-254.

Neisser, U. (1963). The Multiplicity of Thought. *British Journal of Psychology*, *54*, 1-14.

Nijstad, B. A., De Dreu, C. K. W., Rietzschel, E. F., & Baas, M. (2010). The dual pathway to creativity model: Creative ideation as a function of flexibility and persistence. *European Review of Social Psychology*, *21*, 34–77.

Nusbaum, E. C., & Silvia, P. J. (2011). Are intelligence and creativity really so different? Fluid intelligence, executive processes, and strategy use in divergent thinking. *Intelligence*, *39*, 36–45.

Ochse, R. (1990). *Before the gates of excellence*. Cambridge, UK:Cambridge University Press.

Ouspensky, P.D., *The Psychology of Man's Possible Evolution*. Vintage Books, 1974, NY.

Pacini, R & Epstein, S (1999). "The relation of rational and experiential information processing styles to personality, basic beliefs, and the ratio-bias phenomenon". *Journal of Personality and Social Psychology, 76*, 972–87.

Paulhus, D. L., & Vazire, S. (2007). The self-report method. In R.W. Robins, R.C. Fraley, & R.F. Krueger (Eds.), *Handbook of research methods in personality psychology* (pp. 224-239). New York: Guilford.

Penn, D. C., Holyoak, K. J. & Povinelli, D. J. (2008). Darwin's mistake: Explaining the discontinuity between human and nonhuman minds. *Behavioral and Brain Sciences, 31*, 109–78.

Pennycook, G., Fugelsang, J., & Koehler, D. (2012). Are we good at detecting conflict during reasoning? *Cognition, 124,* 101-106.

Pennycook, G., Cheyne, J.A., Barr, N., Koehler, D.J. & Fugelsang, J.A. (2014a). Cognitive style and religiosity: The role of conflict detection. *Memory & Cognition, 42*, 1-10

Pennycook, G., Cheyne, J., Barr, N., Koehler, D., & Fugelsang, J. (2014b). The role of analytic thinking in moral judgements and values. *Thinking & Reasoning, Advance Online Publication,* DOI:10.1080/13546783.2013.865000.

Pennycook, G., Cheyne, J., Seli, P., Koehler, D., & Fugelsang, J. (2012). Analytic cognitive style predicts religious and paranormal belief. *Cognition, 123,* 335-346.

Poincaré, H. (1913). *The foundations of science* (G. B. Halsted, Trans.). New York, NY: Science Press. Retrieved from http://www.gutenberg.org/files/39713/39713-h/39713-h.htm

Posner, M.I., Snyder, C.R.R. (1975). Attention and cognitive control. In: *Information Processing and Cognition*, ed. R.L. Solso. Hillsdale, NJ: Erlbaum

Ramnani, N., & Owen, A. M. (2004). Anterior prefrontal cortex: Insights into function from anatomy and neuroimaging. *Nature Reviews Neuroscience, 5*, 184–194.

Redick, T.S., Broadway, J.M., Meier, M.E., Kuriakose, P.S., Unsworth, N., Kane, M.J., & Engle, R. W. (2012). Measuring working memory capacity with automated complex span tasks. *European Journal of Psychological Assessment*, *28,* 164-171.

Reverberi, C., Toraldo, A., D'Agostini, S., & Skrap, M. (2005). Better without (lateral) frontal cortex? Insight problems solved by frontal patients. *Brain*, *128*, 2882–2890.

Richland, L. E., Morrison, R. G., & Holyoak, K. J. (2006). Children's development of analogical reasoning: Insights from scene analogy problems. *Journal of Experimental Child Psychology*, *94*, 249-271.

Ricks, T. R., Turley-Ames, K. J., & Wiley, J. (2007). Effects of working memory capacity on mental set due to domain knowledge. *Memory & Cognition, 35*, 1456–1462.

Satpute, A. B., Fenker, D. B., Waldmann, M. R., Tabibnia, G., Holyoak, K. J., & Lieberman, M.D. (2005). An fMRI study of causal judgments. *European Journal of Neuroscience, 22*, 1233-1238.

Schacter, D.L., Addis, D.R., Hassabis, D., Martin, V.C., Spreng, R.N., & Spuznar, K.L. (2012). The future of memory: remembering, imagining and the brain. *Neuron*, *76,* 677–694.

Schooler, J.W., Ohlsson, S., & Brooks, K. (1993). Thoughts beyond words: When language overshadows insight. *Journal of Experimental Psychology: General, 122*, 166-183.

Schwartz, L. M., Woloshin, S., Black, W. C., & Welch, H. G. (1997). The role of numeracy in understanding the benefit of screening mammography. *Annals of Internal Medicine, 127,* 966-972.

Scott, G.M., Leritz, L.E. and Mumford, M.D. (2004). The effectiveness of creativity training: A meta-analysis. *Creativity Research Journal*, 16, 361–88.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review,* 84(2), 127-190.

Shlegel, A., Kohler, P.J., Fogelson, S.V., Alexander, P., Konuthula, D. & Tse, P.U. (2013). Network structure and dynamics of the mental workspace. *Proceedings of the National Academy of Sciences, 110*, 16277-16282.

Shipstead, Z., Lindsey, D. R., Marshall, R. L., & Engle, R. W. (2014). The mechanisms of working memory capacity: Primary memory, secondary memory, and attention control. *Journal of Memory and Language, 72,* 116–141.

Skinner, E.I., Manios, M., Fugelsang, J.A. & Fernandes, M.A. (in press). Reinstatement of Encoding Context during Recollection: Behavioural and Neuroimaging Evidence of a Double Dissociation. *Behavioural Brain Research*, *122,* DOI:10.1016/j.bbr.2014.01.033

Silvia, P. J. (2008b). Creativity and intelligence revisited: A latent variable analysis of Wallach and Kogan (1965). *Creativity Research Journal*, *20*, 34 –39.

Silvia, P. J., & Beaty, R. E. (2012). Making creative metaphors: The importance of fluid intelligence for creative thought. *Intelligence*, *40*, 343–351.

Sio, U. N., & Ormerod, T. C. (2009). Does incubation enhance problem solving? A meta-analytic review. *Psychological Bulletin*, *135,* 94–120.

Slepian, M. L., & Ambady, N. (2012). Fluid movement and creativity. *Journal of Experimental Psychology: General*, *141*, 625–629.

Slepian, M. L., Weisbuch, M., Rutchick, A. M., Newman, L. S., & Ambady, N. (2010). Shedding light on insight: Priming bright ideas. *Journal of Experimental Social Psychology, 46,* 696–700.

Simonton, D. K. (1999). Creativity as blind variation and selective retention: Is the creative process Darwinian? *Psychological Inquiry, 10,* 309–328.

Simonton, D. K. (2010). Creative thought as blind-variation and selective retention: Combinatorial models of exceptional creativity. *Physics of Life Reviews*, *7*, 156–179.

Simonton, D. K. (2013). Creative thought as blind variation and selective retention: Why creativity is inversely related to sightedness. *Journal of Theoretical and Philosophical Psychology*, *33*, 253–266.

Sowden, P.T., Pringle, A., & Gabora, L. (2014). The shifting sands of creative thinking: connections to dual-process theory. Thinking & Reasoning. Advance online publication. doi: 10.1080/13546783.2014.885464

Spellman, B.A., Holyoak, K.J. & Morrison, R.G. (2001) Analogical priming via semantic relations. *Memory and Cognition*, 29,383–393.

Stanovich, K. E. (2009). Is it time for a tri-process theory? Distinguishing the reflective and algorithmic mind. In J. St. B. T. Evans & K. Frankish (Eds.), *In two minds: Dual processes and beyond* (pp. 55-88). Oxford, UK: Oxford University Press.

Stanovich, K. E. (2004). *The Robot's rebellion: Finding meaning in the age of Darwin*. Chicago: The University of Chicago Press.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate. *Behavioral and Brain Sciences*, *23*, 645–726.

Sternberg, R. J. (1977). Component processes in analogical reasoning. *Psychological Review, 84*, 353–378.

Süß, H.-M., Oberauer, K.,Wittmann,W.W.,Wilhelm, O., & Schulze, R. (2002). Working-memory capacity explains reasoning ability—and a little bit more. Intelligence, 30, 261–288.

Thagard, P. (2012). Creative combination of representations: Scientific discovery and technological invention. In R. Proctor & E. J. Capaldi (Eds.), *Psychology of science: Implicit and explicit processes* (pp. 389-405). . Oxford: Oxford University Press.

Thagard, P. (in press). Creative intuition: How EUREKA results from three neural mechanisms. In L. M. Osbeck & B. S. Held (Eds.), *Rational intuition: Philosophical roots, scientific investigations*. Cambridge: Cambridge University Press.

Thompson, V. A., Prowse Turner, J., & Pennycook, G. (2011). Intuition, reason and metacognition. *Cognitive Psychology, 63*, 107–140.

Toplak, M. E., West, R. F., & Stanovich, K. E. (2011). The Cognitive Reflection Test as a predictor of performance on heuristics-and-biases tasks. *Memory & Cognition. 39*, 1275–1289.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory*. New York: Academic Press.

Unsworth, N., & Engle, R.W. (2007). On the division of short-term and working memory: An examination of simple and complex span and their relation to higher order ability. *Psychological Bulletin, 133*, 1038-1066.

Vartanian, O. (2009). Variable attention facilitates creative problem solving. *Psychology of Aesthetics, Creativity, and the Arts, 3*, 57-59.

Vartanian, O. (2012), Dissociable neural systems for analogy and metaphor: Implications for the neuroscience of creativity. *British Journal of Psychology*, *103*: 302–316.

Vartanian, O. (2013). Fostering creativity: Insights from Neuroscience. In O. Vartanian, A. Bristol, & J.C. Kaufman (Eds.), Neuroscience of Creativity (pp. 257-271). Cambridge, MA: MIT Press.

Wallas G. (1926). *The Art Of Thought*. New York, NY: Harcourt Brace.

Ward, T. B. (1994). Structured imagination: The role of category structure in exemplar generation. *Cognitive Psychology, 27*, 1–40.

Ward, T. B., Smith, S. M., & Finke, R. A. (1999). Creative cognition. In R. J. Sternberg (Ed.), *Handbook of creativity*. Cambridge: Cambridge University Press.

Ward, T. B., & Kolomyts, Y. (2010). Cognition and creativity. In J. C. Kaufman & R. J. Sternberg (Eds.), *The Cambridge handbook of creativity* (pp. 93–112). New York, NY: Cambridge University Press.

Wegner, D. M., Schneider, D. J., Carter, S., & White, T. (1987). Paradoxical effects of thought suppression. *Journal of Personality and Social Psychology, 53,* 5-13.

Wieth, M., & Zacks, R. (2011). Time of day effects on problem solving: When the non-optimal is optimal. *Thinking & Reasoning, 17,* 387-401.

Wiley J. & Jarosz A. (2012). Working memory capacity, attentional focus, and problem solving. *Current Directions in Psychological Science*, *21*, 258–262.

Wong, E. D. (1993). Self generated analogies as a tool for constructing and evaluating explanations of scientific phenomena. *Journal of Research in Science Teaching, 30,* 367-380.

Wright, R. (2004). *A Short History of Progress*. Toronto: House of Anansi Press.

Zhong, C.-B., Dijksterhuis, A., & Galinsky, A. D. (2008). The merits of unconscious thought in creativity. Psychological Science, 19, 912–918.

Zook, K. B. (1991). Effect of analogical processes on learning and misrepresentation. *Educational Psychology Review, 3*(1), 41-72.

Appendix A

Analogy Stimuli (used in all Experiments)

Note: CD = Cross-domain, WD = Within-domain; For each A:B pair for any given A:B pair, there were three C:D pairs: A cross-domain valid analogy, a within-domain valid analogy, and a non-analogy, half of which were cross- domain and half of which were within-domain.

A	***B***	***C***	***D***	***Domain***
answer	riddle	key	lock	Analogy (CD)
answer	riddle	solution	problem	Analogy (WD)
answer	riddle	jersey	number	Non-Analogy (CD)
ash	fireplace	lint	pocket	Analogy (CD)
ash	fireplace	soot	chimney	Analogy (WD)
ash	fireplace	harness	climber	Non-Analogy (CD)
aspirin	pain	muffler	noise	Analogy (CD)
aspirin	pain	antacid	heartburn	Analogy (WD)
aspirin	pain	foot	sock	Non-Analogy (CD)
baker	cake	scientist	discovery	Analogy (CD)
baker	cake	chef	meal	Analogy (WD)
baker	cake	muffin	blueberry	Non-Analogy (WD)
basket	picnic	holster	gun	Analogy (CD)
basket	picnic	lunchbox	lunch	Analogy (WD)
basket	picnic	knife	napkin	Non-Analogy (WD)
basketball	hoop	traveler	destination	Analogy (CD)
basketball	hoop	soccerball	goal	Analogy (WD)
basketball	hoop	serve	volley	Non-Analogy (WD)
blindness	sight	poverty	money	Analogy (CD)
blindness	sight	deafness	hearing	Analogy (WD)
blindness	sight	wall	paint	Non-Analogy (CD)
blizzard	snowflake	army	soldier	Analogy (CD)
blizzard	snowflake	monsoon	raindrop	Analogy (WD)
blizzard	snowflake	tornado	cloud	Non-Analogy (WD)
bracelet	wrist	moat	castle	Analogy (CD)
bracelet	wrist	ring	finger	Analogy (WD)
bracelet	wrist	skill	practice	Non-Analogy (CD)
burger	bun	book	cover	Analogy (CD)
burger	bun	sub	roll	Analogy (WD)

burger	bun	onion	lettuce	Non-Analogy (WD)
cleanser	face	absolution	sinner	Analogy (CD)
cleanser	face	soap	body	Analogy (WD)
cleanser	face	curtain	shower	Non-Analogy (WD)
eraser	pencil	amnesia	memory	Analogy (CD)
eraser	pencil	whiteout	pen	Analogy (WD)
eraser	pencil	glue	paper	Non-Analogy (WD)
father	son	inventor	invention	Analogy (CD)
father	son	mother	daughter	Analogy (WD)
father	son	nephew	cousin	Non-Analogy (WD)
flock	goose	constellation	star	Analogy (CD)
flock	goose	wolfpack	wolf	Analogy (WD)
flock	goose	pond	turtle	Non-Analogy (WD)
foresight	future	x-ray	bone	Analogy (CD)
foresight	future	hindsight	past	Analogy (WD)
foresight	future	letter	mailman	Non-Analogy (CD)
foundation	house	premise	argument	Analogy (CD)
foundation	house	base	structure	Analogy (WD)
foundation	house	duplex	renter	Non-Analogy (WD)
furnace	coal	stomach	food	Analogy (CD)
furnace	coal	woodstove	wood	Analogy (WD)
furnace	coal	beach	ocean	Non-Analogy (CD)
hoof	hoofprint	introduction	impression	Analogy (CD)
hoof	hoofprint	paw	pawprint	Analogy (WD)
hoof	hoofprint	battery	toy	Non-Analogy (CD)
immunization	disease	forewarning	surprise	Analogy (CD)
immunization	disease	vaccination	infection	Analogy (WD)
immunization	disease	hotel	innkeeper	Non-Analogy (CD)
jacket	zipper	wound	suture	Analogy (CD)
jacket	zipper	overcoat	button	Analogy (WD)
jacket	zipper	actor	film	Non-Analogy (CD)
ketchup	tomato	fuel	petroleum	Analogy (CD)
ketchup	tomato	guacamole	avocado	Analogy (WD)
ketchup	tomato	shoelace	skate	Non-Analogy (CD)
kitten	cat	spark	fire	Analogy (CD)
kitten	cat	puppy	dog	Analogy (WD)
kitten	cat	hamster	wheel	Non-Analogy (WD)

knee	kneepad	snail	shell	Analogy (CD)
knee	kneepad	elbow	elbowpad	Analogy (WD)
knee	kneepad	flag	flagpole	Non-Analogy (CD)
lambchop	lamb	chapter	book	Analogy (CD)
lambchop	lamb	porkchop	pig	Analogy (WD)
lambchop	lamb	fillet	skillet	Non-Analogy (WD)
landscaper	lawn	stylist	hair	Analogy (CD)
landscaper	lawn	gardener	garden	Analogy (WD)
landscaper	lawn	fence	field	Non-Analogy (WD)
launchpad	helicopter	divingboard	diver	Analogy (CD)
launchpad	helicopter	runway	airplane	Analogy (WD)
launchpad	helicopter	thorn	rose	Non-Analogy (CD)
lawschool	lawyer	vineyard	wine	Analogy (CD)
lawschool	lawyer	medschool	doctor	Analogy (WD)
lawschool	lawyer	beard	razor	Non-Analogy (CD)
movie	screen	lightning	sky	Analogy (CD)
movie	screen	gameshow	television	Analogy (WD)
movie	screen	metal	rust	Non-Analogy (CD)
multiplication	product	brewing	beer	Analogy (CD)
multiplication	product	addition	sum	Analogy (WD)
multiplication	product	sleep	pajamas	Non-Analogy (CD)
nose	scent	antenna	signal	Analogy (CD)
nose	scent	tongue	taste	Analogy (WD)
nose	scent	eyelash	mascara	Non-Analogy (WD)
orchard	apple	neighbourhood	apartment	Analogy (CD)
orchard	apple	grove	orange	Analogy (WD)
orchard	apple	cantaloupe	farmstand	Non-Analogy (WD)
painting	canvas	birthmark	skin	Analogy (CD)
painting	canvas	drawing	paper	Analogy (WD)
painting	canvas	mistake	regret	Non-Analogy (CD)
pen	pig	reservoir	water	Analogy (CD)
pen	pig	coop	chicken	Analogy (WD)
pen	pig	hay	horse	Non-Analogy (WD)
rectangle	perimeter	nation	border	Analogy (CD)
rectangle	perimeter	circle	circumference	Analogy (WD)
rectangle	perimeter	octagon	angle	Non-Analogy (WD)
revising	manuscript	evolving	species	Analogy (CD)

revising	manuscript	editing	story	Analogy (WD)
revising	manuscript	price	sale	Non-Analogy (CD)
saxophone	jazz	typewriter	poetry	Analogy (CD)
saxophone	jazz	harmonica	blues	Analogy (WD)
saxophone	jazz	document	copier	Non-Analogy (CD)
sugar	coffee	incentive	deal	Analogy (CD)
sugar	coffee	honey	tea	Analogy (WD)
sugar	coffee	grinder	bean	Non-Analogy (WD)
thermometer	temperature	polygraph	honesty	Analogy (CD)
thermometer	temperature	barometer	pressure	Analogy (WD)
thermometer	temperature	table	leg	Non-Analogy (CD)
train	track	signal	wire	Analogy (CD)
train	track	trolley	rail	Analogy (WD)
train	track	conductor	whistle	Non-Analogy (WD)
watermelon	rind	cigarette	butt	Analogy (CD)
watermelon	rind	orange	peel	Analogy (WD)
watermelon	rind	raspberry	bush	Non-Analogy (WD)

Appendix B

ANOVA Tables for Experiments 1-5

Experiment 1 Accuracy:
2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Domain	Sphericity Assumed	4189.948	1	4189.948	36.301	.000	.476
	Greenhouse-Geisser	4189.948	1.000	4189.948	36.301	.000	.476
	Huynh-Feldt	4189.948	1.000	4189.948	36.301	.000	.476
	Lower-bound	4189.948	1.000	4189.948	36.301	.000	.476
Error(Domain)	Sphericity Assumed	4616.854	40	115.421			
	Greenhouse-Geisser	4616.854	40.000	115.421			
	Huynh-Feldt	4616.854	40.000	115.421			
	Lower-bound	4616.854	40.000	115.421			
Validity	Sphericity Assumed	66.360	1	66.360	.170	.683	.004
	Greenhouse-Geisser	66.360	1.000	66.360	.170	.683	.004
	Huynh-Feldt	66.360	1.000	66.360	.170	.683	.004
	Lower-bound	66.360	1.000	66.360	.170	.683	.004
Error(Validity)	Sphericity Assumed	15653.106	40	391.328			
	Greenhouse-Geisser	15653.106	40.000	391.328			
	Huynh-Feldt	15653.106	40.000	391.328			
	Lower-bound	15653.106	40.000	391.328			
Domain * Validity	Sphericity Assumed	28396.883	1	28396.883	80.593	.000	.668

	Greenhouse-Geisser	28396.883	1.000	28396.883	80.593	.000	.668
	Huynh-Feldt	28396.883	1.000	28396.883	80.593	.000	.668
	Lower-bound	28396.883	1.000	28396.883	80.593	.000	.668
Error(Domain*Validity)	Sphericity Assumed	14093.968	40	352.349			
	Greenhouse-Geisser	14093.968	40.000	352.349			
	Huynh-Feldt	14093.968	40.000	352.349			
	Lower-bound	14093.968	40.000	352.349			

Experiment 1 RT: 2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Domain	Sphericity Assumed	3394507.100	1	3394507.100	15.380	.000	.278
	Greenhouse-Geisser	3394507.100	1.000	3394507.100	15.380	.000	.278
	Huynh-Feldt	3394507.100	1.000	3394507.100	15.380	.000	.278
	Lower-bound	3394507.100	1.000	3394507.100	15.380	.000	.278
Error(Domain)	Sphericity Assumed	8828519.141	40	220712.979			
	Greenhouse-Geisser	8828519.141	40.000	220712.979			
	Huynh-Feldt	8828519.141	40.000	220712.979			
	Lower-bound	8828519.141	40.000	220712.979			
Validity	Sphericity Assumed	3461240.074	1	3461240.074	5.890	.020	.128
	Greenhouse-Geisser	3461240.074	1.000	3461240.074	5.890	.020	.128
	Huynh-Feldt	3461240.074	1.000	3461240.074	5.890	.020	.128
	Lower-bound	3461240.074	1.000	3461240.074	5.890	.020	.128

Error(Validity)	Sphericity Assumed	23507651.100	40	587691.277			
	Greenhouse-Geisser	23507651.100	40.000	587691.277			
	Huynh-Feldt	23507651.100	40.000	587691.277			
	Lower-bound	23507651.100	40.000	587691.277			
Domain * Validity	Sphericity Assumed	10459346.159	1	10459346.159	20.103	.000	.334
	Greenhouse-Geisser	10459346.159	1.000	10459346.159	20.103	.000	.334
	Huynh-Feldt	10459346.159	1.000	10459346.159	20.103	.000	.334
	Lower-bound	10459346.159	1.000	10459346.159	20.103	.000	.334
Error(Domain*Validity)	Sphericity Assumed	20811486.063	40	520287.152			
	Greenhouse-Geisser	20811486.063	40.000	520287.152			
	Huynh-Feldt	20811486.063	40.000	520287.152			
	Lower-bound	20811486.063	40.000	520287.152			

Experiment 2 Accuracy:
2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Domain	Sphericity Assumed	6569.127	1	6569.127	112.418	.000	.733
	Greenhouse-Geisser	6569.127	1.000	6569.127	112.418	.000	.733
	Huynh-Feldt	6569.127	1.000	6569.127	112.418	.000	.733
	Lower-bound	6569.127	1.000	6569.127	112.418	.000	.733
Error(Domain)	Sphericity Assumed	2395.834	41	58.435			
	Greenhouse-Geisser	2395.834	41.000	58.435			
	Huynh-Feldt	2395.834	41.000	58.435			
	Lower-bound	2395.834	41.000	58.435			

Validity	Sphericity Assumed	1104.540	1	1104.540	8.301	.006	.168
	Greenhouse-Geisser	1104.540	1.000	1104.540	8.301	.006	.168
	Huynh-Feldt	1104.540	1.000	1104.540	8.301	.006	.168
	Lower-bound	1104.540	1.000	1104.540	8.301	.006	.168
Error(Validity)	Sphericity Assumed	5455.619	41	133.064			
	Greenhouse-Geisser	5455.619	41.000	133.064			
	Huynh-Feldt	5455.619	41.000	133.064			
	Lower-bound	5455.619	41.000	133.064			
Domain * Validity	Sphericity Assumed	11019.078	1	11019.078	96.048	.000	.701
	Greenhouse-Geisser	11019.078	1.000	11019.078	96.048	.000	.701
	Huynh-Feldt	11019.078	1.000	11019.078	96.048	.000	.701
	Lower-bound	11019.078	1.000	11019.078	96.048	.000	.701
Error(Domain*Validity)	Sphericity Assumed	4703.726	41	114.725			
	Greenhouse-Geisser	4703.726	41.000	114.725			
	Huynh-Feldt	4703.726	41.000	114.725			
	Lower-bound	4703.726	41.000	114.725			

Experiment 2 RT:
2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Domain	Sphericity Assumed	7557801.720	1	7557801.720	56.528	.000	.580
	Greenhouse-Geisser	7557801.720	1.000	7557801.720	56.528	.000	.580
	Huynh-Feldt	7557801.720	1.000	7557801.720	56.528	.000	.580
	Lower-bound	7557801.720	1.000	7557801.720	56.528	.000	.580

Error(Domain)	Sphericity Assumed	5481685.530	41	133699.647			
	Greenhouse-Geisser	5481685.530	41.000	133699.647			
	Huynh-Feldt	5481685.530	41.000	133699.647			
	Lower-bound	5481685.530	41.000	133699.647			
Validity	Sphericity Assumed	1394303.720	1	1394303.720	3.278	.078	.074
	Greenhouse-Geisser	1394303.720	1.000	1394303.720	3.278	.078	.074
	Huynh-Feldt	1394303.720	1.000	1394303.720	3.278	.078	.074
	Lower-bound	1394303.720	1.000	1394303.720	3.278	.078	.074
Error(Validity)	Sphericity Assumed	17441230.530	41	425395.867			
	Greenhouse-Geisser	17441230.530	41.000	425395.867			
	Huynh-Feldt	17441230.530	41.000	425395.867			
	Lower-bound	17441230.530	41.000	425395.867			
Domain * Validity	Sphericity Assumed	2792850.720	1	2792850.720	17.121	.000	.295
	Greenhouse-Geisser	2792850.720	1.000	2792850.720	17.121	.000	.295
	Huynh-Feldt	2792850.720	1.000	2792850.720	17.121	.000	.295
	Lower-bound	2792850.720	1.000	2792850.720	17.121	.000	.295
Error(Domain*Validity)	Sphericity Assumed	6688053.530	41	163123.257			
	Greenhouse-Geisser	6688053.530	41.000	163123.257			
	Huynh-Feldt	6688053.530	41.000	163123.257			
	Lower-bound	6688053.530	41.000	163123.257			

Experiment 1 & 2 CD analogy accuracy:
2 (Experiment: Experiment 1, Experiment 2) × 2 (Domain: Cross-domain, Within-domain) mixed ANOVA

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Domain	Sphericity Assumed	44003.949	1	44003.949	285.257	.000	.779
	Greenhouse-Geisser	44003.949	1.000	44003.949	285.257	.000	.779
	Huynh-Feldt	44003.949	1.000	44003.949	285.257	.000	.779
	Lower-bound	44003.949	1.000	44003.949	285.257	.000	.779
Domain * Task	Sphericity Assumed	618.678	1	618.678	4.011	.049	.047
	Greenhouse-Geisser	618.678	1.000	618.678	4.011	.049	.047
	Huynh-Feldt	618.678	1.000	618.678	4.011	.049	.047
	Lower-bound	618.678	1.000	618.678	4.011	.049	.047
Error(Domain)	Sphericity Assumed	12495.131	81	154.261			
	Greenhouse-Geisser	12495.131	81.000	154.261			
	Huynh-Feldt	12495.131	81.000	154.261			
	Lower-bound	12495.131	81.000	154.261			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	931006.928	1	931006.928	3958.070	.000	.980
Task	2742.686	1	2742.686	11.660	.001	.126
Error	19052.610	81	235.217			

Experiment 3 accuracy:
2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) × 2 (Cue: Analytic cue, No cue)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared

Domain	Sphericity Assumed	13179.038	1	13179.038	92.756	.000	.599
	Greenhouse-Geisser	13179.038	1.000	13179.038	92.756	.000	.599
	Huynh-Feldt	13179.038	1.000	13179.038	92.756	.000	.599
	Lower-bound	13179.038	1.000	13179.038	92.756	.000	.599
Error(Domain)	Sphericity Assumed	8809.103	62	142.082			
	Greenhouse-Geisser	8809.103	62.000	142.082			
	Huynh-Feldt	8809.103	62.000	142.082			
	Lower-bound	8809.103	62.000	142.082			
Validity	Sphericity Assumed	416.330	1	416.330	.947	.334	.015
	Greenhouse-Geisser	416.330	1.000	416.330	.947	.334	.015
	Huynh-Feldt	416.330	1.000	416.330	.947	.334	.015
	Lower-bound	416.330	1.000	416.330	.947	.334	.015
Error(Validity)	Sphericity Assumed	27256.485	62	439.621			
	Greenhouse-Geisser	27256.485	62.000	439.621			
	Huynh-Feldt	27256.485	62.000	439.621			
	Lower-bound	27256.485	62.000	439.621			
Cue	Sphericity Assumed	40.655	1	40.655	.376	.542	.006
	Greenhouse-Geisser	40.655	1.000	40.655	.376	.542	.006
	Huynh-Feldt	40.655	1.000	40.655	.376	.542	.006
	Lower-bound	40.655	1.000	40.655	.376	.542	.006
Error(Cue)	Sphericity Assumed	6703.276	62	108.117			
	Greenhouse-Geisser	6703.276	62.000	108.117			
	Huynh-Feldt	6703.276	62.000	108.117			
	Lower-bound	6703.276	62.000	108.117			
Domain * Validity	Sphericity Assumed	20637.853	1	20637.853	70.113	.000	.531

	Greenhouse-Geisser	20637.853	1.000	20637.853	70.113	.000	.531
	Huynh-Feldt	20637.853	1.000	20637.853	70.113	.000	.531
	Lower-bound	20637.853	1.000	20637.853	70.113	.000	.531
Error(Domain*Validity)	Sphericity Assumed	18249.803	62	294.352			
	Greenhouse-Geisser	18249.803	62.000	294.352			
	Huynh-Feldt	18249.803	62.000	294.352			
	Lower-bound	18249.803	62.000	294.352			
Domain * Cue	Sphericity Assumed	32.691	1	32.691	.218	.642	.004
	Greenhouse-Geisser	32.691	1.000	32.691	.218	.642	.004
	Huynh-Feldt	32.691	1.000	32.691	.218	.642	.004
	Lower-bound	32.691	1.000	32.691	.218	.642	.004
Error(Domain*Cue)	Sphericity Assumed	9290.173	62	149.841			
	Greenhouse-Geisser	9290.173	62.000	149.841			
	Huynh-Feldt	9290.173	62.000	149.841			
	Lower-bound	9290.173	62.000	149.841			
Validity * Cue	Sphericity Assumed	380.761	1	380.761	3.120	.082	.048
	Greenhouse-Geisser	380.761	1.000	380.761	3.120	.082	.048
	Huynh-Feldt	380.761	1.000	380.761	3.120	.082	.048
	Lower-bound	380.761	1.000	380.761	3.120	.082	.048
Error(Validity*Cue)	Sphericity Assumed	7567.434	62	122.055			
	Greenhouse-Geisser	7567.434	62.000	122.055			
	Huynh-Feldt	7567.434	62.000	122.055			
	Lower-bound	7567.434	62.000	122.055			
Domain * Validity * Cue	Sphericity Assumed	159.990	1	159.990	1.867	.177	.029
	Greenhouse-Geisser	159.990	1.000	159.990	1.867	.177	.029

	Huynh-Feldt	159.990	1.000	159.990	1.867	.177	.029
	Lower-bound	159.990	1.000	159.990	1.867	.177	.029
Error(Domain*Validity*Cue)	Sphericity Assumed	5311.797	62	85.674			
	Greenhouse-Geisser	5311.797	62.000	85.674			
	Huynh-Feldt	5311.797	62.000	85.674			
	Lower-bound	5311.797	62.000	85.674			

Experiment 3 RT:
2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) × 2 (Cue: Analytic cue, No cue)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Domain	Sphericity Assumed	95802238.613	1	95802238.613	56.700	.000	.478
	Greenhouse-Geisser	95802238.613	1.000	95802238.613	56.700	.000	.478
	Huynh-Feldt	95802238.613	1.000	95802238.613	56.700	.000	.478
	Lower-bound	95802238.613	1.000	95802238.613	56.700	.000	.478
Error(Domain)	Sphericity Assumed	104757236.063	62	1689632.840			
	Greenhouse-Geisser	104757236.063	62.000	1689632.840			
	Huynh-Feldt	104757236.063	62.000	1689632.840			
	Lower-bound	104757236.063	62.000	1689632.840			
Validity	Sphericity Assumed	108287177.041	1	108287177.041	22.150	.000	.263
	Greenhouse-Geisser	108287177.041	1.000	108287177.041	22.150	.000	.263
	Huynh-Feldt	108287177.041	1.000	108287177.041	22.150	.000	.263
	Lower-bound	108287177.041	1.000	108287177.041	22.150	.000	.263
Error(Validity)	Sphericity Assumed	303109319.508	62	4888859.992			

	Greenhouse-Geisser	303109319.508	62.000	4888859.992			
	Huynh-Feldt	303109319.508	62.000	4888859.992			
	Lower-bound	303109319.508	62.000	4888859.992			
Cue	Sphericity Assumed	23100706.436	1	23100706.436	15.663	.000	.202
	Greenhouse-Geisser	23100706.436	1.000	23100706.436	15.663	.000	.202
	Huynh-Feldt	23100706.436	1.000	23100706.436	15.663	.000	.202
	Lower-bound	23100706.436	1.000	23100706.436	15.663	.000	.202
Error(Cue)	Sphericity Assumed	91442022.376	62	1474871.329			
	Greenhouse-Geisser	91442022.376	62.000	1474871.329			
	Huynh-Feldt	91442022.376	62.000	1474871.329			
	Lower-bound	91442022.376	62.000	1474871.329			
Domain * Validity	Sphericity Assumed	66005232.082	1	66005232.082	41.379	.000	.400
	Greenhouse-Geisser	66005232.082	1.000	66005232.082	41.379	.000	.400
	Huynh-Feldt	66005232.082	1.000	66005232.082	41.379	.000	.400
	Lower-bound	66005232.082	1.000	66005232.082	41.379	.000	.400
Error(Domain*Validity)	Sphericity Assumed	98898950.747	62	1595144.367			
	Greenhouse-Geisser	98898950.747	62.000	1595144.367			
	Huynh-Feldt	98898950.747	62.000	1595144.367			
	Lower-bound	98898950.747	62.000	1595144.367			
Domain * Cue	Sphericity Assumed	2293.290	1	2293.290	.002	.968	.000
	Greenhouse-Geisser	2293.290	1.000	2293.290	.002	.968	.000
	Huynh-Feldt	2293.290	1.000	2293.290	.002	.968	.000
	Lower-bound	2293.290	1.000	2293.290	.002	.968	.000
Error(Domain*Cue)	Sphericity Assumed	86095147.879	62	1388631.417			
	Greenhouse-Geisser	86095147.879	62.000	1388631.417			

	Huynh-Feldt	86095147.879	62.000	1388631.417			
	Lower-bound	86095147.879	62.000	1388631.417			
Validity * Cue	Sphericity Assumed	11593517.593	1	11593517.593	11.018	.002	.151
	Greenhouse-Geisser	11593517.593	1.000	11593517.593	11.018	.002	.151
	Huynh-Feldt	11593517.593	1.000	11593517.593	11.018	.002	.151
	Lower-bound	11593517.593	1.000	11593517.593	11.018	.002	.151
Error(Validity*Cue)	Sphericity Assumed	65236789.277	62	1052206.279			
	Greenhouse-Geisser	65236789.277	62.000	1052206.279			
	Huynh-Feldt	65236789.277	62.000	1052206.279			
	Lower-bound	65236789.277	62.000	1052206.279			
Domain * Validity * Cue	Sphericity Assumed	871584.541	1	871584.541	.654	.422	.010
	Greenhouse-Geisser	871584.541	1.000	871584.541	.654	.422	.010
	Huynh-Feldt	871584.541	1.000	871584.541	.654	.422	.010
	Lower-bound	871584.541	1.000	871584.541	.654	.422	.010
Error(Domain*Validity*Cue)	Sphericity Assumed	82604976.058	62	1332338.324			
	Greenhouse-Geisser	82604976.058	62.000	1332338.324			
	Huynh-Feldt	82604976.058	62.000	1332338.324			
	Lower-bound	82604976.058	62.000	1332338.324			

Experiment 4 Accuracy:
2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) × 2 (Cue: Analytic cue, Intuitive cue)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared

Domain	Sphericity Assumed	16042.352	1	16042.352	123.981	.000	.623
	Greenhouse-Geisser	16042.352	1.000	16042.352	123.981	.000	.623
	Huynh-Feldt	16042.352	1.000	16042.352	123.981	.000	.623
	Lower-bound	16042.352	1.000	16042.352	123.981	.000	.623
Error(Domain)	Sphericity Assumed	9704.487	75	129.393			
	Greenhouse-Geisser	9704.487	75.000	129.393			
	Huynh-Feldt	9704.487	75.000	129.393			
	Lower-bound	9704.487	75.000	129.393			
Validity	Sphericity Assumed	4886.325	1	4886.325	6.297	.014	.077
	Greenhouse-Geisser	4886.325	1.000	4886.325	6.297	.014	.077
	Huynh-Feldt	4886.325	1.000	4886.325	6.297	.014	.077
	Lower-bound	4886.325	1.000	4886.325	6.297	.014	.077
Error(Validity)	Sphericity Assumed	58194.422	75	775.926			
	Greenhouse-Geisser	58194.422	75.000	775.926			
	Huynh-Feldt	58194.422	75.000	775.926			
	Lower-bound	58194.422	75.000	775.926			
Cue	Sphericity Assumed	431.434	1	431.434	3.177	.079	.041
	Greenhouse-Geisser	431.434	1.000	431.434	3.177	.079	.041
	Huynh-Feldt	431.434	1.000	431.434	3.177	.079	.041
	Lower-bound	431.434	1.000	431.434	3.177	.079	.041
Error(Cue)	Sphericity Assumed	10184.896	75	135.799			
	Greenhouse-Geisser	10184.896	75.000	135.799			
	Huynh-Feldt	10184.896	75.000	135.799			
	Lower-bound	10184.896	75.000	135.799			
Domain * Validity	Sphericity Assumed	24067.575	1	24067.575	119.624	.000	.615

	Greenhouse-Geisser	24067.575	1.000	24067.575	119.624	.000	.615
	Huynh-Feldt	24067.575	1.000	24067.575	119.624	.000	.615
	Lower-bound	24067.575	1.000	24067.575	119.624	.000	.615
Error(Domain*Validity)	Sphericity Assumed	15089.578	75	201.194			
	Greenhouse-Geisser	15089.578	75.000	201.194			
	Huynh-Feldt	15089.578	75.000	201.194			
	Lower-bound	15089.578	75.000	201.194			
Domain * Cue	Sphericity Assumed	2168.975	1	2168.975	26.721	.000	.263
	Greenhouse-Geisser	2168.975	1.000	2168.975	26.721	.000	.263
	Huynh-Feldt	2168.975	1.000	2168.975	26.721	.000	.263
	Lower-bound	2168.975	1.000	2168.975	26.721	.000	.263
Error(Domain*Cue)	Sphericity Assumed	6087.775	75	81.170			
	Greenhouse-Geisser	6087.775	75.000	81.170			
	Huynh-Feldt	6087.775	75.000	81.170			
	Lower-bound	6087.775	75.000	81.170			
Validity * Cue	Sphericity Assumed	.163	1	.163	.001	.973	.000
	Greenhouse-Geisser	.163	1.000	.163	.001	.973	.000
	Huynh-Feldt	.163	1.000	.163	.001	.973	.000
	Lower-bound	.163	1.000	.163	.001	.973	.000
Error(Validity*Cue)	Sphericity Assumed	10357.688	75	138.103			
	Greenhouse-Geisser	10357.688	75.000	138.103			
	Huynh-Feldt	10357.688	75.000	138.103			
	Lower-bound	10357.688	75.000	138.103			
Domain * Validity * Cue	Sphericity Assumed	1360.257	1	1360.257	8.784	.004	.105
	Greenhouse-Geisser	1360.257	1.000	1360.257	8.784	.004	.105

	Huynh-Feldt	1360.257	1.000	1360.257	8.784	.004	.105
	Lower-bound	1360.257	1.000	1360.257	8.784	.004	.105
Error(Domain*Validity*Cue)	Sphericity Assumed	11614.356	75	154.858			
	Greenhouse-Geisser	11614.356	75.000	154.858			
	Huynh-Feldt	11614.356	75.000	154.858			
	Lower-bound	11614.356	75.000	154.858			

Experiment 4 RT:
2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False) × 2 (Cue: Analytic cue, Intuitive cue)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Domain	Sphericity Assumed	117634925.880	1	117634925.880	124.328	.000	.624
	Greenhouse-Geisser	117634925.880	1.000	117634925.880	124.328	.000	.624
	Huynh-Feldt	117634925.880	1.000	117634925.880	124.328	.000	.624
	Lower-bound	117634925.880	1.000	117634925.880	124.328	.000	.624
Error(Domain)	Sphericity Assumed	70962181.253	75	946162.417			
	Greenhouse-Geisser	70962181.253	75.000	946162.417			
	Huynh-Feldt	70962181.253	75.000	946162.417			
	Lower-bound	70962181.253	75.000	946162.417			
Validity	Sphericity Assumed	55138469.232	1	55138469.232	26.293	.000	.260
	Greenhouse-Geisser	55138469.232	1.000	55138469.232	26.293	.000	.260
	Huynh-Feldt	55138469.232	1.000	55138469.232	26.293	.000	.260
	Lower-bound	55138469.232	1.000	55138469.232	26.293	.000	.260

Error(Validity)	Sphericity Assumed	157282624.794	75	2097101.664			
	Greenhouse-Geisser	157282624.794	75.000	2097101.664			
	Huynh-Feldt	157282624.794	75.000	2097101.664			
	Lower-bound	157282624.794	75.000	2097101.664			
Cue	Sphericity Assumed	313630664.200	1	313630664.200	45.058	.000	.375
	Greenhouse-Geisser	313630664.200	1.000	313630664.200	45.058	.000	.375
	Huynh-Feldt	313630664.200	1.000	313630664.200	45.058	.000	.375
	Lower-bound	313630664.200	1.000	313630664.200	45.058	.000	.375
Error(Cue)	Sphericity Assumed	522049732.448	75	6960663.099			
	Greenhouse-Geisser	522049732.448	75.000	6960663.099			
	Huynh-Feldt	522049732.448	75.000	6960663.099			
	Lower-bound	522049732.448	75.000	6960663.099			
Domain * Validity	Sphericity Assumed	25664752.943	1	25664752.943	24.285	.000	.245
	Greenhouse-Geisser	25664752.943	1.000	25664752.943	24.285	.000	.245
	Huynh-Feldt	25664752.943	1.000	25664752.943	24.285	.000	.245
	Lower-bound	25664752.943	1.000	25664752.943	24.285	.000	.245
Error(Domain*Validity)	Sphericity Assumed	79262576.610	75	1056834.355			
	Greenhouse-Geisser	79262576.610	75.000	1056834.355			
	Huynh-Feldt	79262576.610	75.000	1056834.355			
	Lower-bound	79262576.610	75.000	1056834.355			
Domain * Cue	Sphericity Assumed	10098582.677	1	10098582.677	9.681	.003	.114
	Greenhouse-Geisser	10098582.677	1.000	10098582.677	9.681	.003	.114
	Huynh-Feldt	10098582.677	1.000	10098582.677	9.681	.003	.114
	Lower-bound	10098582.677	1.000	10098582.677	9.681	.003	.114
Error(Domain*Cue)	Sphericity Assumed	78235837.483	75	1043144.500			

	Greenhouse-Geisser	78235837.483	75.000	1043144.500			
	Huynh-Feldt	78235837.483	75.000	1043144.500			
	Lower-bound	78235837.483	75.000	1043144.500			
Validity * Cue	Sphericity Assumed	4727200.329	1	4727200.329	5.134	.026	.064
	Greenhouse-Geisser	4727200.329	1.000	4727200.329	5.134	.026	.064
	Huynh-Feldt	4727200.329	1.000	4727200.329	5.134	.026	.064
	Lower-bound	4727200.329	1.000	4727200.329	5.134	.026	.064
Error(Validity*Cue)	Sphericity Assumed	69055548.421	75	920740.646			
	Greenhouse-Geisser	69055548.421	75.000	920740.646			
	Huynh-Feldt	69055548.421	75.000	920740.646			
	Lower-bound	69055548.421	75.000	920740.646			
Domain * Validity * Cue	Sphericity Assumed	4631374.453	1	4631374.453	4.743	.033	.059
	Greenhouse-Geisser	4631374.453	1.000	4631374.453	4.743	.033	.059
	Huynh-Feldt	4631374.453	1.000	4631374.453	4.743	.033	.059
	Lower-bound	4631374.453	1.000	4631374.453	4.743	.033	.059
Error(Domain*Validity*Cue)	Sphericity Assumed	73234796.760	75	976463.957			
	Greenhouse-Geisser	73234796.760	75.000	976463.957			
	Huynh-Feldt	73234796.760	75.000	976463.957			
	Lower-bound	73234796.760	75.000	976463.957			

Experiment 4 accuracy by group: 2 (Domain: Cross-domain, Within-domain) × 2 (Cue: Analytic cue, Intuitive cue) × 2 (Reflectiveness: Non-reflective, Reflective) × 2 (Intuitiveness: Non-intuitive, Intuitive)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared

Domain	Sphericity Assumed	40157.507	1	40157.507	274.164	.000	.792
	Greenhouse-Geisser	40157.507	1.000	40157.507	274.164	.000	.792
	Huynh-Feldt	40157.507	1.000	40157.507	274.164	.000	.792
	Lower-bound	40157.507	1.000	40157.507	274.164	.000	.792
Domain * NFC_split	Sphericity Assumed	9.252	1	9.252	.063	.802	.001
	Greenhouse-Geisser	9.252	1.000	9.252	.063	.802	.001
	Huynh-Feldt	9.252	1.000	9.252	.063	.802	.001
	Lower-bound	9.252	1.000	9.252	.063	.802	.001
Domain * FI_split	Sphericity Assumed	585.525	1	585.525	3.998	.049	.053
	Greenhouse-Geisser	585.525	1.000	585.525	3.998	.049	.053
	Huynh-Feldt	585.525	1.000	585.525	3.998	.049	.053
	Lower-bound	585.525	1.000	585.525	3.998	.049	.053
Domain * NFC_split * FI_split	Sphericity Assumed	582.609	1	582.609	3.978	.050	.052
	Greenhouse-Geisser	582.609	1.000	582.609	3.978	.050	.052
	Huynh-Feldt	582.609	1.000	582.609	3.978	.050	.052
	Lower-bound	582.609	1.000	582.609	3.978	.050	.052
Error(Domain)	Sphericity Assumed	10546.042	72	146.473			
	Greenhouse-Geisser	10546.042	72.000	146.473			
	Huynh-Feldt	10546.042	72.000	146.473			
	Lower-bound	10546.042	72.000	146.473			
Cue	Sphericity Assumed	200.927	1	200.927	2.546	.115	.034
	Greenhouse-Geisser	200.927	1.000	200.927	2.546	.115	.034
	Huynh-Feldt	200.927	1.000	200.927	2.546	.115	.034
	Lower-bound	200.927	1.000	200.927	2.546	.115	.034
Cue * NFC_split	Sphericity Assumed	30.776	1	30.776	.390	.534	.005

	Greenhouse-Geisser	30.776	1.000	30.776	.390	.534	.005
	Huynh-Feldt	30.776	1.000	30.776	.390	.534	.005
	Lower-bound	30.776	1.000	30.776	.390	.534	.005
Cue * FI_split	Sphericity Assumed	116.489	1	116.489	1.476	.228	.020
	Greenhouse-Geisser	116.489	1.000	116.489	1.476	.228	.020
	Huynh-Feldt	116.489	1.000	116.489	1.476	.228	.020
	Lower-bound	116.489	1.000	116.489	1.476	.228	.020
Cue * NFC_split * FI_split	Sphericity Assumed	365.522	1	365.522	4.631	.035	.060
	Greenhouse-Geisser	365.522	1.000	365.522	4.631	.035	.060
	Huynh-Feldt	365.522	1.000	365.522	4.631	.035	.060
	Lower-bound	365.522	1.000	365.522	4.631	.035	.060
Error(Cue)	Sphericity Assumed	5683.221	72	78.934			
	Greenhouse-Geisser	5683.221	72.000	78.934			
	Huynh-Feldt	5683.221	72.000	78.934			
	Lower-bound	5683.221	72.000	78.934			
Domain * Cue	Sphericity Assumed	62.983	1	62.983	.976	.327	.013
	Greenhouse-Geisser	62.983	1.000	62.983	.976	.327	.013
	Huynh-Feldt	62.983	1.000	62.983	.976	.327	.013
	Lower-bound	62.983	1.000	62.983	.976	.327	.013
Domain * Cue * NFC_split	Sphericity Assumed	23.561	1	23.561	.365	.548	.005
	Greenhouse-Geisser	23.561	1.000	23.561	.365	.548	.005
	Huynh-Feldt	23.561	1.000	23.561	.365	.548	.005
	Lower-bound	23.561	1.000	23.561	.365	.548	.005
Domain * Cue * FI_split	Sphericity Assumed	205.038	1	205.038	3.176	.079	.042
	Greenhouse-Geisser	205.038	1.000	205.038	3.176	.079	.042

	Huynh-Feldt	205.038	1.000	205.038	3.176	.079	.042
	Lower-bound	205.038	1.000	205.038	3.176	.079	.042
Domain * Cue * NFC_split * FI_split	Sphericity Assumed	731.644	1	731.644	11.333	.001	.136
	Greenhouse-Geisser	731.644	1.000	731.644	11.333	.001	.136
	Huynh-Feldt	731.644	1.000	731.644	11.333	.001	.136
	Lower-bound	731.644	1.000	731.644	11.333	.001	.136
Error(Domain*Cue)	Sphericity Assumed	4648.070	72	64.557			
	Greenhouse-Geisser	4648.070	72.000	64.557			
	Huynh-Feldt	4648.070	72.000	64.557			
	Lower-bound	4648.070	72.000	64.557			

Experiment 4 WD analogy accuracy by group:
2 (Cue: Analytic cue, Intuitive cue) × 2 (Reflectiveness: Non-reflective, Reflective) × 2 (Intuitiveness: Non-intuitive, Intuitive)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Cue	Sphericity Assumed	244.449	1	244.449	7.233	.009	.091
	Greenhouse-Geisser	244.449	1.000	244.449	7.233	.009	.091
	Huynh-Feldt	244.449	1.000	244.449	7.233	.009	.091
	Lower-bound	244.449	1.000	244.449	7.233	.009	.091
Cue * NFC_split	Sphericity Assumed	.241	1	.241	.007	.933	.000
	Greenhouse-Geisser	.241	1.000	.241	.007	.933	.000
	Huynh-Feldt	.241	1.000	.241	.007	.933	.000
	Lower-bound	.241	1.000	.241	.007	.933	.000
Cue * FI_split	Sphericity Assumed	6.217	1	6.217	.184	.669	.003

	Greenhouse-Geisser	6.217	1.000	6.217	.184	.669	.003
	Huynh-Feldt	6.217	1.000	6.217	.184	.669	.003
	Lower-bound	6.217	1.000	6.217	.184	.669	.003
Cue * NFC_split * FI_split	Sphericity Assumed	31.445	1	31.445	.930	.338	.013
	Greenhouse-Geisser	31.445	1.000	31.445	.930	.338	.013
	Huynh-Feldt	31.445	1.000	31.445	.930	.338	.013
	Lower-bound	31.445	1.000	31.445	.930	.338	.013
Error(Cue)	Sphericity Assumed	2433.248	72	33.795			
	Greenhouse-Geisser	2433.248	72.000	33.795			
	Huynh-Feldt	2433.248	72.000	33.795			
	Lower-bound	2433.248	72.000	33.795			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1294742.451	1	1294742.451	14155.550	.000	.995
NFC_split	14.809	1	14.809	.162	.689	.002
FI_split	55.126	1	55.126	.603	.440	.008
NFC_split * FI_split	19.323	1	19.323	.211	.647	.003
Error	6585.506	72	91.465			

Experiment 4 CD analogy accuracy by group: 2 (Cue: Analytic cue, Intuitive cue) × 2 (Reflectiveness: Non-reflective, Reflective) × 2 (Intuitiveness: Non-intuitive, Intuitive)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Cue	Sphericity Assumed	19.461	1	19.461	.177	.675	.002
	Greenhouse-Geisser	19.461	1.000	19.461	.177	.675	.002
	Huynh-Feldt	19.461	1.000	19.461	.177	.675	.002
	Lower-bound	19.461	1.000	19.461	.177	.675	.002
Cue * NFC_split	Sphericity Assumed	54.096	1	54.096	.493	.485	.007
	Greenhouse-Geisser	54.096	1.000	54.096	.493	.485	.007
	Huynh-Feldt	54.096	1.000	54.096	.493	.485	.007
	Lower-bound	54.096	1.000	54.096	.493	.485	.007
Cue * FI_split	Sphericity Assumed	315.310	1	315.310	2.874	.094	.038
	Greenhouse-Geisser	315.310	1.000	315.310	2.874	.094	.038
	Huynh-Feldt	315.310	1.000	315.310	2.874	.094	.038
	Lower-bound	315.310	1.000	315.310	2.874	.094	.038
Cue * NFC_split * FI_split	Sphericity Assumed	1065.721	1	1065.721	9.715	.003	.119
	Greenhouse-Geisser	1065.721	1.000	1065.721	9.715	.003	.119
	Huynh-Feldt	1065.721	1.000	1065.721	9.715	.003	.119
	Lower-bound	1065.721	1.000	1065.721	9.715	.003	.119
Error(Cue)	Sphericity Assumed	7898.043	72	109.695			
	Greenhouse-Geisser	7898.043	72.000	109.695			
	Huynh-Feldt	7898.043	72.000	109.695			
	Lower-bound	7898.043	72.000	109.695			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	730116.358	1	730116.358	1952.263	.000	.964
NFC_split	.205	1	.205	.001	.981	.000
FI_split	718.023	1	718.023	1.920	.170	.026
NFC_split * FI_split	884.439	1	884.439	2.365	.128	.032
Error	26926.893	72	373.985			

Experiment 4 CD analogy accuracy for Reflective and Non-reflective groups:
2 (Cue: Analytic cue, Intuitive cue) × 2 (Intuitiveness: Non-intuitive, Intuitive) for each group

Tests of Within-Subjects Effects

Measure: MEASURE_1

NFC_split	Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Non Reflective	Cue	Sphericity Assumed	4.338	1	4.338	.039	.845	.001
		Greenhouse-Geisser	4.338	1.000	4.338	.039	.845	.001
		Huynh-Feldt	4.338	1.000	4.338	.039	.845	.001
		Lower-bound	4.338	1.000	4.338	.039	.845	.001
	Cue * FI_split	Sphericity Assumed	110.986	1	110.986	.995	.325	.027
		Greenhouse-Geisser	110.986	1.000	110.986	.995	.325	.027
		Huynh-Feldt	110.986	1.000	110.986	.995	.325	.027
		Lower-bound	110.986	1.000	110.986	.995	.325	.027
	Error(Cue)	Sphericity Assumed	4014.003	36	111.500			
		Greenhouse-Geisser	4014.003	36.000	111.500			
		Huynh-Feldt	4014.003	36.000	111.500			
		Lower-bound	4014.003	36.000	111.500			
Reflective	Cue	Sphericity Assumed	69.128	1	69.128	.641	.429	.017

	Greenhouse-Geisser	69.128	1.000	69.128	.641	.429	.017
	Huynh-Feldt	69.128	1.000	69.128	.641	.429	.017
	Lower-bound	69.128	1.000	69.128	.641	.429	.017
Cue * FI_split	Sphericity Assumed	1268.439	1	1268.439	11.757	.002	.246
	Greenhouse-Geisser	1268.439	1.000	1268.439	11.757	.002	.246
	Huynh-Feldt	1268.439	1.000	1268.439	11.757	.002	.246
	Lower-bound	1268.439	1.000	1268.439	11.757	.002	.246
Error(Cue)	Sphericity Assumed	3884.039	36	107.890			
	Greenhouse-Geisser	3884.039	36.000	107.890			
	Huynh-Feldt	3884.039	36.000	107.890			
	Lower-bound	3884.039	36.000	107.890			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

NFC_split	Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Non Reflective	Intercept	365177.468	1	365177.468	1064.245	.000	.967
	FI_split	4.338	1	4.338	.013	.911	.000
	Error	12352.785	36	343.133			
Reflective	Intercept	364939.425	1	364939.425	901.449	.000	.962
	FI_split	1595.916	1	1595.916	3.942	.055	.099
	Error	14574.108	36	404.836			

Experiment 5 accuracy:
2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Domain	Sphericity Assumed	13844.045	1	13844.045	203.583	.000	.668
	Greenhouse-Geisser	13844.045	1.000	13844.045	203.583	.000	.668
	Huynh-Feldt	13844.045	1.000	13844.045	203.583	.000	.668
	Lower-bound	13844.045	1.000	13844.045	203.583	.000	.668
Error(Domain)	Sphericity Assumed	6868.185	101	68.002			
	Greenhouse-Geisser	6868.185	101.000	68.002			
	Huynh-Feldt	6868.185	101.000	68.002			
	Lower-bound	6868.185	101.000	68.002			
Validity	Sphericity Assumed	3219.642	1	3219.642	13.437	.000	.117
	Greenhouse-Geisser	3219.642	1.000	3219.642	13.437	.000	.117
	Huynh-Feldt	3219.642	1.000	3219.642	13.437	.000	.117
	Lower-bound	3219.642	1.000	3219.642	13.437	.000	.117
Error(Validity)	Sphericity Assumed	24201.172	101	239.616			
	Greenhouse-Geisser	24201.172	101.000	239.616			
	Huynh-Feldt	24201.172	101.000	239.616			
	Lower-bound	24201.172	101.000	239.616			
Domain * Validity	Sphericity Assumed	34485.113	1	34485.113	162.042	.000	.616
	Greenhouse-Geisser	34485.113	1.000	34485.113	162.042	.000	.616
	Huynh-Feldt	34485.113	1.000	34485.113	162.042	.000	.616
	Lower-bound	34485.113	1.000	34485.113	162.042	.000	.616
Error(Domain*Validity)	Sphericity Assumed	21494.397	101	212.816			
	Greenhouse-Geisser	21494.397	101.000	212.816			
	Huynh-Feldt	21494.397	101.000	212.816			
	Lower-bound	21494.397	101.000	212.816			

Experiment 5 RT:
2 (Domain: Cross-domain, Within-domain) × 2 (Validity: True, False)

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Domain	Sphericity Assumed	63916792.081	1	63916792.081	195.025	.000	.659
	Greenhouse-Geisser	63916792.081	1.000	63916792.081	195.025	.000	.659
	Huynh-Feldt	63916792.081	1.000	63916792.081	195.025	.000	.659
	Lower-bound	63916792.081	1.000	63916792.081	195.025	.000	.659
Error(Domain)	Sphericity Assumed	33101358.169	101	327736.219			
	Greenhouse-Geisser	33101358.169	101.000	327736.219			
	Huynh-Feldt	33101358.169	101.000	327736.219			
	Lower-bound	33101358.169	101.000	327736.219			
Validity	Sphericity Assumed	10037019.728	1	10037019.728	8.108	.005	.074
	Greenhouse-Geisser	10037019.728	1.000	10037019.728	8.108	.005	.074
	Huynh-Feldt	10037019.728	1.000	10037019.728	8.108	.005	.074
	Lower-bound	10037019.728	1.000	10037019.728	8.108	.005	.074
Error(Validity)	Sphericity Assumed	125031028.522	101	1237930.975			
	Greenhouse-Geisser	125031028.522	101.000	1237930.975			
	Huynh-Feldt	125031028.522	101.000	1237930.975			
	Lower-bound	125031028.522	101.000	1237930.975			
Domain * Validity	Sphericity Assumed	41373788.297	1	41373788.297	78.500	.000	.437
	Greenhouse-Geisser	41373788.297	1.000	41373788.297	78.500	.000	.437
	Huynh-Feldt	41373788.297	1.000	41373788.297	78.500	.000	.437
	Lower-bound	41373788.297	1.000	41373788.297	78.500	.000	.437

Error(Domain*Validity)	Sphericity Assumed	53232521.953	101	527054.673
	Greenhouse-Geisser	53232521.953	101.000	527054.673
	Huynh-Feldt	53232521.953	101.000	527054.673
	Lower-bound	53232521.953	101.000	527054.673

Appendix C

Rational-Experiential Inventory Items (used in Experiment 4 & 5)

Rationality scale
I try to avoid situations that require thinking in depth about something
I'm not that good at figuring out complicated problems
I enjoy intellectual challenges
I am not very good at solving problems that require careful logical analysis
I don't like to have to do a lot of thinking
I enjoy solving problems that require hard thinking
Thinking is not my idea of an enjoyable activity
I am not a very analytical thinker
Reasoning things out carefully is not one of my strong points
I prefer complex problems to simple problems
Thinking hard and for a long time about something gives me little satisfaction
I don't reason well under pressure
I am much better at figuring things out logically than most people
I have a logical mind
I enjoy thinking in abstract terms
I have no problem thinking things through carefully
Using logic usually works well for me in figuring out problems in my life
Knowing the answer without having to understand the reasoning behind it is good enough for me
I usually have clear, explainable reasons for my decisions
Learning new ways to think would be very appealing to me

Experientiality scale
I like to rely on my intuitive impressions
I don't have a very good sense of intuition
Using my gut feelings usually works well for me in figuring out problems in my life
I believe in trusting my hunches
Intuition can be a very useful way to solve problems
I often go by my instincts when deciding on a course of action
I trust my initial feelings about people
When it comes to trusting people, I can usually rely on my gut feelings
If I were to rely on my gut feelings, I would often make mistakes
I don't like situations in which I have to rely on intuition
I think there are times when one should rely on one's intuition
I think it is foolish to make important decisions based on feelings
I don't think it is a good idea to rely on one's intuition for important decisions
I generally don't depend on my feelings to help me make decisions
I hardly ever go wrong when I listen to my deepest gut feelings to find an answer
I would not want to depend on anyone who described himself or herself as intuitive
My snap judgments are probably not as good as most people's
I tend to use my heart as a guide for my actions
I can usually feel when a person is right or wrong, even if I can't explain how I know
I suspect my hunches are inaccurate as often as they are accurate

Appendix D

Cognitive Style & Ability Measures (used in Experiment 5)

Cognitive Reflection Test

1) A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost? ____ cents **(5)**

2) If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? ____ minutes **(5)**

3) In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? ____ days **(47)**

Base-Rate

1. In a study 1000 people were tested. Among the participants there were 5 engineers and 995 lawyers. Jack is a randomly chosen participant of this study. Jack is 36 years old. He is not married and is somewhat introverted. He likes to spend his free time reading science fiction and writing computer programs. What is most likely? A) Jack is a lawyer, B) Jack is an engineer
2. In a study 1000 people were tested. Among the participants there were 3 who live in a condo and 997 who live in a farmhouse. Kurt is a randomly chosen participant of this study. Kurt works on Wall Street and is single. He works long hours and wears Armani suits to work. He likes wearing sunglasses. What is most likely? A) Kurt lives in a condo, B) Kurt lives in a farmhouse
3. In a study 1000 people were tested. Among the participants there were 997 nurses and 3 doctors. Paul is a randomly chosen participant of this study. Paul is 34 years old. He lives in a beautiful home in a posh suburb. He is well spoken and very interested in politics. He invests a lot of time in his career. What is most likely? A) Paul is a doctor, B) Paul is a nurse
4. In a study 1000 people were tested. Among the participants there were 4 women and 996 men. Jamie is a randomly chosen participant of this study. Jamie is a 36-year-old writer. Jamie has two brothers and one sister. Jamie likes running and watching a good movie. What is most likely? A) Jamie is a man, B) Jamie is a woman
5. In a study 1000 people were tested. Among the participants there were 3 who play the saxophone and 997 who play the drums. Tom is a randomly chosen participant of this study. Tom is 20 years old. He is studying in Washington and has no steady girlfriend. He just bought a second-hand car with his savings. What is most likely? A) Tom plays the saxophone, B) Tom plays the drums
6. In a study 1000 people were tested. Among the participants there were 996 who live in Los Angeles and 4 who live in New York. Christopher is a randomly chosen participant of this study. Christopher is 28 years old. He has a girlfriend and shares an apartment with a friend. He likes watching basketball. What is most likely? A) Christopher lives in New York, B) Christopher lives in Los Angeles

WordSum

We would like to know something about how people go about guessing words they do not know. On this card are listed some words. You may know some of them, and you may not know quite a few of them. On each line, the first word is in capital letters--- like BEAST. Then there are five other words. Please choose the word that comes closest to the meaning of the word in capital letters. For example, if the word in capital letters is BEAST, you would choose “animal” because it comes closer to BEAST than any of the other words.

Circle only one number for each item below.

EXAMPLE

BEAST 1. afraid 2. words 3. large 4. animal 5. separate 6. don’t know

A. SPACE 1. school 2. noon 3. captain 4. room 5. board 6. don’t know

B. BROADEN 1. efface 2. make level 3. elapse 4. embroider 5. widen 6. don’t know

C. EMANATE 1. populate 2. free 3. prominent 4. rival 5. come 6. don’t know

D. EDIBLE 1. auspicious 2. eligible 3. fit to eat 4. sagacious 5. able to speak 6. don’t know

E. ANIMOSITY 1. hatred 2. animation 3. disobedience 4. diversity 5. friendship 6. don’t know

F. PACT 1. puissance 2. remonstrance 3. agreement 4. skillet 5. pressure 6. don’t know

G. CLOISTERED 1. miniature 2. bunched 3. arched 4. malady 5. secluded 6. don’t know

H. CAPRICE 1. value 2. a star 3. grimace 4. whim 5. inducement 6. don’t know

I. ACCUSTOM 1. disappoint 2. customary 3. encounter 4. get used to 5. business 6. don’t know

J. ALLUSION 1. reference 2. dream 3. eulogy 4. illusion 5. aria 6. don’t know

H. AUDACIOUS 1. Daring 2. Smart 3. Brave 4. Loud 5. Outgoing 6. Don’t know

I. ENCUMBER 1. Impede 2. Oppress 3. Gather 4. Press 5. Encompass 6. Don’t know

Numeracy Scale

i) Imagine that we flip a fair coin 1,000 times. What is your best guess about how many times the coin would come up heads in 1,000 flips? ____times out of 1,000.

ii) In the BIG BUCKS LOTTERY, the chance of winning a $10 prize is 1%. What is your best guess about how many people would win a $10 prize if 1000 people each buy a single ticket to BIG BUCKS?____person(s) out of 1,000.

iii) In ACME PUBLISHING SWEEPSAKES, the chance of winning a car is 1 in 1,000. What percent of tickets to ACME PUBLISHING SWEEPSAKES win a car?____%.

Appendix E

Creativity Measure Items (used in Experiment 5)

Category-Inclusiveness Task

Category	*Item*	*Strength*
CLOTHING	cane	weak
CLOTHING	ring	weak
CLOTHING	purse	weak
CLOTHING	stockings	moderate
CLOTHING	tuxedo	moderate
CLOTHING	shoes	moderate
CLOTHING	shirt	strong
CLOTHING	pants	strong
CLOTHING	dress	strong
FURNITURE	fan	weak
FURNITURE	stove	weak
FURNITURE	telephone	weak
FURNITURE	cabinet	moderate
FURNITURE	stool	moderate
FURNITURE	lamp	moderate
FURNITURE	chair	strong
FURNITURE	sofa	strong
FURNITURE	table	strong

Category	*Item*	*Strength*
VEGETABLE	rice	weak
VEGETABLE	pickles	weak
VEGETABLE	seaweed	weak
VEGETABLE	parsnip	moderate
VEGETABLE	bean	moderate
VEGETABLE	potato	moderate
VEGETABLE	carrot	strong
VEGETABLE	pea	strong
VEGETABLE	broccoli	strong
VEHICLE	elevator	weak
VEHICLE	camel	weak
VEHICLE	feet	weak
VEHICLE	boat	moderate
VEHICLE	jet	moderate
VEHICLE	bike	moderate
VEHICLE	car	strong
VEHICLE	truck	strong
VEHICLE	bus	strong

Remote Associates Test

Item 1	*Item 2*	*Item 3*	*Solution*	*Item 1*	*Item 2*	*Item 3*	*Solution*
Sense	Courtesy	Place	**Common**	Basket	Eight	Snow	**Ball**
Print	Berry	Bird	**Blue**	Sandwich	House	Golf	**Club**
Horse	Human	Drag	**Race**	Pie	Luck	Belly	**Pot**
Main	Sweeper	Light	**Street**	Fly	Clip	Wall	**Paper**
Opera	Hand	Dish	**Soap**				
Dress	Dial	Flower	**Sun**				
Down	Question	Check	**Mark**				
Carpet	Alert	Ink	**Red**				
Flower	Friend	Scout	**Girl**				
Hound	Pressure	Shot	**Blood**				
Mill	Tooth	Dust	**Saw**				

Appendix F

Complete Correlation Table from Experiment 5

		CRT	Base Rate Incongruent	Word Sum	Numeracy	Need for Cognition	Faith in Intuition	Cross domain analogy accuracy	Within domain analogy accuracy	Cross domain non-analogy accuracy	Within domain non-analogy accuracy	RAT	Originality Ratings (1-7)	Fluency	Category-Inclusiveness Task (Weak Exemplars)
CRT	**Pearson Correlation**	--	.400	.256	.492	.471	-.226	.397	.186	.296	.436	.303	.114	.180	.124
	Sig. (2-tailed)		.000	.009	.000	.000	.035	.000	.061	.003	.000	.002	.254	.070	.213
Base Rate Incongruent	**Pearson Correlation**		--	.176	.367	.308	-.169	.335	.045	.074	.310	.232	.117	-.076	.056
	Sig. (2-tailed)			.077	.000	.004	.115	.001	.654	.460	.002	.019	.241	.449	.576
Word Sum	**Pearson Correlation**			--	.173	.277	-.098	.466	.352	.116	.284	.416	.365	.031	.053
	Sig. (2-tailed)				.082	.009	.363	.000	.000	.244	.004	.000	.000	.754	.598
Numeracy	**Pearson Correlation**				--	.363	-.155	.322	.168	.132	.384	.211	.119	-.029	.044
	Sig. (2-tailed)					.001	.149	.001	.091	.185	.000	.033	.233	.772	.659
Need for Cognition	**Pearson Correlation**					--	-.203	.363	.121	.004	.315	.219	.136	.050	-.003
	Sig. (2-tailed)						.058	.001	.263	.972	.003	.040	.206	.643	.980
Faith in Intuition	**Pearson Correlation**						--	-.002	.114	-.222	-.048	.027	-.031	-.039	.061
	Sig. (2-tailed)							.983	.291	.038	.655	.800	.772	.716	.573
Cross domain analogy accuracy	**Pearson Correlation**							--	.382	-.178	.337	.476	.203	-.012	.115
	Sig. (2-tailed)								.000	.074	.001	.000	.041	.906	.248
Within domain analogy accuracy	**Pearson Correlation**								--	.186	.221	.347	.197	-.082	.124
	Sig. (2-tailed)									.061	.025	.000	.047	.411	.213
Cross domain non-analogy accuracy	**Pearson Correlation**									--	.472	.122	.137	-.049	.184
	Sig. (2-tailed)										.000	.223	.170	.621	.064
Within domain non-analogy accuracy	**Pearson Correlation**										--	.441	.209	-.039	.075
	Sig. (2-tailed)											.000	.035	.696	.452
RAT	**Pearson Correlation**											--	.340	.115	-.109
	Sig. (2-tailed)												.000	.250	.275
Originality Ratings (1-7)	**Pearson Correlation**												--	-.134	-.085
	Sig. (2-tailed)													.179	.398
Fluency	**Pearson Correlation**													--	-.059
	Sig. (2-tailed)														.557
Category-Inclusiveness Task (Weak Exemplars)	**Pearson Correlation**														--