EXPLORATIONS OF COGNITIVE AGILITY:
A REAL TIME ADAPTIVE CAPACITY

by

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*We also certify that written approval has been obtained for any proprietary material contained therein.
This dissertation is dedicated to my wife, Rachel, who made a commitment to me, which
will always surpass in meaning what is on the pages to follow.
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<tr>
<td>ACS</td>
<td>Attentional Control Scale</td>
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<td>AUT</td>
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<td>BWVT</td>
<td>Basic Word Vocabulary Test</td>
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<td>DDM</td>
<td>Dynamic Decision Making</td>
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<td>LMS</td>
<td>Langer Mindfulness Scale</td>
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<td>MAI</td>
<td>Metacognitive Awareness Inventory</td>
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<td>NFC</td>
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Explorations of Cognitive Agility:  
A Real Time Adaptive Capacity

ABSTRACT

By

DARREN J. GOOD

This dissertation proposes and tests a new construct applicable to real-time adaptation. *Cognitive agility* is a formative construct that measures the individual ability to exhibit cognitive flexibility, cognitive openness and focused attention. This research seeks to demonstrate whether the formative construct of *cognitive agility* predicts adaptive performance in a dynamic-decision-making microworld. 181 undergraduates performed three consecutive trials, each of increasing difficulty and cognitive demand, in a microworld computer game called Networked Fire Chief (NFC). The changes within and between trials require the participants to flexibly adapt strategies using both cognitive openness and focused attention, in order to score highly. The individual variables that form *cognitive agility*, as well as the formative construct, explain unique variance beyond measures of general intelligence on the total score of adaptive performance. Most notably, the *cognitive agility* construct explains unique variance beyond general intelligence in each of the respective methods of measurement ($R^2\Delta=11\%$ for performance measures and $R^2\Delta=6\%$ for both the self reports and other rater reports). The results indicate a novel combination of abilities that may further the study of real-time adaptability.
CHAPTER I

INTRODUCTION

Members of today’s organizations face rapid change. This is caused in part by technological advancements (Hollenbeck and McCall, 1999; Ilgen & Pulakos, 1999; Pulakos et al., 2002; Thach & Woodman, 1994), increased competition (Edwards and Morrison, 1994), shorter product lifecycles (Bowonder and Miyake, 2000), the boundaryless nature of career (Arthur, Inkson, & Pringle, 1999; Boyatzis and Kram, Hall, 2002), cultural complexity (Cascio, 2003; Sanchez and Levine, 2001), globalization (Black, 1990; Noe and Ford 1992) and an increase in mergers and acquisitions (Kinicki and Latack, 1990). An additional level of complexity comes from the knowledge worker’s need to self-develop in order to stay competitive (Boyatzis and Kram, 1999; Hall & Mirvis, 1995; London and Mone, 1999; Senge, 1990). Taken together, this combination of environmental elements creates a dynamic context of increased complexity within which an individual must contend (Milliken, 1990; Weick, 1995)
These conditions foster a continual increase in the load of information processing and dynamic decision-making demands that individuals face (Farhoomand and Drury, 2002; Kozlowski et al., 2001; Mendelson and Pillai, 1998; Schroder et al., 1967). While these demands are more obvious in times of punctuated change, such as a shift in job role; they are often less obvious within our daily routines at work. Yet, with the constancy of change individuals are often managing the micro-momentary-processes (Porac, Thomas, & Baden-Fuller, 1989; Weick, 1995), such as dealing with the numerous ongoing distractions that crowd one’s attention at work (e.g. ringing phones, influx of emails, coworkers asking questions, information scraps and a list of tasks to be accomplished). In essence, individuals at work have to manage the big changes along with the continual ones (Kegan, 1994).

A common way that scholars suggest responding to both types of demands is through individual adaptability, a construct that has been written about with heightened frequency (Baird and Griffin, 2006; Goleman, Boyatzis and Kram, 1998; Edwards and Morrison, 1994; Hesketh, 1997; Ilgen & Pulakos, 1999; O’Connel et al., 2008; Pulakos et al., 2000; Smith et al., 1997). Adaptability is generally referred to as an ability to change when necessary. However, scholars who explicitly contribute to the study of adaptability do not often address the complexity inherent in the cognitive aspects of adaptive performance, as it pertains to real-time dynamic tasks.

Understanding an individual’s ability to be adaptive at the cognitive level may be a vital starting point to successfully navigating dynamic environments (Glynn, 1996). In order to be adaptive in a real time dynamic context, one must create a new understanding of information in the environment (Kozlowski, et al., 2001; Zaccaro, 2001), allow it to
alter the course of thinking when necessary (Mitroff et al, 2002; Savickas, 1997), and remain focused on relevant information (Lustig et al., 2001). The purpose of this paper is to propose and test a new construct: cognitive agility, a potential cognitive ability that can support the micro-momentary or real-time adaptive performance within the scope of a single dynamic decision making task. One such context that has proved useful to researchers studying cognition is the dynamic decision making microworld (DDM).

Microworlds (real-time interactive computer based simulations) mirror the complexity seen in real life (Diehl and Sterman, 1995; Gonzalez et al, 2005) as they present real-time decisions, a changing environment (Brehmer, 1992), nonlinear relationships and feedback delays (Sterman, 2000). Dynamic decision making microworlds offer an experimental alternative to the “paper and pencil” tests that are so often used in the assessment of “dynamic, interactive, and time oriented phenomena” (DiFonzo, Hantula and Bordia, 1998, p. 280). Therefore, this study predicts that cognitive agility will lead to better performance in such a dynamic decision making microworld. The variables that form cognitive agility will be measured using multiple methods (performance measures, self reports and other rater reports) in an attempt to demonstrate construct validity (Campbell and Fiske, 1959).

This dissertation begins with a review of conceptualizations of adaptability and its relation to the proposed formulation of the construct of cognitive agility.
This section provides the theoretical background for the construct of cognitive agility. Specifically, the section will demonstrate the relevance the construct has for real-time adaptive performance and how the name agility helps provide a novel perspective from other existing constructs.

Environmental influences on cognition (like novelty and complexity) are not fixed but instead more perceptual (Haynie, 2005; Hilton, 1995; Neuberg, 1989; Schwarz, 1996; Tetlock, 1992), suggesting individual differences in how information is attended to, filtered, encoded and interpreted (Neisser, 1967). Given that today’s organizational knowledge worker faces an increase in demands on judgment and decision-making skills (Howard, 1995; Ilgen & Pulakos, 1999; LePine et al., 2000), an investigation into cognitive-related constructs that support adaptability in real-time dynamic environments is needed. This dissertation aims to partially fulfill that need.

Adaptability is often used as an overarching term to describe a set of individual behaviors, leading to adaptation (Briscoe and Hall, 1999). Therefore, it becomes important to unbundle the constituent concepts and seek greater clarity in both the concepts and measures. Aspects of adaptability have been interpreted as parts of various aspects of a person, including personality traits (Morrison, 1977; Mumford, et al., 1993; Murphy, 1989), emotional intelligence (Boyatzis and Goleman, 1996; Goleman et al., 1998; Bar-On, 1995), learning style (Kolb, 1984; Kolb et al., 2000), and cognitive style (Martinsen & Kaufman, 1999; Sternberg, 1997). Others admit that, regardless of their definition or approach, adaptability is in part a cognitive
In this dissertation I claim that **Cognitive Agility** is an emergent cognitive ability necessary for adaptive performance within a single real-time dynamic context. Adaptable is a broad ability to support change. **Cognitive agility** is specific cognitive ability that leads to increased performance in a context that requires a series of individual adaptations. While adaptability is viewed generally as the capability to make a successful change in either cognition, behavior or emotion in response to anticipated or actual environmental shifts (LePine et al 2000), it is possible to further categorize it along the dimensions of time and task. For instance, one can adapt in the moment, to real-time tasks (Gonzalez, 2004; Lerch and Harter, 2001), or over a longer period of time, as in adjusting well to a new job (Ashford and Taylor, 1990; Morrison, 1977). Also, one can adapt within a particular task that is changing (Canas et al. 2003) or across various tasks that make up a dynamic context, like adapting well to the introduction of a new technology (Edmondson, Bohmer, and Pisano, 2001).

There have been numerous studies predicting abilities or characteristics of individual adaptability (Pulakos et al., 2000); most of which, at least implicitly, track adaptations across a longer time horizon and across multiple tasks. Fewer studies have focused on the micro-momentary cognitive aspects of adapting within a real-time dynamic decision-making task (exceptions include Canas et al., 2003; LePine et al., 2000). Therefore further inquiry into individual abilities that may lead to real time adaptive performance is a necessary addition to the adaptability literature.
Adaptive Performance

Real time adaptive performance within a task (e.g. how well an individual performs within a changing task - Kozlowski, et al 2001; LePine et al., 2000), likely requires a range of unique skills and abilities. A real-time dynamic decision task context is one in which change, novelty, ambiguity and complexity are prevalent (Brehmer, 1992; Mumford et al., 1993). Such a context presents the individual with a series of continuous decisions to be made, each of which present various task related tradeoffs (Tverskey et al., 1988). In order to be adaptive in such a context one must be flexible enough to create a new understanding of information in the environment (Smith, et al., 1997; Sparrow, 1994) and allow it to alter the course of his or her thinking when necessary (Mitroff et al., 2002; Savickas, 1997). Altering the course of thinking requires the flexibility to override a dominant or automatic response (Clark, 1996; Rende, 2000) in favor of a more appropriate one.

This flexibility is naturally preceded by the ability to notice stimuli of consequence. Kaplan and Simon stated that, “One of the distinguishing characteristics of insightful problem solvers is that they are good noticers.” (1990, p. 396). Conversely, an inability to encode vital elements of the task environment can result in a failure to adapt (Holland et al., 1986; Combe & Greenley, 2002). Yet, attention is a resource of scarcity in regards to decision-making within a real-time task (Simon, 1978). Therefore, noticing too much information or allowing all information to dictate course change would limit one’s adaptive performance (Brunstein & Olbrich, 1985; Kuhl & Kazen-Saad, 1988). As such “distractibility” is a central concern of decision making within tasks, as frequent attention capture can lead to a loss of decision effectiveness (Anderson, 1983). This loss of
effectiveness may be caused by distractions that lead to future relevant pieces of data being missed (Shapiro and Raymond, 1944). Consequently, while it is important to notice relevant stimuli for task adaptability, adaptive decisions are also supported by the capacity to avoid less relevant environmental data (Shanteau, 1988).

*Cognitive agility* is a new, proposed construct that seeks to synthesize and evolve simultaneously the current conceptualizations of adaptability, adaptive performance, and flexibility. Specifically, cognitive agility represents an individual cognitive ability to flexibly operate with cognitive openness and focused attention. The following section provides theoretical reasoning for the choice of *agility* as a construct name as opposed to variations of adaptability or flexibility (i.e. other terms more commonly used to suggest a range of individual appropriate and variable behavior).

There are multiple ways in the literature to describe the ability to make an appropriate change in response to the environment. Adaptability as described throughout this work is perhaps the most common naming convention (Pulakos et al., 1999). Yet, adaptability is often operationalized as performance in a task that is complex, novel or ambiguous (LePine et al., 2000; Mumford et al., 1993), regularly having been referred to as adaptive performance (Allworth, 1997, 1998; Kozlowski et al., 2001). Therefore describing *adaptability* as an ability leading to *adaptive* performance becomes tautological and potentially confusing towards creating a deeper knowledge of the construct. Within the cognitive literature some have simply labeled such adjustments as ‘cognitive adaptability,’ which means an ability to change decision frameworks or knowledge to meet the environmental needs (Haynie, 2005). What this conceptualization may be missing with regard to the current study are the cognitive needs of the *particular*
context. In real-time dynamic tasks, the speed of change is a necessary component, along
with trying to identify what the individual is changing to and from in terms of orientation
and decision frameworks. The context of a real-time dynamic task is different then
adapting on a longer time horizon, across multiple tasks and therefore requires a different
set of abilities (constructs) that may apply directly.

Cognitive flexibility is another commonly used construct to signify the
appropriate cognitive adjustment according to situational needs. Like adaptability, it is
often defined as an appropriate shift in behavior (Zacarro et al., 1992). Yet its definitions
range from being described as creative (Isen et al., 1987) to having an awareness and
belief that situations have alternative options (Martin and Anderson, 1998); thus, making
it hard to pin down an agreed upon definition. Flexibility is often used synonymously
with adaptability (Calarco & Garvis, 2006; Canas et al., 2003; Goleman, 1998; Grattan et
al., 1999; Griffin and Hesketh, 2003; Murphy and Jackson, 1999; Pulakos et al., 2000),
进一步 confusing the two constructs. Statements such as, “Cognitive flexibility is defined
as a person’s willingness to be flexible and adapt to the si-

tuation” are not at all
uncommon (Martin and Anderson, 1998, p.1). Again by using the terms ‘adapt’ and
‘flexible’ together, in place of one another, or to describe flexibility as being flexible,
makes the understanding of the constructs less clear.

Cognitive flexibility is a construct whose conceptualization has not been fully
agreed upon. Yet across the diverse definitions is a theme of intelligently adapting to
one’s environment (Berg & Sternberg, 1985), through various forms of shifting,
restructuring or expanding cognition. It is suggested here that the ability to control one’s
thinking and change the decision strategy is just one aspect of cognition that allows for
more adaptive performance in dynamic contexts (Canas et al., 2003). Yet, cognitive flexibility alone, does not adequately describe what an individual is actually changing about his or cognition. The particular change is likely relevant to specific environmental contexts. The elements encountered in a real-time dynamic context likely require a particular integration of flexibility with other necessary dimensions.

There is a need for identifying unique clusters of ability that support adaptability in specific contexts. Therefore the word agility was chosen as it represents integration, coordination and a balance of multiple abilities amidst changing conditions. It suggests an ability to do so quickly, which lends itself to creating a proper fit with the speed oriented requirements of adapting in a real time dynamic task. At the organizational level, agility describes the capacities of the firm to respond quickly to continual and ongoing environmental changes (Kodish et al., 1995). Therefore cognitive agility is a unique construct at the individual-cognitive level that is predicted to lead to adaptive performance in the specific context of a real-time dynamic task.

As a formative construct, cognitive agility includes the variables of cognitive openness, focused attention and cognitive flexibility. These three variables represent a cluster of abilities that operate in unison within a task that demands dynamic real-time updates. The emergent formative construct of cognitive agility is shown in Figure 1. Each of these variables is considered in greater detail below.
This study focuses on the real-time aspect of adaptability within a particular dynamic task. The task chosen for this study is a dynamic decision-making microworld – which will be reviewed in greater detail in the Methods section. In the particular microworld used (the Networked Fire Chief) as well as others, intelligence has shown to be a predictor of success (Ackerman, 1992; Brehmer & Dörner, 1993; Gonzalez et al., 2005). This study attempts to support these findings and extend them by demonstrating that cognitive agility impacts adaptive performance beyond intelligence in a microworld. The following section provides a review of the variables being tested in this study and demonstrates how each is related to adaptive performance in a dynamic decision making context. Subsequent sections include the methods of testing the individual variables and the construct of cognitive agility, the presentation of results, and a discussion of study outcomes, limitations and implications for future research and practice.
Intelligence and Real-Time Adaptability

Intelligence is the ability to balance the demands of the situation to adapt with success (Sternberg, 1999). General intelligence (g) refers to the individual capability to “broadly” comprehend one’s environment and effectively plan a response (Gottfredson, 1997). Others relate intelligent thought to one’s ability to choose the most effective strategies in novel scenarios (Frensch & Sternberg, 1989). Both interpretations are supported as higher levels of g are associated with greater results in novel tasks (Hartigan and Widgor, 1989; Hunter & Hunter, 1984), and, as task complexity increases, a stronger relationship is found between performance and ability (Ackerman, 1988; Kylönen, 1985). Furthermore, individuals with higher intelligence are shown to be more able to modify attentional processes than those with lower intelligence (Shafer, 1979; Shafer & Marcus, 1973). Multiple forms of intelligence have shown a predictive capacity in determining outcomes in dynamic decision-making scenarios (Gonzalez et al., 2005) and g has been shown to predict adaptive performance in particular (LePine et al., 2000; Pulakos et al., 2002; Zaccaro, 2001).

The Dynamic Decision Making scenario used in this study requires one to adapt in a novel and complex environment (Sterman, 2000). Because past dynamic decision making studies have shown that intelligence predicts success in the changing context(s) (Ackerman 1992; Gonzalez et al., 2005; Rigas, Carling, and Brehmer, 2002; Schoppeck, 1991), it should predict higher performance in the particular dynamic decision making
environment – a changing scenario with conflicting goals and numerous options to choose among (Brehmer, 1995; Omodei et al, 2001).

**Focused Attention and Real-Time Adaptability**

Focused attention, in general, describes the ability to attend to relevant stimuli and ignore distracting ones (Lustig et al., 2001). It serves the individual in being able to filter out information (Kahneman & Treisman, 1984). By bringing focus to essential stimuli, while suppressing awareness of opposing distractions (Van Zomeren & Brouwer, 1994; Kahneman, 1973), one can limit incoming and potentially distracting information, instead of searching for novelty (Lustig et al., 2001). Focused attention is one form of many cited attentional capacities to describe ways that information is selected and filtered (Neisser, 1966).

Various other attentional components, including selective attention and sustained attention, share similarities or relationships and support the understanding of focused attention as researched here. These complementary terms will be explored as well as a brief overview of attention in order to frame the manner in which focused attention operates within the framework of adaptive performance.

All cognitive processes utilize attention to some degree (Kahneman & Triesman 1984). Attention is a resource and like all resources, it is limited. A wide range of conceptualization regarding models of attention exists (Goldhammer & Moosbrugger, 2006). Human attention, defined generally as stimulus selection (Gibson, 1969), also includes maintenance, focus and resource allocation and the processes through which
sensory input is “transformed, reduced, elaborated, stored, recovered, and used” (Neisser, 1966). Coull (1998) characterized attention as "... the appropriate allocation of processing resources to relevant stimuli" (p. 344). Attention is an idea that encompasses many aspects of human information processing experiences.

Scholars often describe the perception of attention through metaphors, which assist in understanding its operations. Some metaphors of attention include: a filter (Broadbent, 1958), effort (Kahneman, 1973), a resource (Shaw and Shaw, 1978), a control process of short-term memory (Shiffrin and Schneider, 1977), orienting (Posner, 1980), a spotlight (Tsal, 1983), a gate (Reeves and Sperling, 1986), a zoom lens (Eriksen and St. James, 1986), and a selective channel (LaBerge and Brown, 1989). For instance, in the zoom lens metaphor, focused attention is viewed as a relatively swift process in which there is a rich output in a limited area (Eriksen & St. James, 1986). In the gate metaphor, attention allows information to enter but in order to do so, an individual must cognitively shut one stream of information in order to open another (LaBerge, 2004). The metaphors used to describe attention inform and structure our models of conceptualization (Gibbs, 1994).

Metaphors for attention have led to several important models which help deepen the conceptualization of attention. Posner serves as a key figure in the conceptualization of attentional models (Posner & Boies, 1971; Posner, Rafal, 1987; Posner & Peterson, 1990). In his view, the multi-component model of attention separates the capacities of alertness and selectivity (Posner & Boies, 1971). Posner proposed that within selectivity there is a separate 'executive' branch of the attentional system, which is accountable for focusing attention on chosen aspects of the environment (Posner & Petersen, 1990).
Sturm and Zimmermann extended Posner’s model to show a hierarchy of attention with both upper and lower levels (Sturm and Zimmermann (2000)). The upper level contains intensity and selectivity. Intensity is associated with alertness, sustained attention, and vigilance. Similar to Posner’s model, the selectivity portion of this level includes focused or selective attention, visual spatial selective attention, attentional switching, and divided attention (Sturm and Zimmermann, 2000; Van Zomeren and Brouwer, 1994). Each of these models describes focused attention as a selective process controlled by an executive system. Yet they do not describe the process of holding this attention to filter out irrelevant information.

There are several terms used to describe the process of holding attention. For instance, sustained attention, or vigilance, refers to the ability of observers to maintain a high level of mental concentration over extended periods of time (Rose et al., 2002). DeGangi and Porges (1990) suggest a three-stage model of sustained attention. In their model, attention that is sustained, and runs the course of: attention getting, attention holding and attention releasing. In this model, attention is held by information that is novel or complex. This however suggests that the executive system has less conscious control of sustaining selection or focus, as it is dependent on environmental cues.

In contrast, James wrote of sustained attention as a fleeting activity: "There is no such thing as voluntary attention sustained for more than a few seconds at a time"; "what is called sustained voluntary attention is a repetition of successive efforts which bring back the topic to the mind" (James, 1890, vol. 1, p. 420). James describes the struggle of bringing attention to a stimuli and speaks about an ongoing interference with information that is irrelevant to current intention.
The ability to limit incoming information is necessary. Although Coull (1998) characterized attention as "... the appropriate allocation of processing resources to relevant stimuli" (p. 344), this assumes a simplification, and does not account for an individual’s degree of skill or ability to regulate and deflect incoming data, which is focused attention.

Focused attention (Schneider et al., 1984) generally describes the ability to attend only to relevant stimuli and to ignore distracting ones (Lustig et al., 2001). Posner proposed that there is a separate 'executive' branch of the attentional system, which is responsible for focusing attention on selected aspects of the environment (Posner & Petersen, 1990). Focused attention can be thought of as part of selective attention, which is the capacity to bring focus or attend to essential stimuli, while suppressing awareness of opposing distractions (Van Zomeren & Brouwer, 1994; Kahneman, 1973). It is this last point that subtly differentiates focus from selection. Selective Attention describes the choice of possible stimuli to focus on and not the reduction or filtering out of irrelevant stimuli (Kahneman & Treisman, 1984).

The incapacity to deny entry of irrelevant information or needless information processing, marks a failure of focused attention. Focusing attention can fail due to a situational occurrence that disrupts ongoing attention (Shiffrin and Schneider 1977, Yantis, 1993; Theeuwes 1994). This disruption can ‘grab’ attention and lead to future relevant pieces of data being missed (Shapiro and Raymond, 1944) or the dilution of attentional resources to accomplish the intended goal.

The use of attentional resources is vital to understating real time adaptation. In dynamic situations, one must be able to manage the effects of incoming information
within the current course of cognitive action. With ongoing changes to the environment, *focusing attention* can fail due to a situational occurrence that disrupts ongoing attention (Theeuwes 1994; Yantis, 1993). Adaptive performance within a task requires that focus be paid to relevant data, which provide ongoing cues to adjust activity accordingly. If *focused attention* were low, then the individual may quickly find a dilution of his or her attentional resources in relation to accomplishment of an intended task. In essence, he or she may become overwhelmed by information, thus not following a coherent decision path toward adapting well with the changes (Anderson, 1983).

*Cognitive Openness and Real-Time Adaptability*

Cognitive openness as a concept is associated with several streams of existing literature, which are each, linked to real time adaptability. There are no existing instruments to measure, explicitly, the cognitive aspects of being open. Yet, the construct of openness in the psychological literature is most often cited as ‘openness to experience,’ as used in the literatures of Big Five Personality Trait Measurements (Costa & McCrae, 1985). Still other constructs such as creativity (Gough, 1979), curiosity (Littman, 2005), and mindfulness (Langer, 1989), while they do not always employ the term *openness* per se, also highlight the importance of “being open” or employing related qualities of cognition in respect to dynamic contexts. Therefore, the theoretical links between adaptability and aspects of openness to experience, curiosity, creativity and mindfulness are established here to support the choice of terminology and measurement.
A brief review of each of these constructs and their application to real time adaptive performance is discussed below.

In the psychological literature the term “openness” is most often attributed and understood in the context of The Big Five Personality Trait called ‘Openness to Experience’ (Costa & McCrae, 1985; McCrae & Costa, 1985). This use of the term openness was first measured by Costa & McCrae (1985) using the NEO Personality Inventory, a 240 item self report (NEO PI-R; Costa & McCrae, 1992). Openness in this context is used to describe a personality type with a proclivity toward sensation seeking and an interest in the non-routine. Since open individuals are comfortable with ambiguity, tend to like intellectual problems and seek novelty (Costa & McCrae, 1992; LePine et al, 2000; King et al., 1996), they are more likely to adapt appropriately to changing conditions (Blickle, 1996).

Measures of ‘openness to experience’ on the Big 5 Personality Inventory (e.g. NEO-PI), indicate individuals who score highly on this dimension as being receptive to new ideas, experiences and perspectives. McCrae and Costa (1997) state that “openness is seen in the breadth, depth, and permeability of consciousness, and in the recurrent need to enlarge and examine experience” (p. 826). Openness as used in the Big Five is often conceptually related to creativity to the point that scholars use the term creativity to refer to openness (Digman, 1990; Matthews & Deary, 1998).

Creativity is the ability to produce novel and appropriate solutions to problems (Amabile, 1996; Lubart, 1994; Jackson & Messick, 1973; Mackinnon, 1962; Sternberg & Lubart, 1996). Creativity has been conceptualized as a personality characteristic (Spearman, 1923, 1927), a thought process (Ward, 1994), an outcome (Amabile, 1996),
and has been measured in a variety of ways (Davis, 1971). Creative individuals and creative processes are associated with the adjustments necessary in adapting to change (Mumford et al., 1991).

As a personality characteristic, creative individuals are often regarded as independent, curious, open-minded, artistic, attracted to novelty (Davis, 1992) and possessing the ability to think divergently (Guilford, 1960). As a process, creativity is often differentiated into the consecutive stages of preparation, incubation, illumination and verification (Lubart, 1994). As an outcome, creativity is viewed in terms of the value of a product (Bailin, 1988). Creative individuals are open to new ideas and are able to establish associations, distinctions and unique perspectives that non-creative individuals are not as able to do. In a real time dynamic context, creative individuals are more able to find ways of approaching a complex situation (Mumford et al., 1993).

One important connection creativity has with cognitive openness is the ability for divergent thinking. Divergent thinking provides the capacity for the creation and inclusion of new ideas (Wallach & Kogan, 1965; Hyman, 1964; Torrance, 1974; Guilford, 1967; Guilford, 1960). The cognitive aspects of creativity have been strongly associated with the concept of divergent thinking (Baer, 1993; Scratchley & Hakstian, 2000), which is defined as an ability to generate as many responses as possible to a stimulus (Guilford, 1950, 1957). Wallach (1970) states that divergent thinking is dependent on the flow of ideas and the "fluidity in generating cognitive units" (p. 1240). Divergent thinking has also been linked to a broad scanning ability that is distinct from

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1 Bailin states that "The only coherent way in which to view creativity is in terms of the production of valuable products." (1988,p. 5). While this is a widely held believe by creativity scholars, this paper will not investigate creativity as an outcome since the main focus is about general capacity to engage with novelty and not a capacity to create a product in a particular domain.
general intelligence (Runco, 1991) and suggestive of one’s ability to see more stimuli in an environment (Mendelsohn, 1976; Mendelsohn & Griswold, 1964, 1966). This wide breadth of attention improves the chances that otherwise unseen stimuli will be used to create new ideas (Mendelsohn, 1976). Cognitive openness is supported by a divergent thinking process and ability and is therefore closely related to this dimension of creativity.

Theoretical models of curiosity inform cognitive openness in that both demonstrate a desire to engage in exploratory behavior (Voss & Keller, 1983; Peterson & Seligman, 2004). Curiosity has been defined as a motivation toward exploratory behavior, which results in acquisition of new knowledge (Berlyne, 1949; Collins, Littman & Spielberger, 2004; McDougall, 1921). Curiosity has been recognized by multiple scholars as both sensation seeking (Scroth & Lund, 1994; Zuckerman, 1979), and exploratory behavior (Voss & Keller, 1983). It is measured as both a motivational state (Berlyne; Day, 1969) and as an individual trait (Spielberger & Butler, 1971). It is broadly considered an approach behavior (Loewenstein, 1994), suggesting an active expression of openness toward stimuli. Several curiosity models demonstrate its variation in the literature and its general association toward adapting in a dynamic context (Reio and Wiswell, 2001).

An early model known as the “curiosity drive model” suggests that individuals require a sense of coherence in their cognitive frames and will seek out information to keep a sense of contiguity intact. Therefore, situations of novelty or complexity, which can create “uncertainty”, compel individuals to reduce this disruption through curiosity seeking behavior (Berlyne, 1950; 1955). This model is very similar to Loewenstein’s
“knowledge gap/approach gradient” theory of curiosity in which individuals discover novelty and then recognize a gap in their knowledge (1994).

Slightly different is the optimal arousal model, which states that curiosity is simply an enjoyable experience that individuals seek (Peterson & Seligman, 2001). Optimal Arousal suggests that there is an optimal point between being over aroused and under aroused. Littman and Jimerson (2004) attempt to reconcile these two prevailing models (Curiosity as Drive and Optimal Arousal) through the interest-deprivation model (ID). This model includes two main components, which are Curiosity as Feeling of Interest (CFI) (Litman & Jimerson, 2004), in which individuals experience curiosity as a feeling of interest versus Curiosity as Feeling of Deprivation (CFD). CFI is suggestive of a perpetual need that is satisfied by a sense of openness. CFI, which the authors compare to ‘openness to experience,’ is motivated by a genuine interest in wanting to know something new. Conversely, CFD is stimulated when one perceives to be lacking some necessary information. Individuals differ in their propensity to experience both CFI and CFD (Litman, 2005).

In yet another model, Berlyne divided notions of curiosity into two types: epistemic and perceptual. Perceptual curiosity is defined as “the curiosity which leads to increased perception of stimuli” (p.180), whereas epistemic curiosity reflects a desire to reduce knowledge gaps. Berlyne also made another delineation in terms of curiosity between two kinds of exploratory behavior, diversive and specific (1960). In diversive exploratory behavior, individuals are compelled by boredom and need for challenge to “seek stimulation regardless of source of content” (p. 26). In contrast, specific exploratory behavior is compelled by the search for depth of knowledge in a certain
domain or activity (Kashdan et al, 2004). These two modes of curiosity are hypothesized to work in conjunction with diverersive behavior leading to contact with novelty and specific curiosity attempting to answer the uncertainty found from the new stimuli (Dav, 1971; Krapp, 1999; Kashdan, 2004). Each of these models of curiosity help to support a mindful approach to novelty seeking (Langer, 1997).

Another exploratory mindset with a distinct similarity to cognitive openness are certain aspects of Langer’s version of mindfulness (1989; Bodner & Langer, 2001). Individuals with a propensity toward being mindful, with respect to openness, are able to “1) view a situation from several perspectives, and (2) see information presented in the situation as novel “(Langer, 1997 p.111). Like the other constructs discussed in this chapter, mindfulness suggests a comfort with the non-routine and an open-mindedness.3

Mindfulness is a state in which a person is both aware that his/her understanding of a situation is always subject to alternative interpretations and is willing to direct his/her attention toward creating those other interpretations (Bodner, 2000). The mindful individual is able to disseminate differences between the past and the present and discover uniqueness when encountering cues. The mindful individual actively creates novel distinctions, thus leading to an increase in multiple interpretations of any stimuli or situation (Langer, 1978, 1989, 1992, 1997; Bodner & Langer, 2001). The creation of novel distinction begins in part by the propensity of the mindful individual to approach novelty.

3 In contrast, Langer discusses mindlessness as the normative human attentional mode in which one’s approach to information is reliant on automatic cognitive functioning. Mindlessness is a state of automaticity in which individuals behave like robots and can be considered a passive version cognitive closedness to contrast openness. This is nicely captured in the familiar experience of driving home from work on the same route, a task we can accomplish without any active attention paid to the necessary turns. More subtly, the mindless state can be found in social interaction when we automatically categorize people with pre-constructed expectations, thus disregarding the sensitivity of context.
A particular aspect of mindfulness that is relevant for cognitive openness is novelty seeking behavior (Epstein 2003, Runco 1994, Langer, 1989; Stokes, 1999) or a preference for novelty (Houston & Mednick, 1963). Novelty seeking as a personality trait is defined by Pearson 1970 as:

a tendency to approach versus a tendency to avoid novel experiences. It is a disposition toward changing, new or unexpected experiences versus a disposition to avoid these experiences. The degree of novelty in any one experience is a function of the discrepancy between an individual’s past experience and the present one. (p. 199).

Novelty seeking is most commonly measured through self reports (Edwards, 1966; Garlington & Shimona; Jackson, 1967; Pearson, 1970). These self reports often identify a series of specific desires to ‘try new things’ or ‘go to new places.’ Fast paced dynamic decision making scenarios present the individual with tremendous novelty.

Aspects of one’s openness, curiosity, creativity and mindfulness likely affect real time adaptive performance in a dynamic context. For instance, openness to experience has been expressed as part of a higher order factor along with extraversion to explain plasticity in personality (DeYoung, Peterson, and Higgins, 2002). John & Srivastava (1999) explain that this higher-order factor is a meta-trait and includes the overarching concerns of an organism to incorporate novel information into that organization, as the state of the organism changes both internally (developmentally) and externally (environmentally). Thus, openness to experience would support one in noticing and including more novel data supporting adaptation in a changing and dynamic context.
In general, adaptability places a ‘premium’ on creativity (LePine et al., 2000). Creativity and specifically one’s capacity for thinking divergently allow for the creation and inclusion of new ideas (Guilford, 1960; Torrance, 1974). As presented above, divergent thinking is defined as an ability to generate as many responses as possible to a stimulus (Guilford, 1950). Divergent thinking has also been linked to a broad scanning ability that is distinct from general intelligence (Runco, 1991) and as previously stated, divergent thinking is suggestive of one’s ability to see more stimuli in an environment (Mendelsohn, 1976; Mendelsohn & Griswold, 1964, 1966). This wide breadth of attention improves the chances that otherwise unseen stimuli will be used to create new ideas (Mendelsohn, 1976).

Curiosity as a need in reducing knowledge gaps and as an inherent interest in understanding something more deeply seems to be foundational for adaptation. As contextual changes are encountered in a dynamic environment new ways of behaving are necessary. Curiosity implies "a direction of development toward differentiated interaction patterns and more effective problem solving" (Voss and Keller 1983, p. 156). Curiosity does not ensure successful adaptation but it starts the process of experimentation and discovery that leads to adaptivity and innovation. Adaptability is strongly linked to curiosity as "that factor which underlies the willingness of an individual to expose himself to information" (Day, Langevin, Maynes, & Spring, 1972, p. 330). Adaptability within a dynamic task requires that one be open to the changes that take place, and be able to notice new information when appropriate.

Mindful awareness allows individuals to be more adaptive (Langer 1989). One area within mindfulness where this is most salient is in regard to novelty seeking (Bodner
Novelty seeking from a mindfulness conceptualization and measurement perspective includes aspects of openness, curiosity and creativity (Bodner and Langer, 2001). In a real time dynamic context this combined resource supports one in seeking understanding (curiosity), embracing change (novelty/openness) and searching for ways to categorize information (creativity) that could lead to adaptive performance.

Cognitive Flexibility and Real-Time Adaptability

Cognitive flexibility is linked to adaptive performance within a real time dynamic decision-making context (Canas et al., 2003). Cognitive flexibility is both a meta-cognitive and executive function that supports successful adaptation through its underlying components of cognitive monitoring and cognitive control (Clark, 1996). This notion of cognitive monitoring and control (Monsell, 1996; Rostan, 1994) allows one to overcome dominant or automatic response sets (Jost, et al., 1998; Diekman, 1994), and shift to a more appropriate contextual response (Reder & Schunn, 1999). Cognitive flexibility, the ability to cognitively control and shift mental set (Canas, 2003; Clark, 1996; Rende, 2000), is necessary in real-time adaptive performance.

It is instructive to note at the outset that definitions of cognitive flexibility encompass a diverse range of conceptualizations. For example, cognitive flexibility has been described as being creative (Isen et al., 1987), attending to novel events (Barcelo & Perianez, 2002), demonstrating divergent thinking (Guildford, 1959), intelligently adapting to one’s environment (Berg & Sternberg), being open to new views within a domain (Scott, 1967), having the ability to see distinctions (Murray et al 1990), forming
associations or interrelationships (Murray et al., 1990; Mednick, 1962) switching strategies (van Zomeren, 1981; Showers & Cantor, 1985), shifting sets (Luchins & Luchins, 1959), having an awareness and belief that situations have alternative options (Martin and Anderson, 1998), displaying the ability to restructure knowledge (Spiro & Jehng, 1990; Chi, 1997; Mumford, Baughman, Maher, Costanza & Supinski, 1997; Perkins, 1988), and using cognitive control to override automatic responses (Canas, 2003; Clark, 1996; Rende, 2000).

Another way cognitive flexibility has been defined, which is relevant to real time adaptive performance, is an individual’s ability to shift attention in order to respond to the environment in a new way (Eslinger & Grattan, 1993). This shift can either be initiated within oneself or dictated by external requirements that necessitate a new way of responding (Richard et al., 1993). The distinction of cognitive flexibility can be more specifically described in the separation of reactive or adaptive flexibility and spontaneous flexibility\(^4\) (Eslinger & Grattan, 1993). And while this describes where the need for flexibility originates it does not explain what underlying abilities are necessary to create this attentional shift.

Using the analogy of a train track, cognitive flexibility serves as the “switch” in determining track direction. On one level, cognitive flexibility is about cognitive monitoring—noticing the need to switch direction. On another level, it is about cognitive control—being able to execute the track change. These two dimensions, monitoring and control, are what makes cognitive flexibility and ultimately cognitive agility possible.

\(^4\) The other type of flexibility is spontaneous flexibility. Is similar to divergent thinking. Broken up into ideational and semantic, ideational is the number of ideas and semantic is the variety of ideas.
Cognitive monitoring and cognitive control are two aspects of regulation or flexible use of cognition. They are encompassed within the established literatures of cognitive control (Groborz and Necka, 2003) and metacognition (Moses & Baird, 1999; Paris & Lindauer, 1982; Pintrich et al., 1993; Nelson & Narens, 1994; Schraw & Dennison, 1994; Flavell, 1979). For example, metacognition generates flexible cognition if someone perceives through cognitive monitoring that they do not fully comprehend an experience (Flavell and Wellman, 1977; Brown and Palinscar, 1982; Whimbey and Lochhead, 1999). In such a situation, he may choose, through cognitive regulation, to increase attentional focus to reduce other distractions (Hacker, 1998). Similarly, cognitive control is an executive capacity which allows one to overcome automatic responses in favor of more controlled consciousness, allowing contextual cognitive adjustments (Norman & Shallice, 1986; Fernandez-Duque & Johnson, 1999).

Therefore, cognitive flexibility as conceptualized here, is a meta-cognitive regulative capability. Meta-cognition, which is commonly referred to as “thinking about thinking” (Flavell, 1979), includes both the knowledge and regulation of cognitive activity (Moses & Baird, 1999). The regulation component of meta-cognition is synonymous to cognitive flexibility, as it encompasses bottom up processes like monitoring (e.g., error detection, source monitoring) (Fernandez-Duque, et al., 2000), and the top-down processes of cognitive control (Fernandez-Duque, et al., 2000) which include error correction, inhibitory control, planning and resource allocation (Nelson & Narens, 1990; Reder & Schunn, 1996). The processes or abilities of cognitive control

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5 Cognitive Knowledge is...which is not necessary for the present examination of flexibility
and metacognitive regulation are presented as brief reviews below to support the theoretical development of cognitive flexibility.

Strategies used in cognitive operations that are monitored and controlled rely on metacognition. Metacognition is essentially ‘thinking about thinking’ (Schacter, 1996; Wyer & Srull, 1989), but has several other definitions (Van Zile-Tamsen, 1994, 1996) and models (Flavell, 1979; Brown, 1987; Tobias, 1995). This broad ability is underpinned by the abilities to monitor (Moses & Baird, 1999; Paris & Lindauer, 1982; Pintrich et al., 1993) and regulate thinking (Moses & Baird, 1999; Nelson & Narens, 1994; Schraw & Dennison, 1994). Metacognition refers to "One’s knowledge concerning one’s own cognitive processes and products or anything related to them (...) [and] refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes (...), usually in the service of some concrete goal or objective” (Flavell, 1976, p. 232). Metacognition exists at a higher level of the strategy processing hierarchy and is less domain specific than the employed cognitive strategies (Flavell, 1979) suggesting a general ability beyond expertise or task exposure.6

Metacognition requires an ability to monitor one’s ongoing thought processes as they relate to accomplishing a goal (Nelson & Narens, 1990). Monitoring is used to scan the mental landscape in order to see if attention is being properly distributed according to the task at hand (Pintrich & Schrauben, 1992). Metacognitive awareness also responds to whether attention allocation with regard to strategy use is working successfully (Montague, & Bos, 1990; Tobias, 1995; Weinstein & Mayer, 1986). Monitoring works

6 ‘Knowledge about’ cognitive states refers to awareness of prior knowledge about specific task and one’s ability in that task. This is more domain specific and therefore an area of metacognition that I will not explore in as much detail as regulation.
in concert with regulation, as awareness through monitoring creates ground for controlled change (Hart, 1965; Koriat & Goldsmith, 1996; Nelson, Dunlosky, Graf, & Narens, 1994; Vernon and Usher 2003). A mismatch in goals and what one deduces through current monitoring creates a subjective awareness of a need to change cognitive strategies.

The controlled component of metacognitive regulation is very similar to cognitive control (mentioned above and described in greater detail below) or the executive function that is said to guide so much of our conscious behavior (Posner & Snyder, 1975). Yet, despite the obvious connections between metacognitive regulation and executive control that exist, the two streams of literature are rarely associated (Carlson, Moses, & Hix, 1998; Garner, 1994; Hughes, 1998; Mazzoni & Nelson, 1998; Metcalfe & Shimamura, 1994).

Cognitive control is a mechanism responsible for a diverse range of psychological functioning (Monsell, 1996; Rostan, 1994). These functions can include memory (Baddeley & Hitch, 1974; Hasher & Zacks, 1979; Jacoby, 1991; Koriat & Goldsmith, 1996), attention (Kane et al., 2001; Norman & Shallice, 1986; Posner & Snyder, 1975; Shiffrin, 1988; Shiffrin & Schneider, 1977), and general fluid intelligence (Conway, et al., 2002; Engle, Tuholski, et al., 1999; Kyllonen & Christal, 1990). Cognitive control directs thinking and behaving as it leads to self-selected goals and is responsible for inhibiting automatic responses that may sidetrack goal achievement (Canas, 2003). Groborz and Necka (2003) state that cognitive control is responsible for the reduction of “chaos” in the processing of information, defining it as the “ability to suppress inadequate responses and evoke the proper ones “ (Groborz & Necka, 2003 p. 185). Cognitive control provides the capacity to choose what to approach or to avoid in the environment.
of possible stimuli.

There is an executive branch for attentional processing which is able to bring attention to intended parts of the environment (Posner & Petersen, 1990). As stated above, this level of control starts with intentional allocation of the attention needed for “….maintaining temporary goals, in the face of distraction and interference and for blocking, gating, and /or suppressing distracting events” (Engle et al., 1999 p 102). Yet it is also responsible for overriding the automatic processing of information through schemas (Posner, DiGirolamo, & Fernandez-Duque, 1997). In instances where there is an injury to the executive system, individuals are reported to activate the same schema to the point of perseveration (Milner & Petrides, 1984). In contrast, lesions to the frontal lobe (where the executive system exists) can lead to an increase in distractibility when schemas are activated by a host of inappropriate stimuli (Shallice, 1988). The executive system is most effective when “under the conscious control of the subject” (Posner & Snyder, 1975, p. 73).

James viewed cognitive control (mental control) as an activity similar to that of physical effort (1890). He thought that similar to the physical body and its muscles which could operate according to reflex, so too the mind had muscles (i.e. attention) that could operate automatically without control or volition (James, 1890). Humans are automatized via our currently held schemas and mental models or our top down processing (Posner, DiGirolamo, & Fernandez-Duque, 1997). Alternatively, cognitive control allows one to slow down the processing of information in a way that may lead to a change in schemas (Norman & Shallice, 1986; Fernandez-Duque & Johnson, 1999) or strategy (Reder & Schunn, 1996).
Cognitive flexibility is necessary for adaptive performance within real time dynamic decision-making contexts (Canas et al., 2003). While cognitive flexibility is defined as the capacity to shift cognitive set, the actual ability to accomplish this is grounded in monitoring and control of cognition (Clark, 1996). It is this monitoring and cognitive control to shift strategies midstream, which leads to increased adaptivity in real time dynamic situations (Earley & Ang, 2003). Studies of performance taken from numerous domains demonstrate that most people use many different strategies on tasks (Reder, 1982; Siegler, 1996) thus showing strategy use is not fixed per task. The metacognitively adept individual has been found to be more open to the information in the environment and more able to integrate this information into existing representations of decisions (Melot, 1998; Schraw & Dennison, 1994). This process of controlled regulation is responsible for choosing the strategies and putting them into effect (Nelson & Narens, 1990).

In addition cognitive flexibility and/or cognitive control is used to override automatic responses (Canas, 2003; Clark, 1996; Rende, 2000). Cognitive regulation is necessary in making adaptive changes in processing strategy (Payne, Bettman and Johnson, 1993), which requires elements of overriding automatic responses to familiar cues in the environment (Deikman, 1982). This requires cognitive control (Clark, 1996; Rende, 2000; Bargh, 1994; Schneider & Schiffrin, 1977), metacognition (Flavell, 1979) and an ability to override dominant logic (Ireland et al., 2003; Deikman, 1982). Diekman writes about this ability to overrule a usual response as “an undoing of the automatic processes that control perception and cognition” (p. 137). This is defined as “deautomization” in which one separates oneself from the automatic sequence and
increases the likelihood of choosing a more fitting reaction (Deikman, 1982). In a real time dynamic context, one must be able to override preprogrammed responses as the situation calls for new strategies.

Cognitive Agility and Real-Time Adaptability

Adapting successfully within a real time dynamic task context requires that one flexibly operate, being both open and focused. An individual must be able to notice novelty and have the capacity for the creation and inclusion of new information (Kozlowski, et al, 2001; Zaccaro, 2001; Wallach & Kogan, 1965; Hyman, 1964; Torrance, 1974; Guilford, 1967; Guilford, 1960). Cognitive openness thus supports one in noticing relevant stimuli, and being more likely to consider parts of the environment that others may miss (Chan & Schmitt, 2000; Langer, 1989). Yet, the inclusion of too much information may indicate a failure in focused attention (Schneider et al., 1984), causing the individual to lose the cognitive thread of what is most relevant for the given task (Anderson, 1983; Brunstein & Olbrich, 1985; Kuhl & Kazen-Saad, 1988; Salvucci & Taatgen, 2008). An over inclusiveness of information can hamper individuals who see many associations between ideas but have trouble focusing on one thing (Necka, 1999). On the other hand, being too focused limits one’s capacity to find new and necessary information and prevents adaptation. An over-focus can be found in those who have ‘tunnel vision’ and operate with incredible efficiency within a bounded space (Fiol & Huff, 2007). In this sense, having the capacity to be flexible, utilizing both openness and focus may help determine successful adaptation within a given task. One must be able to
shift between being open and focused throughout the real-time task. In other words, in order to adapt one must be able to shift from a currently utilized thought routine, to a new one that favors the changes to the environment (Canas, 2003; Clark, 1996). *Cognitive flexibility*, the ability to cognitively control and shift mental set (Clark, 1996; Rende, 2000), then is also necessary in real-time adaptive performance. A combination of these three capacities should support adaptive performance through a real-time changing task context.
CHAPTER II

METHODS

Study Overview

This is an initial criterion related predictive validity, laboratory study. It examines the relationship between cognitive openness, cognitive flexibility, focused attention, two forms of cognitive intelligence and their effects on a computer based dynamic decision-making game. Independent variable data come from questionnaires, three performance tests, a vocabulary test using a multiple-choice format and a visual-spatial intelligence test. Furthermore, external raters are selected to complete each of the questionnaires on behalf of the participants in an attempt to further validate the construct (Campbell & Fiske, 1959). None of the three self report measures used in this study has been previously subjected to correlation comparisons with measures from external raters. The use of self report, performance scores and other rater reports provide data to properly employ analysis through a multimethod (self, other and performance), multitrait (cognitive openness, cognitive flexibility, focused attention) comparison approach
(Campbell and Fiske, 1959). The dependent variable was a total performance score (i.e. adaptive performance) on three trials of the dynamic decision making game known as the Networked Fire Chief (NFC).

**Design**

The study had two parts. In Part I, participants were invited via email to take part in a lab experiment in exchange for a modest cash reward. The lab experiment included the data collection of some basic demographic information, a series of questionnaires and performance tests that were completed at individual computer terminals. Participants completed three questionnaires to include the subsections of the Langer Mindfulness Scale – Novelty Seeking (Langer 2001), The Attentional Control Scale – Focused Attention (Derryberry, 1998) and the Metacognitive Awareness Inventory – The Metacognitive Regulation Sub-scale (Schraw and Dennison, 1994). Once the questionnaires were completed the participants were instructed to complete the following performance tests: The Stroop Color Test (Stroop, 1935), The Basic Word Vocabulary Test (Dupuy, 1974), The Go No Go Paradigm (Zimmerman and Fimm, 2000), the Alternate Uses Test (two objects, brick and paper clip) (Guilford, 1956) and The Card Rotations Test (Ekstrom, 1976). Once completed participants took part in three separate five minute trials of a dynamic decision making computer simulation known as the Networked Fire Chief (NFC). Total test time lasted approximately one hour per participant. Testing for Part I of the study took place over a six week period.

Once Part I was completed, Part II began with an automated email sent to person(s) the participant provided as knowing very well. As part of the demographic
information collected, participants were required to provide one to three email addresses of people who “know them best” to take a survey on their behalf. The survey included the same three questionnaires the participants completed in Part I, but were reworded to collect information about how the selected ratee considered the behavior of the participant. Other than a change to the pronouns (from “I” to “Him/Her” the items remained exactly the same.

Participants

Undergraduate students at a mid size Midwestern University volunteered to be included on a contact list to take part in university supported research studies. Data were collected from 185 undergraduate students. However, four participants were eliminated from the sample due to technical errors. A total viable sample of 181 participants was available for self-data. 152 participants provided usable data for self and other (i.e. that had at least one person who knew them, successfully complete the reworded questionnaires on their behalf).

All participants in this study had voluntarily signed up to be on a contact list to participate in paid research studies through the Economics department of the University. Participants received emails inviting them to take part in the study (see Appendix A). The overall response rate from the research contact list was 44% (420 email invitations were sent; 195 agreed to participate) with the effective response rate being 43% (181/420 for scores of self) and 36% (152/420) for scores of self and other, respectively. The total sample (185) consisted of 102 males and 83 females. The sample of completed self reports (181) consisted of 101 males and 80 females. The sample of completed self and
others (152) consisted of 89 males and 63 females. Participants were of traditional college age ranging from 18-25 with 78% between the ages of 19-21.

Procedure

The descriptive outline of the procedures for this experiment are shown in Table 1. After agreeing to take part in the study, participants were asked to arrive at the computer lab at the University’s School of Management at a predetermined time. Upon arrival participants were assigned to an individual computer terminal. The principal investigator remained present during testing to answer technical questions. All the tests were completed on a computer. Use of the lab allowed for uniformity of experience across participants. The computer screen displayed the following information and tests in this order:

- A brief description of the research, instructions on how to proceed and thanking them for their participation
- A prompt to insert their log-in participant code
- A short demographic questionnaire (i.e., age, gender, use of computer games)
- A combination of items from subscales of three questionnaires (including the LMS, MAI & ACS).
- The Basic Word Vocabulary Test (BWVT)
- An online version of the Stroop Task (the name of a color written in a different color i.e. – the word RED written in the color green).
- A reaction time test using the go/no go paradigm
- The Alternate Uses Test utilizing 2 objects (brick, paper clip)
- A short computer based video recreation of how to operate the Networked Fire Chief
- A practice trial of the Networked Fire Chief
- A trial 1 of the NFC
- A trial 2 of the NFC
- A trial 3 of the NFC
<table>
<thead>
<tr>
<th>Name of Variable</th>
<th>Name of Measure</th>
<th>Number of Items</th>
<th>Estimated Time of Measure</th>
<th>Time of Measure</th>
<th>Authors of Measure</th>
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<td>Performance</td>
<td>Alternate Uses Test</td>
<td>2 objects</td>
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<td>Guilford (1959)</td>
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<td>Langer Mindfulness Scale</td>
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<td>5 minutes</td>
<td>Bodner &amp; Langer (2001)</td>
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<td>Other Rater Report</td>
<td>Langer Mindfulness Scale</td>
<td>9</td>
<td>5 minutes</td>
<td>Bodner &amp; Langer (2001)</td>
</tr>
<tr>
<td>2 Focused Attention</td>
<td>Performance</td>
<td>Go No Go paradigm</td>
<td>60 trials</td>
<td>5 minutes</td>
<td>Derryberry (1988)</td>
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<td>Attentional Control Scale</td>
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<td>5 minutes</td>
<td>Derryberry (1988)</td>
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<td>Attentional Control Scale</td>
<td>9</td>
<td>5 minutes</td>
<td>Derryberry (1988)</td>
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<tr>
<td>3 Cognitive Flexibility</td>
<td>Performance</td>
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<td>60 trials</td>
<td>5 minutes</td>
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<td>Metacognitive Awareness</td>
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<td>4 Intelligence</td>
<td>Verbal</td>
<td>Basic Word Vocabulary</td>
<td>40</td>
<td>10 minutes</td>
<td>Dupuy, (1974)</td>
</tr>
<tr>
<td></td>
<td>Visual-Spatial Test</td>
<td>Card Rotations Test</td>
<td>80</td>
<td>6 minutes</td>
<td>Ekstron, (1976)</td>
</tr>
<tr>
<td>5 Adaptive Performance</td>
<td>Trial 1</td>
<td>The Networked Fire Chief</td>
<td>1 trial</td>
<td>5 minutes</td>
<td>Omodei and Wearing (1995)</td>
</tr>
<tr>
<td></td>
<td>Trial 2</td>
<td>The Networked Fire Chief</td>
<td>1 trial</td>
<td>5 minutes</td>
<td>Omodei and Wearing (1995)</td>
</tr>
<tr>
<td></td>
<td>Trial 3</td>
<td>The Networked Fire Chief</td>
<td>1 trial</td>
<td>5 minutes</td>
<td>Omodei and Wearing (1995)</td>
</tr>
</tbody>
</table>

TOTAL TIME = 71 minutes
Measures

Dependent Variable - Adaptive Performance in DDM

**DDM Task– The Networked Fire Chief (NFC).** The (NFC) program is used in this study to create task demands that change dynamically (Omodei & Wearing, 1995). The NFC is used as a laboratory-based microworld for this study to create a contextual change that operates across participants in a controlled fashion (Lepine et al., 2000). The NFC is a Dynamic Decision Making environment, which presents ongoing change under a time pressured situation (See Figure 2 – The Networked Fire Chief).

Figure 2. Networked Fire Chief Screen Shot
The NFC program allows participants to “play” the role of a “fire chief” who must extinguish simulated forest fires. The subject extinguishes the fires as quickly as possible using water carried by helicopters and fire trucks. The helicopters and trucks are deployed to fires by using a drag and drop approach with a computer mouse. The user must contend with changes in the microworld as the fire becomes more intense (size of flames) and spreads faster depending on the wind direction and wind intensity (both demarcated by a compass). Fire trucks and helicopters run out of water and therefore users must monitor water levels of each fire truck and helicopter, which appear toward the bottom of the computer screen demarcated with a water percentage (%) left in reserve. The fire trucks and helicopters can be refilled with water at clearly marked water supply sites on the computer screen. Users can only see ¼ of the game space at a given time, and must click on a map on the left side of the screen to move to other views of the game (i.e. other parts). Thus the participants have multiple demands of the DDM environment to consider when playing the game. The program produces a performance score (dependent variable) at the end of each trial, determined by the percentage of landscape that remains unburned.

Three trials of the NFC program were used. The trials were preceded by an instruction session in which a ‘moving’ demonstration was provided using the software program Captivate. Preceding the first trial was a three minute practice session to give the participants a chance to familiarize themselves with the system controls. The three successive trials all lasted 5 minutes apiece. Each of the three consecutive trials was of increasing difficulty. Trial one was virtually static with limited wind change and only a few developing fires of low intensity. Trial two, included more frequent fire
development, switches in wind direction and increases in wind intensity. The third trial incorporated more difficult conditions, with more developed fires, more frequent wind changes, and greater intensity levels of both wind and fire.

While the NFC uses the context of fire fighting it is not meant to provide direct external validity. Instead the NFC, as with other dynamic decision making microworlds, intends to simulate conditions of dynamism presented to individuals in external working conditions (Brehmer & Dorner, 1993; Funke, 1991). The reason for using the microworld is to “map the functional relationships between the variables studies in the MV, and not necessarily the surface similarities between the MW and a particular field setting” (DiFonzo, Hantula & Bordia, 1998, p282). An example of this is from Brehmer’s study (1992), in which he used a similar fire fighting based microworld to study “the more general problem of how subjects cope with spatio-temporal processes of the kind exemplified by the fire fighting task” (pp. 214-215).

The Networked Fire Chief (NFC) has been used in a number of studies measuring phenomena at both the group (McLennan et al., 2006) and the individual decision-making level (Canas et al, 2003). The NFC has consistently demonstrated good reliability at .70 (Omodei et al., 2001). Several studies help demonstrate validity for the NFC as a decision making performance measurement. In one study, in the journal Intelligence, Gonzalez et al., (2005) refute the different demands hypothesis by measuring cognitive intelligence as a predictor of success in the NFC. This study demonstrated a strong relationship between fluid intelligence (measured by the Ravens Progressive Matrices) and performance on the Networked Fire Chief across 16 trials (n=13, r=.60, p<.05). Another study outcome which supports the validity of the NFC as a
naturalistic decision-making scenario appeared in the journal *Behavior and Research Methods*. This study predicted that the core perceptual-cognitive characteristics of naturalistic decision-making; namely speed, accuracy, efficiency, and planning would be associated with performance on the NFC (Glaser, 1976; Klein & Peio, 1989). The results indicate significant correlations between behavioral aspects of each of these elements and performance on the NFC (significant correlations ranging from $r=.75$, $p<.01$ for proactive planning to $r=.36$, $p<.05$ for the percentage of time the closest appliance was allocated first) (Elliott et al., 2007). In a series of studies with team performance in the NFC, a team leader’s tendency to micromanage (i.e., bypassed subordinates) led to decreases in overall performance ($r=-.41$, $p<.05$) (Omodei et al., 1999). One way to establish validity for the NFC is to compare performance scores to an expert’s decision-making (the action an expert would perform in the exact situation). In a study of decision quality, experts rated appropriateness of priorities in decision strategy (on a scale of 1 to 4 with one being completely inappropriate and 4 being completely appropriate) at four points in a final experimental trial (Clancy et al., 2003). The NFC has a play back function, which allows one to go back and review the actions taken during each trial. In this case there was a significant correlation between expert rated decision quality and performance ($r = 0.62$, $p < .01$).

At the end of each trial an overall performance score is produced by the program, which is calculated adding every safe cell (i.e. unburned). Demonstrating gains over losses after an individual has interacted with a changing environment is a way of calculating adaptive performance (Baltes & Staudinger, 1996; Featherman et al, 1990). A composite for the three trials is used as adaptive performance.
Measures for Independent Variables

Cognitive Openness - The Novelty Seeking Subscale from the Langer Mindfulness Scale (LMS)

The Langer Mindfulness Scale (LMS) is a 21 item self-report scored on a seven point Likert scale (Bodner and Langer, 2001). It measures an individual’s propensity to experience mindfulness. The full scale consists of four subscales to include flexibility, engagement, novelty seeking and novelty producing. Only the novelty seeking subscale was used for this study as a measure of cognitive openness.

The novelty seeking subscale contains six items. Some examples of questions that appear on the LMS Novelty Seeking Subscale are “I do not actively seek to learn new things” and “I try to think of new ways of doing things.” Validity for this scale is established with correlations with the Big Five Factor Model of “openness to experience” at (r=.50), the Multiple Perspectives Inventory (r=.64) and is negatively correlated with the Need for Cognitive Closure (r = -.20) (all measures from Bodner, 2000).

The standardized factor loadings are .53 to .62 for the novelty seeking subscale (Bodner, 2000). The Novelty Seeking subscale measures the manner of engagement with the environment. Those scoring highly on this subscale are more likely to look for new information and engage in new learning opportunities.

Cognitive Openness - Alternative Uses Test

The performance score of cognitive openness was assessed using the fluency results from The Alternate Uses Test (AUT) (Guilford et al., 1978; Wallach & Krogan, 1965). The AUT requires one to list as many possible uses for a common item (such as a
brick, a rubber band, a paperclip, a newspaper, or shoe). This is a common test of divergent thinking which is a label given to a collection of terms which include elaboration, fluency, flexibility, redefinition, and originality (Guilford, 1956). While divergent tests are criticized by some in their global measurement of creativity (Sternberg, 1985) they do measure abilities of creative achievement (Barron & Harrington, 1981). In this study participants were asked to think of as many uses for a “brick” and a “paper clip” and were provided with four minutes per item to complete their lists.

The AUT has long been used as a performance measure of creativity. While cognitive openness is not meant to be a direct measure of creativity, there are obvious links. In fact Openness as used in the Big Five is often conceptually related to creativity to the point that scholars use the term creativity to refer to openness (Digman, 1990; Matthews & Deary, 1998). Reliability for the AUT has been demonstrated from .62 to .85 (AUT Manual). For this study validity is established with fluency scores on the AUT correlating significantly with Openness on the NEO at (r=.46) (Chamorro-Premuzic, 2006), the Barron Symbolic Equivalence Test (r=.49) (Barron, 1988; Glicksohn et al., 1993), and with greater sensitivity in a habituation process (r=.36) (Martindale et al., 1996). The total number of responses for both objects is used to determine performance of cognitive openness.

Focused Attention - The Attentional Control Scale - The Focus of Attention Subscale

The self report score for focused attention was assessed using the Focus of Attention Subscale from The Attentional Control Scale (Derryberry & Rothbart, 1988).
This scale was designed to assess individual differences in voluntary attentional focusing and attentional shifting. The measure has three subscales to include focus of attention, shift of attention and flexible control of attention. An example of an item found in the focus subscale is “When concentrating, I can focus my attention so that I become unaware of what’s going on in the room around me.” High scores on the scale indicate a self-perception of an ability to limit the influences of goal irrelevant information from the environment. Validity for the total scale has been shown with correlations on the Inhibitory Control Scale (r = .25), and with Trait Anxiety (r=.50) (Derryberry & Rothbart, 1988). The three scales together have been shown through factor analysis to measure an overall capacity for attentional control. The measure is internally consistent (alpha =.88). This study will use the 9-item subscale of focus of attention.

**Focused Attention Performance- Go/NoGo Paradigm**

The Go/NoGo was used as a performance test of focused attention. This test employed a standard go/nogo paradigm in which participants must press a response key as fast as possible when presented with a “go” stimuli. Conversely, the participant must desist from pressing a key when presented with “no-go” stimuli. This task used 6 target stimuli, presented in the form of shapes (squares with different textures 3x3 cm) in which two of the squares are “go” targets and the remaining 4 are “no go” targets (See Figure 3, Go No Go Shapes). Participants must memorize the two patterns that are to be “go” stimuli. Then one of the six squares is presented and the participant must decide which kind of stimuli it is (a Go or No/Go). The inter-stimulus interval varies between 1000 and 2000 ms. There are 60 trials and the time between the presentation of the target and the
response is measured and stored at the millisecond level. The ability to block out the “no go” stimuli is an expression of focused attention ability.

The go/no go paradigm has been widely used to measure response inhibition in both experimental and clinical studies (Garavan et al., 2002; Laurens et al., 2003). This paradigm has been used on the Test of Attentional Performance (TAP) as a measure of focused attention (Zimmermann and Fimm, 2000). The go/nogo paradigm demonstrates validity, correlating with the Barrett Impulsiveness Scale (r=.40, p<.01) and perseverative error on the Wisconsin Card Sorting Task (r = 0.46) (Keilp et al., 2005). Reliability for go/no go has been demonstrated with split half and odd even coefficients at .998 (Zimmerman and Fimm, 2000). This study employed 60 trials and the time between the presentation of the target and the response was measured and stored at the millisecond level. Response times were used to measure focused attention ability.

Figure 3 – GO/NO/GO Shapes
The Metacognitive Awareness Inventory (MAI) is a 52 item questionnaire scored on a 7 point Likert scale with two main scales consisting of knowledge and regulation of cognition.

The knowledge section contains 17 items broken down into three subscales: declarative, procedural, and conditional. Knowledge scales measure the capacity of understanding one has for their cognitive resources, how to use this understanding and when to use it (Shraw & Dennison, 1994).

The second main subscale, defined as regulation, is composed of 35 items. The regulation section is made up of five subscales to include regulation of cognition: planning, information management, monitoring, debugging, and evaluation. Schraw and Dennison define the subscales as:

1. Planning: planning, goal setting, and allocating resources prior to learning;
2. Information management: skills and strategy sequences used on-line to process information more efficiently;
3. Monitoring: assessment of one’s learning or strategy use;
4. Debugging: strategies used to correct comprehension and performance errors;
Only items from The Regulation subscale will be used to measure Cognitive Flexibility. Items were chosen based on clean Factor loadings from Schraw and Dennison’s original validation of the instrument.

Examples of items from the Regulation subscale include “I am aware of what strategies I use when I study” “I consider several alternatives to a problem before I answer.” “I change strategies when I fail to understand” and “I stop and reread when I get confused” “I ask myself how well I accomplished my goals once I’m finished” “I think of several ways to solve a problem and choose the best one.”

High scores on these subscales are indicative of an ability to monitor and control strategies in goal driven learning. This is predicted to be the underlying abilities of cognitive flexibility, as changing mental representation is necessary for strategy shifting. The original MAI has shown strong reliability at .90 (Schraw & Dennison, 1994). The cognitive regulation factor correlates with the Motivated Strategies for Learning Questionnaire on the Individual Learning Strategies Scale (.72) (Pintrich et al., 1991). It has shown consistently high validity and reliability in use across a range of task domains (Schraw, 1998).

*Cognitive Flexibility-The Stroop Task*

The Stroop Task (Stroop, 1935) is a widely studied paradigm used to measure aspects of cognitive control and flexibility. The word-color Stroop task requires the participant to respond to a font color in which an incongruent word of a color is presented (i.e. the word *green* written in *red* font). The participant must choose the word *red* instead of choosing the word green, which is the stronger response (MacLeod, 1991). The ability
for participants to override the stronger response tendency (i.e., reading the color word rather than responding to the color) and produce a correct response to an incongruent Stroop stimulus requires additional time (known as the Stroop interference effect) compared with control stimuli in which colors and words are congruent (Dyer, 1973; Jensen & Rohwer, 1966; MacLeod, 1991).

In this study words were presented in colored font with two colored fonts below and arrows pointing to the two different colors. Participants were told to press the corresponding arrow to the font color that matches the stimuli presented. There were 60 total trials.

Validity for the Stroop Task has been demonstrated with a significant correlation on the Self Monitoring Scale at \((r=.43)\), with demonstrated reliability at .86 (Koch, 2003). Reaction times for 60 trials were recorded at the level of milliseconds were used to determine performance of cognitive flexibility.

*Measure for Intelligence Tests*

**Verbal Intelligence - The Basic Word Vocabulary Test**

The Basic Word Vocabulary (BWVT) test measures the number of basic words that one knows (Dupuy, 1974). The BWVT was used as a measure of verbal intelligence. The measure has high internal consistency (.96). The measure is highly correlated with other nationally standardized measures of verbal ability. This includes a .76 is median correlation of the BWVT with the verbal sections of five different nationally standardized tests, including the Sequential Tests of Educational Progress and the School and College
abilities Tests (the STEP and the SCAT respectively) (Dupuy, 1974). Total correct responses (out of 40) were used to measure verbal ability.

Spatial Intelligence - The Card Rotations Test

The Card Rotations Test from the ETS kit of reference tests for cognitive factors (Ekstrom et al, 1976), is used as a measure of visual spatial intelligence. The test consists of two sections each lasting three minutes. Subjects are asked to look at a two dimensional shape on the left hand column of the screen. They must determine whether the eight figures to the right are rotated within the plane or are mirror images of the primary shape (see Figure 4 below, Card Rotations Test). Each section has 14 lines of images which creates 112 potential correct responses, and 224 total possibilities. The test has shown correlation ($r=.66$) for monozygotic twins who were reared apart (Ekstrom et al, 1976). Validity for this test has been demonstrated with significant correlations on the Tower of Hanoi task ($r=.34$) (Miyake et al., 2004), the Raven’s Progressive Matrices ($r=.40$) (Pallier, 2000), and the Short Form Test of Academic Aptitude ($r=.41$) (Burns and Gallini, 1983). The total number of correct responses were used to measure visual spatial intelligence.

Figure 4 – Card Rotations Test
Participant Data Form

The participant data form is a self report designed to gather basic data such as age, gender, and the frequency of video game play.

Research Hypotheses

The hypotheses for this study fall into four primary groupings. The first set of hypotheses (H1-H11) predict that significant correlations will be found between independent variables and the dependent variable. The next set of hypotheses (H12-H14) predict that relationships will be found between various measures of each construct (e.g. measures of performance, self report and other rater report for cognitive openness will be significantly correlated). The next set of hypotheses (H 15-24) predict that each of the individual variables and constructs will explain unique variance in the adaptive performance score on the NFC. Finally, a combination of Cognitive Openness, Focused Attention and Cognitive Flexibility (the formative construct of Cognitive Agility) are predicted to demonstrate unique variance in the adaptive performance score (H25-H27).

Below is a list of each of the study hypotheses:

I. Significant correlations between independent variables and dependent variable

**Hypothesis 1:** The total score on verbal intelligence will be significantly correlated with the adaptive performance score on the NFC.

**Hypothesis 2:** The total score on visual-spatial intelligence will be significantly correlated with the adaptive performance score on the NFC.
**Hypothesis 3:** The performance score for Focused Attention will be significantly correlated with the adaptive performance score on the NFC.

**Hypothesis 4:** The performance score for Cognitive Openness will be significantly correlated with the adaptive performance score on the NFC.

**Hypothesis 5:** The performance score for Cognitive Flexibility will be significantly correlated with the adaptive performance score on the NFC.

**Hypothesis 6:** The self-report measure for Focused Attention will be significantly correlated with the adaptive performance score on the NFC.

**Hypothesis 7:** The self-report measure for Cognitive Openness will be significantly correlated with the adaptive performance score on the NFC.

**Hypothesis 8:** The self-report measure for Cognitive Flexibility will be significantly correlated with the adaptive performance score on the NFC.

**Hypothesis 9:** The other rater-report measure for Focused Attention will be significantly correlated with the adaptive performance score on the NFC.

**Hypothesis 10:** The other rater-report measure for Cognitive Openness will be significantly correlated with the adaptive performance score on the NFC.

**Hypothesis 11:** The other rater-report measure for Cognitive Flexibility will be significantly correlated with the adaptive performance score on the NFC.

II. Significant correlations between variables measuring same construct

**Hypothesis 12:** Cognitive Openness - Self report measure of Cognitive Openness (LMS), the Performance score for Cognitive Openness (Alternate Uses Test) and the Other Rater Report of Cognitive Openness will be significantly correlated.
**Hypothesis 13:** Focused Attention - Self Report measure of Focused Attention (ACS), performance score for Focused Attention (Go/NoGo Paradigm) and the Other Rater Report measure of Focused Attention will be significantly correlated.

**Hypothesis 14:** Cognitive Flexibility - Self Report measure of Cognitive Flexibility, the Performance score for Cognitive Flexibility (the Stroop Task) and the Other Rater Report measure of Cognitive Flexibility will be significantly correlated.

III. Linear and Hierarchical Regression demonstrating unique variance explained by each of the variables and constructs on adaptive performance on the NFC.

**Hypothesis 15** - Intelligence (as a factor score) will explain significant variance in the adaptive performance score in the dynamic decision making scenario.

**Hypothesis 16:** Focused attention performance score will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.

**Hypothesis 17:** Cognitive openness performance score will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.

**Hypothesis 18:** Flexibility performance score will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.
**Hypothesis 19:** Focused Attention Self Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.

**Hypothesis 20:** Cognitive Openness Self Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.

**Hypothesis 21:** Cognitive Flexibility Self Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.

**Hypothesis 22:** Focused Attention Other Rater Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.

**Hypothesis 23:** Cognitive Openness Other Rater Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.

**Hypothesis 24:** Cognitive Flexibility Other Rater Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.

**IV.** Linear and Hierarchical Regression demonstrating unique variance explained by the formative construct of *Cognitive Agility* on adaptive performance on the NFC.

**Hypothesis 25:** The formative performance construct (composite of all three performance measures) of cognitive agility will explain significant variance in
the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.

**Hypothesis 26:** The formative self report construct (composite of all three Self Report measures) of cognitive agility will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.

**Hypothesis 27:** The formative other rater report construct (composite of all three other rater report measures) of cognitive agility will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence.
CHAPTER III

RESULTS

Results are presented as relevant to each research hypothesis. In addition, an ad hoc results section follows to show findings not predicted but discovered during the analysis.

Descriptive Statistics

Table 2 (Descriptive Statistics for the Dependent Variable) presents the descriptive statistics for performance on the Networked Fire Chief. The descriptive statistics of the performance scores for the three NFC trials (labeled Adaptive Performance for NFC), suggest an increase in difficulty across the 3 trials as intended. The mean score on Trial of 1 of the Fire Chief was 98.24 out of 100 with a standard deviation of .685. The mean score on Trial 2 of the Fire Chief was 87.69 with a standard deviation of 2.85. The mean score of Trial 3 of the Fire Chief was 78.19 with a standard deviation of 3.23. The difference between Trials 1 and 2 was 10.5 points in performance. The difference between Trials 2 and 3 was 9.5 points in performance. Thus the mean
change suggests a near uniform degree of increased difficulty, which was intended. The mean score of total trials on the NFC was 264.13 with a standard deviation of 6.07. The skewness and kurtosis scores all fall within threshold normality.

Table 3 (Descriptive Statistics for Independent Variables) presents the descriptive statistics for the independent variables that form cognitive agility (cognitive openness, focused attention and cognitive flexibility) and the three methods of measurement to correspond with them (Performance, Self Report and Other Report).

The performance measure for Cognitive Openness was the Alternate Uses Test (2 trials), which had a Mean of 21.6 total items listed per participant with a standard deviation of 8.76. The self report measure of Cognitive Openness yielded a mean score of 5.34 out of 7 with a standard deviation of .829. The Other Rater Report for Cognitive Openness yielded a mean score of 5.44 with a standard deviation of .944.

The Performance measure for Focused Attention yielded a mean score of 1361.36 milliseconds with a standard deviation of 31.20 milliseconds. The Self Report measure of Focused Attention had a mean score of 4.0 out of 7.0 and a standard deviation of 1.15.
The Other Rater Report measure of Focused Attention had a mean score of 4.6 and a standard deviation of 1.2.

Table 3. Descriptive Statistics for Independent Variables of Cognitive Agility

<table>
<thead>
<tr>
<th>Construct</th>
<th>Test</th>
<th>M</th>
<th>S.D</th>
<th>N</th>
<th>Skewness Statistic</th>
<th>SE</th>
<th>Kurtosis Statistic</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Openness</td>
<td>Performance</td>
<td>21.6</td>
<td>8.76</td>
<td>181</td>
<td>1.19 (.004)1</td>
<td>.181</td>
<td>3.95 (.071)1</td>
<td>.359</td>
</tr>
<tr>
<td></td>
<td>Self Report</td>
<td>5.34</td>
<td>.829</td>
<td>181</td>
<td>-.492</td>
<td>.181</td>
<td>-.023</td>
<td>.359</td>
</tr>
<tr>
<td></td>
<td>Other Report</td>
<td>5.44</td>
<td>.944</td>
<td>152</td>
<td>-.579</td>
<td>.197</td>
<td>-.362</td>
<td>.391</td>
</tr>
<tr>
<td>Focused Attention</td>
<td>Performance</td>
<td>1361.36</td>
<td>31.20</td>
<td>181</td>
<td>-1.539 (.000)1</td>
<td>.181</td>
<td>8.603 (.075)1</td>
<td>.359</td>
</tr>
<tr>
<td></td>
<td>Self Report</td>
<td>4.020</td>
<td>1.145</td>
<td>181</td>
<td>.112</td>
<td>.181</td>
<td>-.319</td>
<td>.359</td>
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<tr>
<td></td>
<td>Other Report</td>
<td>4.584</td>
<td>1.204</td>
<td>152</td>
<td>-.269</td>
<td>.197</td>
<td>-.422</td>
<td>.391</td>
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<tr>
<td>Flexibility</td>
<td>Performance</td>
<td>1332.90</td>
<td>233.859</td>
<td>181</td>
<td>.653</td>
<td>.181</td>
<td>1.359</td>
<td>.359</td>
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<tr>
<td></td>
<td>Self Report</td>
<td>4.576</td>
<td>.801</td>
<td>181</td>
<td>-.320</td>
<td>.181</td>
<td>.218</td>
<td>.359</td>
</tr>
<tr>
<td></td>
<td>Other Report</td>
<td>4.957</td>
<td>.888</td>
<td>152</td>
<td>-.374</td>
<td>.197</td>
<td>.481</td>
<td>.391</td>
</tr>
</tbody>
</table>

The Performance score for Cognitive Flexibility yielded a mean score of 1332.9 milliseconds with a standard deviation of 233.86. The Self Report measure of cognitive flexibility had a Mean of 4.6 out of 7 with a standard deviation of .80. The Other Report
rater measure of cognitive flexibility had a mean score of 4.9 and a standard deviation of .89.

Table 4 (Descriptive Statistics for Intelligence Measures) shows the descriptive statistics for both the intelligence measures. The Card Rotations Test, which serves as the visual spatial test of intelligence had a mean score of 170.02 out of 224. The standard deviation was 24.58. The Basic Word Vocabulary Test had a mean score of 32.34 out of 40 with a standard deviation of 3.25.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Test</th>
<th>M</th>
<th>SD</th>
<th>N</th>
<th>Skewness Statistic</th>
<th>SE</th>
<th>Kurtosis Statistic</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intelligence</td>
<td>Card Rotations</td>
<td>170.02</td>
<td>24.58</td>
<td>181</td>
<td>-.828</td>
<td>.181</td>
<td>2.866</td>
<td>.359</td>
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<tr>
<td>Intelligence</td>
<td>BWVT</td>
<td>32.34</td>
<td>3.25</td>
<td>181</td>
<td>-1.047</td>
<td>.181</td>
<td>1.929</td>
<td>.359</td>
</tr>
</tbody>
</table>

The skewness measure for independent variables are within normality (+/-1.00) for all but two measures (George & Mallery, 2003). Performance measures for openness and focused attention each have a skewness and kurtosis beyond +/-1.00 suggesting a departure from suggested normality (George & Mallery, 2003; Morgan, Griego, & Gloeckner, 2001). An area transformation using Rankits formula was employed which created z scores from the standard normal distribution (Garson, 2008). This method was successful in correcting the data to meet normality estimates. Both the raw data and transformed data are shown in Table 2.
Reliability Estimates

Table 5. Scale Reliabilities (n=181 for self reports/n=152 for other reports)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Open Self</th>
<th>Open Other</th>
<th>Focus Self</th>
<th>Focus Other</th>
<th>Flex Self</th>
<th>Flex Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Items</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Cronbach’s Alpha</td>
<td>.759</td>
<td>.804</td>
<td>.828</td>
<td>.890</td>
<td>.906</td>
<td>.951</td>
</tr>
</tbody>
</table>

Table 5 (Reliabilities) represents the reliability data for each scale. The total
questionnaire for Self and Other Rater Reports contained 58 items. As previously stated,
the items were identical with changes made only to the pronoun to reflect the rater’s
perspective (in the Other Rater Reports). Negative items were recoded for scoring
purposes. A factor analysis showed three strong factors as predicted. Five items from the
Self Report Cognitive Flexibility scale were dropped based on weak factor loadings.
Two items from the Self Report Focused Attention were dropped due to weak factor
loadings. Two items from the Self Report Openness Scale were dropped due to weak
factor loadings. One item from the Cognitive Flexibility Other Rater Report scale was
dropped due to weak factor loadings. One item was dropped from the Focused Attention
Other Rater Report due to weak factor loading. Three items were dropped from the
Cognitive Openness Other Rater Report due to weak factor loadings. The reliability
analysis was performed for all scales in the Self-Reports and Other Rater Reports. The
scale reliabilities ranged from .759 to .951. All of the Cronbach’s Alphas are very strong
and thus represent acceptable scale reliability.
Table 6 (Reliabilities for Performance Measures) represents the reliability data for each of the performance tests (Independent and dependent measures). The Alternate Uses Test demonstrated an alpha of .81; the Stroop Task demonstrated an alpha of .82 and the Go/NO Go paradigm was .73. Both intelligence tests (the BWVT and the Card Rotations Test) show alphas at .80. In addition, the dependent measure (NFC) demonstrated an alpha of .73 across three trials.

<table>
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<tr>
<th>Construct</th>
<th>Measure</th>
<th>Reliability Estimate</th>
</tr>
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<tbody>
<tr>
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</tr>
<tr>
<td>Focused Attention</td>
<td>Go No Go</td>
<td>.73</td>
</tr>
<tr>
<td>Cognitive Flexibility</td>
<td>Stroop Task</td>
<td>.82</td>
</tr>
<tr>
<td>Verbal Intelligence</td>
<td>Basic Word Voc Test</td>
<td>.80</td>
</tr>
<tr>
<td>Spatial Intelligence</td>
<td>Card Rotations</td>
<td>.80</td>
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<tr>
<td>Adaptive Performance</td>
<td>Networked Fire Chief</td>
<td>.80</td>
</tr>
</tbody>
</table>

**Test of Hypotheses 1-11**

This section provides the results for Hypotheses 1-11. The intercorrelations are presented in Table 7 (Correlation Table). In general the dependent variable, Adaptive Performance Score (Total Score of Three trials on the NFC), correlated significantly with almost all of the independent variables. Despite this finding there are some mixed results in terms of support for the first set of hypotheses, which predict that there will be significant correlations between each of the individual independent variables and the dependent variable.
Hypothesis 1: A significant correlation will be found between the dependent variable and the measure of verbal intelligence.

Hypothesis 1 was upheld as the measure of verbal intelligence (BWVT) was significantly correlated with the adaptive performance score on the NFC (r=.236, p<.001).

Hypothesis 2: A significant correlation will be demonstrated between the dependent variable and the measure of visual-spatial intelligence.

Hypothesis 2 was upheld as the card rotations test used to measure visual spatial intelligence was significantly correlated with the adaptive performance score on the NFC (r=.446, p<.001).
Hypothesis 3: A significant correlation will be demonstrated between the dependent variable and the performance measure of focused attention.

Hypothesis 3 was upheld as the go/no go test used to measure focused attention performance was significantly correlated with the adaptive performance score on the NFC (r=.161, p<.05).

Hypothesis 4: A significant correlation will be demonstrated between the dependent variable and the performance measure of cognitive openness.

Hypothesis 4 was upheld as the Alternate Uses Test used to measure performance of Cognitive Openness was significantly correlated with the adaptive performance score on the NFC (r=.237, p<.001).

Hypothesis 5: A significant correlation will be demonstrated between the dependent variable and the performance measure of cognitive flexibility.

Hypothesis 5 was upheld as the Stroop Task used to measure performance of Cognitive Flexibility was significantly correlated with the adaptive performance score on the NFC (r=.323, p<.001).

Hypothesis 6: A significant correlation will be demonstrated between the dependent variable and the self report measure of focused attention.

Hypothesis 6 was upheld as the focused attention subscale of the Attentional Control scale used to measure the self report score for focused attention was significantly correlated with the adaptive performance score on the NFC (r=.159, p<.05).

Hypothesis 7: A significant correlation will be demonstrated between the dependent variable and the self report measure of cognitive openness.
Hypothesis 7 was upheld as the Novelty Seeking subscale of the Langer Mindfulness inventory used as the self report measure Cognitive Openness was significantly correlated with the adaptive performance score on the NFC (r=.221, p<.01).

_Hypothesis 8: A significant correlation will be demonstrated between the dependent variable and the self report measure of cognitive flexibility._

Hypothesis 8 was not upheld as the cognitive regulation subscale of the Meta-cognitive Awareness Inventory used to measure the self report score for cognitive flexibility reached a near significant correlation with the adaptive performance score on the NFC, yet demonstrated an inverse relationship (r= -.109, p=.10).

_Hypothesis 9: A significant correlation will be demonstrated between the dependent variable and the other rater report measure of focused attention._

Hypothesis 9 was not upheld as the measure of focused attention as rated by an external rater was not significantly correlated with the dependent variable (r=.087, p>.1).

_Hypothesis 10: A significant correlation will be demonstrated between the dependent variable and the other rater report measure of Cognitive Openness._

Hypothesis 10 was not upheld as the measure of cognitive openness as rated by an external rater was not significantly correlated with the dependent variable (r=.115, p>.1).

_Hypothesis 11: A significant correlation will be demonstrated between the dependent variable and the other rater report measure of cognitive flexibility._

Hypothesis 11 was not upheld as the measure of cognitive flexibility as rated by an external rater was significantly correlated with the dependent variable, yet demonstrated an inverse relationship (r=-.203, p< .01).
In summary of Hypotheses 1-11, only Openness Other Report and Focused Attention Other Report did not correlate significantly or reach near significance with the Fire Chief Performance score. The Other Rater Report measure of Cognitive Flexibility and the Self Report measure of Cognitive Flexibility each had negative correlations with Adaptive Performance (Cognitive Flexibility Other r= -.203, p=.01; Cognitive Flexibility Self, r= -.109, p=.10).

Results for Hypotheses 12-14

As previously stated the corresponding correlation table is Table 7, in which the results for these hypotheses can be found. There are some mixed results in terms of support for this set of hypotheses, which predict that there will be significant correlations between trait (e.g. openness self report, openness other report and openness performance).

Hypothesis 12 - Self-report measure of Cognitive Openness (LMS), the Performance score for Cognitive Openness (Alternate Uses Test) and the Other Rater Report of Cognitive Openness will be significantly correlated.

In support of hypothesis 12, the Self Report for Cognitive Openness is correlated with the Other Rater Report for Openness (r=.21, p<.01). In addition the Cognitive Openness Performance and Cognitive Openness Self Report correlate at a near significant level (r=.11, p<.1). However the other rater report for Cognitive Openness and the Cognitive Openness Performance score are not significantly correlated (r=.07, p>.1). Therefore this hypothesis is not fully supported as not all measures are significantly intercorrelated.
Hypothesis 13 - Self Report measure of Focused Attention (ACS), performance score for Focused Attention (Go/NoGo Paradigm) and the Other Rater Report measure of Focused Attention will be significantly correlated.

In support of hypothesis 13, the Self Report for Focused Attention and the Other Rater Report for Focused Attention are significantly correlated (r=.35, p=.000). Yet, neither the Self Report or Other Rater Report are significantly correlated with the performance score for focused attention. In summary, Hypothesis 13 is not fully supported as the performance measure does not appear to share a relationship to the self and other rater reports for the focused attention construct.

Hypothesis 14 - Self Report measure of Cognitive Flexibility, the Performance score for Cognitive Flexibility (the Stroop Task) and the Other Rater Report measure of Cognitive Flexibility will be significantly correlated.

In support of hypothesis 14, the Self Report for Cognitive Flexibility and the Other Rater Report for Cognitive Flexibility are correlated significantly (r=.22, p<.01). Yet, the performance score for cognitive flexibility does not show any relationship to the either the self report or other rater report. Therefore this hypothesis is not fully supported by the results.

In summary, hypotheses 12-14 can only be partially supported by the results. Support is evident in that the scores on the three Self Reports (for cognitive openness, cognitive flexibility and focused attention) and Others Reports appear to be correlated significantly (e.g. Flexibility are correlated significantly (r=.22, p=.01). Yet, the story is not quite as clear for the correlations between Self and Other Reports and the corresponding trait performance scores for each variable. In this case only the Openness
Performance measure correlates with a corresponding construct Self Report score ($r=.11$, $p<.1$).

**Factor Analysis**

Given the proposed formative nature of the cognitive agility construct, one way to further assess construct validity prior to regression analysis is through a factor analysis (Rossiter, 2002). A principal component analysis with a promax rotation was conducted with three factors. The number of factors was specified since the theory and hypotheses suggested that the factors would form across method by construct (e.g. Openness Performance, Openness Self Report and Openness Other Rater Report would form a single factor). The factor analysis shows three solid factors with the exception of Focused Attention Self Report which loads weekly (.331) on factor 2. The results of this analysis appear in Table 8. Due to the formative nature of the proposed construct this variable was left in the analysis, as its removal would violate the structure of the proposed construct (Jarvis et al., 2003). The pattern matrix shows three factors, yet the loadings are not consistent with the original hypotheses. Rather than loading by construct the variables loaded by method. However this is to be expected in view of results from the correlation matrix (Table 7) in which the only performance score to significantly correlate with a questionnaire was Openness Performance and Openness Self Report ($r=.11$, $p<.1$). As shown in Table 8, three factors emerge by method: Performance, Other Rater Reports and Self Reports. These results help in grouping the variables for adequate regression analyses.
Due to the unpredicted negative correlation that the cognitive flexibility self report and other rater report have to the dependent variable, it will not be possible to create a proper composite score. Therefore reliability analysis was run to see the alpha score for the factors 1 and 2 established through the factor analysis. The Other Rater Reports had a Cronbach’s Alpha of .703, which suggests a strong grouping. The Self Report measures for the Self Report had an Alpha of .501, which is weak yet adequate. Both scores are within the acceptable threshold. The performance measure does not require a reliability score since it will be combined into a composite score or formative construct (Jarvis, 2003).

**Test of Hypotheses 15-24**

Hypotheses 15-24 are tested through a series of regressions. Regression results are found below in Tables 9 – 17. The tables include, $R^2$, $R^2\Delta$ and $\beta$. In addition, collinearity diagnostics are included with both Tolerance and VIF results.

Table 9 (Regression Analyses for Individual Performance Measures) shows the regressions chart for all steps testing Hypotheses 15-18. Standard linear regression
models were used to measure the impact of each variable on overall performance on the dependent variable. Prior to testing Hypothesis 15 the two intelligence scores were formed in a factor score since both are well validated instruments (Hair, et al., 1998). Combining the verbal and spatial measures of intelligence is used to create a general cognitive intelligence factor reflecting both crystallized (verbal) and fluid intelligence (spatial) (Cattell, 1963, 1943; Horn, 1985, 1998).

Hypothesis 15 predicted that the intelligence factor would demonstrate significant variance when regressed on the total adaptive performance score in the dynamic decision making scenario.

In Model 1 within Table 9, intelligence is regressed on the dependent variable. Hypothesis 15 was supported as significant variance was found ($R^2=.20$, $p<.001$).

Hypotheses 16 -18 sought to measure whether the individual performance variables of cognitive openness, focused attention and cognitive flexibility would demonstrate significant variance beyond the intelligence factor when regressed on the adaptive performance score in the dynamic decision making scenario (NFC). Regression analysis was used to study the additive effects of the independent variables beyond intelligence.
The corresponding regression results for hypotheses (16-18) are also shown in Table 9.

Hypothesis 16 states that the focused attention performance score will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence. Model 2a shows that Hypothesis 16 was upheld as focused attention demonstrates unique variance beyond the intelligence factor ($\Delta R^2 = .02 = p<.05; \beta = .16$). The results of the collinearity diagnostics demonstrate a Tolerance score of 1.00 and a VIF of 1.00.

Hypothesis 17 states that the cognitive openness performance score will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence. Model 2b shows that Hypothesis 17 was

### Table 9: Regression Table for Intelligence and Individual Performance Measures

<table>
<thead>
<tr>
<th>Variable</th>
<th>NFC- DDM Performance</th>
<th>NFC- DDM Performance</th>
<th>NFC- DDM Performance</th>
<th>NFC- DDM Performance</th>
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<td>Model 2b</td>
<td>Model 2c</td>
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<td>1.028</td>
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<td>1.043</td>
</tr>
</tbody>
</table>

$+ p<.1; * p<.05; ** p<.01; ***p<.001; N=181$
supported as the openness performance measure demonstrated unique variance beyond the intelligence factor (\(\Delta R^2 = .03 = p < .001; \beta = .17\)).

*Hypothesis 18* states that the Flexibility performance score will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence *Hypothesis 18* was supported as Model 2c (Cognitive Flexibility) shows unique variance beyond the intelligence factor (\(\Delta R^2 = .07, p < .001; \beta = .27\)).
The corresponding regression results for hypotheses (19-21) are shown in Table 10 (Regression Table for Individual Self Reports). Hypothesis 19 states that the Focused Attention Self Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence. Model 2a shows that Hypothesis 19 was not supported as the self report for focused attention did not demonstrate unique variance beyond the intelligence factor ($\Delta R^2 = .01 = p = .195; \beta = .08$).

Hypothesis 20 states that the Cognitive Openness Self Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence. Model 2b shows that Hypothesis 20 was supported as the openness self report measure demonstrated unique variance beyond the intelligence factor ($\Delta R^2 = .03 = p < .05; \beta = .16$).

Hypothesis 21 states that the Cognitive Flexibility Self Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence. Model 2c shows that Hypothesis 21 was unsupported as the self report for cognitive flexibility did not demonstrate unique variance beyond the intelligence factor ($\Delta R^2 = .01 = p = .30; \beta = -.07$).

The corresponding regression results for hypotheses (22-24) are shown in Table 11 (Regression Table for Individual Other Rater Reports). Hypothesis 22 states that the Focused Attention Other Rater Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence. Model 2a shows that Hypothesis 22 was not supported as the other rater
report for focused attention did not demonstrate unique variance beyond the intelligence factor (ΔR² = .00; p = .58; β = .04).

Hypothesis 23 states that the Cognitive Openness Other Rater Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence. Model 2b shows that Hypothesis 23 was unsupported as the openness other report measure did not demonstrate unique variance beyond the intelligence factor (ΔR² = .00; p = .89; β = -.01).

Table 11 Regression Table for Individual Other Rater

<table>
<thead>
<tr>
<th>Variable</th>
<th>NFC- DDM Adaptive Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
</tr>
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<td>Intelligence Factor</td>
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<tr>
<td>R²</td>
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</tbody>
</table>

+ p<.1; * p<.05; ** p<.01; ***p<.001; N=181; N=152 for Other Reports

Hypothesis 24 states that the Cognitive Flexibility Other Rater Report will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence. Model 2c shows that Hypothesis 24 was
partially supported as the other rater report for cognitive flexibility did demonstrate unique variance beyond the intelligence factor ($\Delta R^2 = .04 = p < .001; \beta = -.20$). Yet the direction of the $\beta$ suggests an inverse relationship which was not explicitly or implicitly predicted by the original hypothesis.

*Hypotheses 25-27*

Based on the factor analysis and theoretical basis of cognitive agility, formative constructs based on method were sought. Formative constructs are a composite of multiple measures (MacCallum and Browne, 1993). Since multiple measures (i.e. Cognitive Openness, Focused Attention and Cognitive Flexibility) create cognitive agility, a formative or composite measure is ideal (Jarvis et al, 2003). Unfortunately, given the negative correlations that both of the Cognitive Flexibility scales (Self Report and Other Rater Report) have to the Dependent Variable, the Self Report and Other Rater Reports could not be made into a composite or formative measure; since the negative correlations would dilute the power of the measure. The performance scores each had positive correlations with the dependent variable and therefore Cognitive Openness, Focused Attention and Cognitive Flexibility were formed into a formative factor to be used in the regression analysis, while Self Reports and Other Rater Reports were entered into separate blocks in the regression analyses. As mentioned earlier, reliability scores are unnecessary for the Performance scores since the composite is meant to be measuring different facets of the same construct.
Hypothesis 25 sought to measure whether the performance method, formative construct of *cognitive agility*, would demonstrate significant variance beyond the intelligence factor when regressed on the adaptive performance score in the DDM. Theory helps support the creation of a formative construct for *cognitive agility*. Formative constructs are a composite of multiple measures (MacCallum and Browne, 1993). The formative construct for cognitive agility was created by taking a composite score of cognitive openness, focused attention and cognitive flexibility (Jarvis et al, 2003). Results are presented within Table 12 (Regression Analysis for Cognitive Agility Performance Measure). A regression analysis was run to show how the formative construct measure of cognitive agility influenced the adaptive performance score on the NFC. In Table 12, Model 1 provides the factor of Intelligence Tests (Spatial and Verbal). The addition of the *cognitive agility* formative construct entered listwise provided 11.0% unique variance on the NFC beyond the intelligence factor ($\Delta R^2 = .11$). The total $R^2$ in this model is .31 and is significant ($p = .000$). The beta weight shows that the measure of *cognitive agility* was positively related to the adaptive performance score on the NFC ($\beta = .35$).
Hypothesis 26 sought to demonstrate that the formative self report construct (composite of all three Self Report measures) of cognitive agility will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence. As mentioned earlier, given the negative correlations that both of the Cognitive Flexibility scales (Self Report and Other Rater Report) have to the Dependent Variable, the Self Report and Other Rater Reports could not be made into a composite or true formative measure; since the negative correlations would dilute the power of the measure. Therefore a linear regression was used entering all three self report measures into a single block listwise. This method will allow each of the individual measures to interactively demonstrate impact on the dependent variable rather than have the cognitive flexibility measure dilute the results with a negative correlation. Results for this regression are found in Table 13. Hypothesis 26 was upheld as the addition of the self reports accounted for 6% unique explained variance in the

<table>
<thead>
<tr>
<th>Variable</th>
<th>NFC- DDM Performance</th>
<th></th>
</tr>
</thead>
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</table>

+p<.1; * p<.05; ** p<.01; ***p<.001; N=181
adaptive performance score on the dynamic decision making scenario ($\Delta R^2 = .06$, $p=.006$). Though a closer examination of the results demonstrate findings that are more nuanced. The focused attention self report within Model 2 does not add any unique variance to the overall model ($\beta = .05$, $p=.49$). The cognitive flexibility self report does add significant unique variance within the model, yet as discussed previously, it retains an inverse relationship to the dependent variable ($\beta = -.19$, $p=.01$). The cognitive openness self report adds unique variance within the model as predicted ($\beta = .24$, $p=.002$).

<table>
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<tr>
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<th>Model 2</th>
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</table>

$+ p<.1; * p<.05; ** p<.01; ***p<.001; N=181$

**Hypothesis 27** sought to demonstrate that the formative other rater report construct (composite of all three Other Rater Report measures) of cognitive agility will explain significant variance in the adaptive performance score in the dynamic decision making scenario beyond that explained by intelligence. Like the self reports, the other rater report for cognitive flexibility has a negative correlation with the Dependent
Variable. Therefore a linear regression was used entering all three other rater report measures into a single block listwise. Table 13 shows the results of this regression analysis. Hypothesis 27 was upheld as the total model explained 6% unique variance on the dependent variable (ΔR²=.06, p=.002). Like the self reports, the other reports have more nuanced results beyond the total change in R². The focused attention other rater measure is significant in this model (β=.14, p=.05). The Cognitive Openness other rater measure is near significant in this model (β=.13, p=.10). The Cognitive Flexibility other rater measure retains significance but its relationship remains negatively associated to the dependent variable in this model (β= - .32, p=.000).

<table>
<thead>
<tr>
<th>Table 14. Regression for Cognitive Agility Other Reports</th>
</tr>
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<tbody>
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<td>Variable</td>
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<td>F Δ</td>
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</table>

* p<.1; * p<.05; ** p<.01; ***p<.001; N=181; N=152 for Other Reports
### Table 21. Summary of Hypotheses Support

#### Hypotheses 1-11:
*Significant Correlations Between Independent Variables and Dependent Variable*

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Supported</th>
<th>Unsupported</th>
<th>Partial/Mixed Support</th>
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<td>2. Spatial Intelligence</td>
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<td>4. Openness Performance</td>
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<td>5. Flexibility Performance</td>
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<td>6. Focus Self Report</td>
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<td>7. Openness Self Report</td>
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<td>8. Flexibility Self Report</td>
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<td>9. Focus Other Report</td>
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<td>11. Flexibility Other Report</td>
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#### Hypotheses 12-14:
*Significant Correlations Between Variables Measuring the Same Construct*

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<th>Partial/Mixed Support</th>
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#### Hypotheses 15-24:
*Unique Variance Explained by each of the Variables (beyond intelligence)*

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<td>16. Focus Performance</td>
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<td>17. Openness Performance</td>
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<td>18. Flexibility Performance</td>
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</tr>
<tr>
<td>19. Focus Self Report</td>
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<td>✓</td>
<td></td>
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<td>20. Openness Self Report</td>
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<td></td>
<td></td>
</tr>
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<td>21. Flexibility Self Report</td>
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</tr>
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<td>22. Focus Other Report</td>
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<td>✓</td>
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<td>23. Openness Other Report</td>
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<tr>
<td>24. Flexibility Other Report</td>
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<td>✓</td>
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#### Hypotheses 25-27:
*Unique Variance explained by Cognitive Agility by Method*

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<th>Partial/Mixed Support</th>
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<td>26. Self Reports</td>
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<tr>
<td>27. Other Reports</td>
<td>✓</td>
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</tr>
</tbody>
</table>
Post Hoc Analysis

There were two additional variables collected as potential control variables. Previous Micro World studies used as foundational literature for this study do not investigate the effects of Gender or Video Game Experience (Gonzalez et al 2005; LePine et al., 2000). Yet it made intuitive sense that the Dependent Variable was similar to a video or computer game. Therefore the amount of weekly video game experience was a question included in the demographic questionnaire. Gender was collected as basic demographic information. Males play more video games than females and generally perform better on them (Brown et al, 1997), so therefore it is expected that those two variables may be related.

As evidenced from the correlation table (Table 7 – Correlation Matrix) both gender and video game experience showed significant relationship to the dependent variable. Video game experience was significantly correlated to the adaptive performance score from the NFC (.41, p<.001). As well, gender was significantly correlated to the NFC (.28, p<.001). The two potential control variables were significantly correlated (Gender and Video Game Experience (r=.427, p=.000). This suggests that both measures may be potential control variables to support further explanation of performance variation on the NFC.

Several other interesting relationships emerge from the correlation matrix regarding gender, which was collected as a potential control variable. The Cognitive Flexibility Performance score was significantly correlated with gender (r=.152, p=.01). Also, Openness Self Report and Gender were significantly correlated (r=.175, p=.01).
Finally, Gender and the test of visual-spatial intelligence were significantly correlated (Gender and The Card Rotations Test at r=.139, p<.05).

Regressions were performed to see if the independent variables retained their effect on the dependent variable beyond Gender and Video Game Experience. Table 14 (Regression Analysis For Control Measures and Individual Performance Scores) shows the results of these operations as they pertain to the individual performance measures. In the first model, the two control variable each explain unique variance on the adaptive performance score on the NFC decision making scenario. The two measures entered listwise within the same step explain about 22% of the variance ($\Delta R^2=.22, p<.001$).

According to the regression results males perform better than women on the NFC ($\beta=.24, p=.001$). Video game experience also demonstrated unique variance ($\beta=.34, p<.001$).

The intelligence factor was then entered in a separate block in the regression analysis. The intelligence factor still retains significance beyond gender and video game experience ($\beta=.40, p<.001$). The intelligence factor explains approximately 16% unique variance beyond the control variables. This is approximately 4% less variance than intelligence accounted for in the regression without the control variables. Next the performance measure for focused attention explains approximately 1% variance at near significant levels ($\Delta R^2=.01, \beta=.11; p=.07$) beyond the controls and intelligence factor.

The measure of cognitive openness performance still remains significant beyond controls and intelligence, accounting for about 2% explained variance ($\beta=.15; p=.016$ ). The measure of cognitive flexibility performance score also remains significant, accounting for 8% of explained variance ($\beta=.30, p<.001$ ).
Next a similar set of regressions was run to measure the additive effect of the individual self report and other report measures beyond the controls and intelligence. Table 15 presents these results. In this case only the measures that were significant
beyond intelligence from the previous set of regression were included in this analysis. Cognitive openness self report no longer remains significant after the control variables and the intelligence factor ($\beta=.087, p=.15$). The cognitive flexibility other rater report remains significant accounting for 2% of unique variance beyond the controls and intelligence ($\beta=-.14, p=.017$).

<table>
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<tr>
<td>Video Game Experience and Gender</td>
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</tr>
<tr>
<td>$R$</td>
<td>.47</td>
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<tr>
<td>$R^2$</td>
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<td>Flexibility Other report</td>
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<td>Tolerance</td>
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<td>VIF</td>
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<td>Openness Self-report</td>
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<td>$R^2\Delta$</td>
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</tr>
<tr>
<td>$F\Delta$</td>
<td>25.52***</td>
</tr>
</tbody>
</table>

As with prior steps, the next set of analyses was to use linear and hierarchical regressions to test the additive impact of cognitive agility beyond the controls and intelligence. The formative construct of cognitive agility for performance measures remains significant, accounting for 9% unique variance ($B=.31, p<.001$). This result is
found in Table 16 – Regression Analysis for Cognitive Agility Performance Score

Beyond Controls.

<table>
<thead>
<tr>
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<tr>
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<td>Video Game Experience and Gender</td>
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<td>$R^2\Delta$</td>
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<tr>
<td>$F\Delta$</td>
<td>25.52***</td>
</tr>
</tbody>
</table>

+ p<.1; * p<.05; ** p<.01; ***p<.001; N=181
Since a composite score was not feasible for the self and other rater reports, the three corresponding measures were entered listwise into a single step within a regression. The results of the three self report measures indicate an overall model that is no longer significant ($\Delta R^2 = .02$, $p = .148$). When looking at the individual measures within the model there remains some variation as to the significance of each. The self report for focused attention remains an insignificant predictor of performance ($\beta = .008$, $p = .89$). The self report for cognitive openness remained significant in this model ($\beta = .15$, $p = .038$). The cognitive flexibility self report which was not significant in the model as a singular variable beyond intelligence, reaches near significance in this model ($\beta = -.13$, $p = .07$). Table 17 demonstrates these results.

<table>
<thead>
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<td>Intelligence Factor</td>
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<td>Flexibility Self Report</td>
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<td>$R^2$</td>
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<tr>
<td>$F \Delta$</td>
<td>25.52***</td>
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* $p<.1$; * $p<.05$; ** $p<.01$; *** $p<.001$; N=181
The other rater report version of cognitive agility accounted for nearly 4% unique variance beyond the controls and intelligence. ($R^2 = .037$, $p = .014$). Focused Attention
Other rater report reaches near significance in this current model ($\beta=.09, p<.1$). Cognitive openness which was near significant in the prior model, no longer retains any significance. ($\beta=.11, p=.23$). Cognitive Flexibility remains a significant variable in this model ($\beta=-.24, p=.002$). Table 18 shows these results.

Next, a hierarchical regression was run including the controls, the intelligence factor, the composite performance measure, the three self reports and the three other rater reports. The results of this are displayed in Table 19. The total model has an $R^2$ of .499 and is significant ($p=.000$). The composite measure, self reports and other reports (entered in a single step listwise) explain 12% unique variance beyond the controls and intelligence. The only measures that remain significant are Cognitive Flexibility Other Rater Report ($\beta=-.19, p=.008$) and the Composite Performance measure ($\beta=.275, p=.000$). The Self Report Cognitive Openness results suggest a near significant relationship in this model to the dependent variable ($\beta=.12, p=.074$).
Table 19. Regression Analysis for All Measures with Controls

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<th>Variable</th>
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<td><strong>Video Game Experience and Gender</strong></td>
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+ p<.1; * p<.05; ** p<.01; ***p<.001; N=181; N=152 for Other Rater Reports
### Table 20. Correlation Matrix - FEMALE

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*p<.1;  *p<.05;  **p<.01;  ***p<.001  Variables 1-10, pearson r (1 tailed) N=101, except N=89 for vars 5-7

### Table 21. Correlation Matrix - MALES

<table>
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<td>9. FOCUS_SELF</td>
<td>.210</td>
<td>.019</td>
<td>.077</td>
<td>.195</td>
<td>.043</td>
<td>.269</td>
<td>-.087</td>
<td>.170</td>
<td>-</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>10. FLEX_SELF</td>
<td>-</td>
<td>-.027</td>
<td>-.005</td>
<td>-.086</td>
<td>-.012</td>
<td>-.071</td>
<td>.234</td>
<td>.470</td>
<td>-.020</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. INT_FACT</td>
<td>.012</td>
<td>.162</td>
<td>.053</td>
<td>.371</td>
<td>.385</td>
<td>.332</td>
<td>-.032</td>
<td>.194</td>
<td>.191</td>
<td>-.102</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>12. VIDEO_GAME</td>
<td>.355</td>
<td>.042</td>
<td>.087</td>
<td>.162</td>
<td>.028</td>
<td>-.102</td>
<td>-.097</td>
<td>-.021</td>
<td>-.078</td>
<td>.256</td>
<td>-.079</td>
<td>.110</td>
</tr>
</tbody>
</table>

*p<.1;  *p<.05;  **p<.01;  ***p<.001  Variables 1-10, pearson r (1 tailed) N=101, except N=89 for vars 5-7
A final analysis was performed to see the potential difference in the relationships between the predictor variables and the dependent variable broken out by Gender. This is not a theoretically driven analysis but one performed ad hoc based solely on the significant correlation between Gender and adaptive performance on the Networked Fire Chief \((r=.23, p<.001)\). Tables 20 and 21 display the results of this analysis. Table 20 shows just the female correlations and Table 21 is just the male group.

Overall the results taken from the two tables demonstrate a power of the predictor variables emerging largely from the male gender rather than the female gender or a balance of the two. For the male group, most notably, each of the performance measures result in higher correlations to the dependent variable than in the overall correlation matrix found in Table 7 (Cognitive Openness, \(r=.25, p<.05\); Focused Attention, \(r=.25, p<.05\); Cognitive Flexibility, \(r=.59, p<.001\)). The Cognitive Flexibility Other Rater Report had a stronger negative correlation for the males \((r=-.273, p<.05)\). The Cognitive Openness Self Report was no longer significant for the males \((r=.13, p=.17)\), while the Focused Attention Self Report \((r=.21, p<.05)\) and the Cognitive Flexibility Self Report \((r=-.19, p<.05)\) are more significant (these comparison are being made to the total correlation matrix in Table 7). The correlations for the women are distinctly less significant. There is not a single predictor variable that reaches significance other than the intelligence factor (variable number 11 in Table 20).

Based on these initial findings a regression analysis was run as a test of moderation. Given the gender driven correlations, the regression below (Table 22) shows how gender moderates the relationship between Cognitive Agility and the Networked
Fire Chief. Model 1 shows the impact of the Cognitive Agility formative performance measure, model 2 shows the impact of Gender and Model 3 shows the impact of the interaction term – Gender X Cognitive Agility. The test shows a moderating relationship for Gender ($R^2\Delta = .05, p<.001$).

| Table 22. Regression Results for Moderator Variable Gender/Agility | NFC- DDM Adaptive Performance |
|---|---|---|
| Variable | Model 1 | Model 2 | Model 3 |
| Cognitive Agility Per | | | |
| $R$ | .42 | .42 | .42 |
| $R^2$ | .17*** | .17*** | .17*** |
| Gender | | .35*** | .27*** |
| Moderation Interaction | | | |
| Gender X Cognitive Agility | | | |
| $R^2$ | .17*** | .30*** | .35** |
| $R^2\Delta$ | - | .12*** | .05*** |
| $F\Delta$ | 38.58*** | 32.23*** | 5.68** |

+ p<.1; * p<.05; ** p<.01; ***p<.001; N=181
CHAPTER IV

DISCUSSION

Discussion of Results

This chapter provides a discussion of the empirical results. As noted throughout, there is a need to better understand the cognitive abilities necessary for successful adaptation. The results of this study demonstrate the need for greater knowledge regarding these abilities that support adaptability in a real time dynamic context. Of particular interest here, is the formative construct of cognitive agility and whether it predicts success in a dynamic decision making exercise beyond measures of intelligence.

Discussion Overview

The primary research question asks whether there is a relationship between the combination of cognitive openness, focused attention and cognitive flexibility, and adaptation within a changing task condition. Specifically, the following general hypotheses were made:
1. There would be a significant relationship between each of the independent variables and the dependent variable (Hypotheses 1-11).

2. There would be a positive relationship between trait measures of each construct (e.g. The multiple measures of Openness would be significantly correlated across the methods of Self, Other and Performance). (Hypotheses 12-14).

3. Building off of Hypotheses 1-11; each of the independent variables were intended to predict performance outcomes in the dependent variable beyond intelligence (Hypotheses 15-24).

4. Lastly, it was hypothesized that each of the methods of observation – self reports, other rater reports and performance tests (e.g. the composite measure of Openness Performance, Focus Performance and Flexibility Performance) would demonstrate unique variance beyond intelligence tests when regressed on the DDM. (Hypotheses 25-27).

Overall, it was predicted that a real time dynamic decision-making task requires one to operate flexibly with cognitive openness and focused attention in order to successfully adapt in real-time.

Summary of Results

Overall, the results of this study support the idea that cognitive agility is important to discuss within a real time dynamic decision-making task context. The overall adaptive performance score on the dynamic decision-making microworld (the Networked Fire
Chief or NFC) significantly correlates with most of the independent variables and the potential control variables (gender and video game experience). The only variables that do not significantly correlate with the dependent variable are the Other Rater Reports: Focused Attention and Cognitive Openness. However, there are mixed results regarding the impact that each of the individual independent variables have in predicting adaptive performance on the dynamic decision making microworld beyond intelligence. Yet perhaps of greatest significance, cognitive agility, as measured for each method (self-report, other rater report and performance tests), accounts for unique variance beyond the measures of intelligence.

Discussion of Results for Hypotheses 1-11

Overall the first set of hypotheses produce strong results. As discussed above, all but two of the independent variables correlate significantly with the dependent variable (adaptive performance on the dynamic decision making microworld). Despite mostly significant correlations, two of these correlations inversely relate to the dependent variable. The inversely related variables present the greatest cause for concern regarding the current study and present an interesting point for discussion.

One intriguing finding that was not predicted were the negative correlations found between Self and Other Questionnaires for Cognitive Flexibility with the Dependent Variable (NFC). (Self report $r=-.11$, $p<.1$; Other report $r=-.20$, $p<.01$). The self report/other rater report Cognitive Flexibility measures are taken from the metacognitive regulation subscale of the Metacognitive Awareness Inventory (Schraw and Dennison,
Metacognitive regulation accounts for control of cognitive operations leading to greater flexibility (Fernandez-Duque et al., 2000; Nelson & Narens, 1994). It is predicted that metacognitive regulation (i.e. monitoring and control over one’s cognition) leads to increased adaptive performance in a real time dynamic context. Research shows that metacognitive capacities are linked to expert decision making (Chi et al., 1991) successful problem solving (Clements, 1986; Mayer, 1998) and increased adaptability in uncertain and dynamic contexts (Earley & Ang, 2003). In addition metacognitive capacities have been associated with higher performance in real time activities like aviating (Valot, 2002) and driving (Lesch & Hancock, 2004). Therefore it was predicted that in an environment of change that being able to regulate one’s cognition to meet the demands of the context would lead to higher performance.

The results from this study do not support the predictions made regarding the Cognitive Flexibility self/other report measures. Metacognitive regulation has been predictive of success in dynamic contexts but has not been widely tested as a self report measure in a true real time dynamic decision making microworld (Haynie, 2005). Dynamic decision making microworlds require a series of continual and real-time rapid decisions, which may represent a completely distinct class of performance, separate from single decisions (Sitkin & Pablo, 1992). Perhaps the ongoing and constant decisions that must be made require one to be less “regulated” in how one thinks through each decision. In such a dynamic context, speed of operation compliments accuracy of decisions. Strong metacognitive regulatory tendencies may increase a participant’s likelihood to monitor and evaluate his/her ongoing perception of success and failure (Jacobs & Paris, 1987; Schraw & Dennison, 1994). Past studies indicate that as one detects error they
tend to slow down speed of operation in order to increase accuracy (Rabbit, 1966; Rabbit & Rodgers, 1977; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). Therefore in this context, participants with strong metacognitive regulation may by more engaged in online monitoring and evaluation and therefore more aware of possible errors. This awareness may slow down processing at a time when doing so may cause performance decrements. This performance deficit may also be linked to literature on intuitive thought, which suggests that such metacognitive activity creates interference in necessary unconscious material (Baylor, 2001; Kuhn, 1989; Mandler 1995). Given the short time horizon of the microworld used here (15 minutes), slowing down and controlling cognitive operation may lead to a decrease in performance.

Two independent variables do not significantly correlate with the dependent variable. These variables are the Cognitive Openness other rater report (r=.115, p>.1) and the Focused Attention other rater report (r=.087, p>.1). Therefore, how an external rater views a ratees’ tendency to be cognitively open or focused, is of little to no consequence to performance in the context of a real time dynamic decision making microworld. In contrast both of the corresponding self reports demonstrate significant correlations with the dependent variable (Cognitive Openness self report, r=.221, p<.01; Focused Attention self report, r=.159, p<.05). In this case self-perception relates stronger to adaptive performance than the other’s perception. Ashford (1989) stated that “Individuals often know more about their abilities...than do observers because the abilities may not yet become manifest in actual behavior” (p. 141). Since items from both of these measures describe some elements of potentially private experience (e.g. “He/She is very curious” and “When he/she needs to concentrate and solve a problem, he/she has trouble focusing their attention” there may be some important internal experience that is not fully
conveyed to an external party.

The remainder of the variables demonstrate significant correlations with the dependent variable. The correlations ranged from .446 (p<.001) for the visual spatial intelligence measure to .159 (p<.05) for the Focused Attention self report. This is suggestive of moderate to strong relationships between the independent variables and the dependent variable. Overall, there are some potential measurement issues – namely the inverse correlations between measures of Cognitive Flexibility (in the self and other rater reports) and the dependent variables. Yet, most measures correlate significantly with the dependent variable suggesting promise regarding measurement choice.

*Discussion of results Hypotheses 12-14*

The results do not fully support each of the hypotheses generated by the mixed methods and mixed traits model (MTMM) that was followed (Table 23 shows MTMM Matrix Results). Table 23 is simply another way of examining the correlation matrix with regard to the variables that form *cognitive agility*. Table 23 shows the correlations between traits, between methods, across traits and across methods (with the reliabilities in parentheses). Mixed trait mixed method models (MTMM) help validate constructs by suggesting that correlations between traits and methods will be significant (Campbell and Fiske, 1959) and that correlations will be greatest between trait and within method. While it was anticipated that significant correlations would be found within traits and between methods, the results do not fully support this. The limited support for these
hypotheses is seen most strongly in regard to the lack of significant correlations between performance measures and the corresponding self and other rater reports.

Only the Cognitive Openness performance measure (the Alternate Uses Test) shows a significant correlation to a corresponding questionnaire (see Table 23 and Table 7 for full Correlation Matrix). In this case there is a small, yet near significant correlation between the Cognitive Openness Performance measure and the Self Report for Cognitive Openness (.11 p<.1). Neither the Focused Attention or Cognitive Flexibility Performance measures correlate with any of the corresponding self and other rater report measures for each trait. These findings suggest that the performance tests do not measure the same construct measured by the questionnaires. Since each of these performance tests has never been measured alongside the chosen questionnaires these results offer significant findings to the extent literature.

Table 23. MTMM Output

<table>
<thead>
<tr>
<th>Traits</th>
<th>Self Reports</th>
<th>Other Raters</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OP1  FA1  FL1</td>
<td>OP2  FA2  FL2</td>
<td>OP3  FA3  FL3</td>
</tr>
<tr>
<td>Self Reports</td>
<td>.76 (.83)</td>
<td>.24 (.83)</td>
<td>.47 (.91)</td>
</tr>
<tr>
<td>Other Raters</td>
<td>.21 .05 .10</td>
<td>.07 .35 .03</td>
<td>.15 .05 .22</td>
</tr>
<tr>
<td>Performance</td>
<td>.43 .02 .00</td>
<td>.02 .03 .16</td>
<td>.35 (.90)</td>
</tr>
</tbody>
</table>

There are several possible explanations for the lack of relationship between the questionnaires and performance tests. One possible reason for this measurement difference may be the fact that the performance tests measure ability while the
questionnaires measure behavioral practices or different aspects of perceived performance. It is not unusual to find that explicit self-reports do not correlate strongly with implicit reaction time tasks (Blair, 2001; Dovidio, Kawakami, & Beach, 2001). There are several potential reasons for this. One may be due to Greenwald and Banaji’s (1995) definition of implicit representation as “introspectively unidentified traces of past experience” (p.5). This indicates that absence of correlations are a result of differences in awareness regarding implicit representation (Greenwald and Banaji, 1995). Another explanation for correlation differences can be taken from Wilson, Lindsey, and Schooler’s (2000) dual attitudes model. This suggests that implicit measurement happens automatically when an individual is confronting the stimuli but explicit judgments are subject to motivational and cognitive limitations in the retrieval process. Thus correlations tend to be lower when individuals engage in very deliberate versus spontaneous retrieval processes (Florack, Scarabis, & Bless, 2001).

Another explanation may be that the performance tests measure completely different constructs than the questionnaires. For instance, the other rater report for the Cognitive Openness measure (LMS), measures perceived preferences for engaging with novelty and idea generation. While it may be assumed that this preference correlates with ability to produce ideas in the Alternative Uses Test, it is possible that a significant difference exists between actual capacity to produce novel associations, and an external rater’s perception of another’s ability or orientation toward seeking novelty.

The Focused Attention performance test (Go-No-Go Paradigm) and the Focused Attention questionnaire (Attentional Control Scale) may be measuring different aspects of attention. For instance the performance test measures ability to limit the impact of
irrelevant visual information and make a quick decision (Garavan et al., 1999). The Focused Attention questionnaire measures perceived ability to maintain focus or concentration in the face of other information from the environment (Derryberry and Reed, 2002; Derryberry and Rothbart, 1988). Several of the items involve limiting incoming auditory data while remaining focused on a task such as “My concentration is good even if there is music in the room around me.” The questionnaire does ask about general concentration and blocking out distracting thoughts but nothing of a purely visual-attentive condition. Therefore it is possible that these two tests are tapping different aspects of a similar construct or perhaps completely different constructs altogether.

The Cognitive Flexibility performance task (Stroop Task) and the corresponding Cognitive Flexibility questionnaire (the MAI) may also be measuring different aspects of a construct or different constructs altogether. The Stroop Task has been used in many ways to measure different constructs. For instance the Stroop Task has been used to measure cognitive flexibility (Kalmijn et al., 2002) and executive control (Rubinstein et al., 2001). The scale for the Cognitive Flexibility measure in this study is the Meta-cognitive Regulation subscale of the Metacognitive Awareness Inventory (Schraw and Dennison, 1994). The Stroop Task measures an ability to overcome an automatic response by measuring how quickly and accurately the participant can identify the color a word is written in as opposed to the word itself (which is the more dominant response) (MacLeod, 2005; Galotti, 1999). In this way it demonstrates an aspect of cognitive

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7 There are not any well aligned cognitive flexibility scales measuring the capacity to overcome cognitive set (to the best of the researcher’s knowledge), therefore this scale was used as an alternative measure representing the regulative aspect of being cognitively flexible.
flexibility associated with overcoming automaticity (MacLeod, 2005; Galotti, 1999). The questionnaire (MAI) measures the degree to which participant’s perceive their cognitive regulation of planning, thinking, and evaluation of tasks (Schraw and Dennison, 1994). Someone who pays very close attention to the cognitive regulation of his or her cognitive processes should score highly on this scale. While items ask how often a participant assesses strategies when the demands of the task require it, (such as “When performing a task, I frequently assess my progress against my objectives”) it does not explicitly ask questions about overcoming a routinized response set. Therefore, a different aspect of cognitive flexibility may be captured by the two measures. The Stroop Task, like the Focused Attention Performance test (Go/No Go), is a measure that is entirely visual in nature and tests reaction speed. The MAI measures other cognitive processes relating to the amount of attention one allots to task assessment and the perceived “regulation” one employs to change when necessary.

The Self and Other reports within each trait are significantly correlated. This makes theoretical sense given that the questions were the same with the exception of the rewording for other raters to address the ratee (e.g. changed from “I” to “He/She”). The correlations between corresponding self/other ratings range from .206 to .345. This is consistent with past studies that demonstrate an average correlation of .30 for self/other ratings on behavioral assessments (Church, 1997)

The Self Report and Other Rater measures of Cognitive Openness show the weakest correlation of the three constructs. The correlation though significant is only of moderate strength (.20, p<.01). This suggests that though related there is still a difference in how one perceives their interest in seeking novelty and how that interest manifests in
presentation to others. Similar to the explanation above, this questionnaire is mostly about orientation and not about ability or behavior. For instance, one can be highly interested in ideas or very curious without ever demonstrating this preference to others. A self/other comparison of this instrument has not been performed in prior research. This finding adds further validity to the existing instrument (LMS) as a significant correlation is present.

The self report and other rater measures of Focused Attention show a stronger correlation ($r = .35, p < .001$). This suggests a moderate to strong relationship between self-perceptions of focused attention and that perceived by the raters. This stronger correlation could be attributed to the behavioral indications that individuals supply (e.g. expressing annoyance) when they get distracted, especially by noise (Jones & Davies, 1984; Kjellberg et al., 1996). Since the raters are individuals the ratees know well, and the fact that they are undergraduate students, the kinds of study conditions that the ratee prefers to work in may be known by the raters. For instance, if the ratee does not work well in a loud coffee shop and requires a quiet library, this may be shared knowledge between the rater and ratee, which could positively impact related scoring. Again this scale has not been measured by an external rater so this adds further validity to the instrument (ACS).

The self report and other rater measures of Cognitive Flexibility show a significant yet moderate relationship ($r = .218, p < .01$). The agreement between self and other scoring on this measure may again make sense due to the student population. Some of the items in this questionnaire may be more evident as experienced behaviors seen by the rater. For instance, the amount of “cognitive regulation” one allots to tests or projects prior to
beginning, during or in evaluation may be shared between close friends in a university setting. An example would be when students speak directly after a test, trying to evaluate how they did and what they could have done differently. For example the item “I ask myself how well I’ve accomplished my goals once I’ve finished” may be quite evident within the context of a school-based relationship. Yet the reason for only a moderate correlation, as opposed to a high correlation, could be due to other items, which may be of a more private-cognitive nature. Most items require one to answer the degree to which one is ‘monitoring’ or ‘adjusting’ his/her cognitive activity as it is happening. Some example items that capture this private experience are “I stop and re-read when I get confused” and “I find myself analyzing the usefulness of a given strategy while engaged in a given task.” This type of item may be more difficult for raters to accurately assess. In the process of sharing and comparing results, parts of one’s private experience of thinking may remain private. Again this scale has not been tested with an external rater prior to this study, thus the results here add to the further validity of the measure.

As anticipated the results demonstrate both convergent and discriminant validity across the majority of the questionnaire measures for self and other. Convergent and discriminant validity suggests that each of the constructs here is unique as measures correlate stronger between traits than across traits. The one exception is the Cognitive Flexibility Other Rater measure and Cognitive Openness self measure which shows a small, yet significant correlation (.15, p<.05). A potential reason for this may have to do with the items on the Cognitive Openness Self scale that ask about interest in ideas, for example “I do not actively seek to learn new things” (reverse scored). The Cognitive Flexibility other rater questionnaire, asks how much the ratee questions assumptions and
considers options, such as “He/She stops and goes back over new information that is not clear”. The Cognitive Openness scale in part tests openness to ideas (assumptions) and interest in seeking out new ways of doing things. Some items form the Cognitive Flexibility questionnaire also capture an interest in trying to gain additional understanding. This similarity may account for the small intercorrelation among the measures.

While there are significant correlations between self/other ratings, stronger correlations are instead found within method and across trait. The performance tests in general show the smallest within method correlations. The Cognitive Openness performance score correlates with both the Focused Attention and Cognitive Flexibility scores at near significant levels ($r=.11$, $p=.10$). The small and near significant correlation between cognitive openness and cognitive flexibility is inconsistent with past findings. Generally, creative individuals record slower reaction times to the Stroop Task (Kwiatkowski, Vartanian, & Martindale, 1999). In addition creativity has been linked to weaker attentional control which is associated with the Stroop Task (Dewing & Battye, 1971; Dykes & McGhie, 1976; Mendelsohn & Griswold, 1964; Toplyn & Maguire, 1991). Yet the small correlation between the AUT and the Stroop found here may be explained by a quality of flexibility that is shared in both tasks. The AUT can be thought of as a test of spontaneous flexibility (Eslinger and Grattan, 1993), or the ability to produce an unprompted shift in one’s thinking. Creating a list of uses for an object requires this ability, as one must choose to break set spontaneously. The Stroop Task challenges the ability for reactive flexibility (Eslinger and Grattan, 1993) as one must shift mental set quickly when the stimuli creates a prompt to do so. This common use of
flexibility may account for the small correlation.

Cognitive openness and focused attention may be considered opposing abilities. For instance as attention becomes defocused, one’s cognitive network expands in nodal associations (Finke et al., 1992; Martindale, 1991). Yet Martindale also wrote that creative individuals (those scoring highly on the Alternate Uses Test) are able to bring focus of attention when the task calls for it (1999), suggesting a more nuanced view of opposing capacities. Creative individuals are more able to gather their attentional focus to complete tasks when necessary (Dykes & McGhie, 1976). Specific to the modest correlation between the Go-No-Go and the Alternate Uses Test, creative individuals are more able to inhibit “peripheral” data when appropriate (Stavridou and Furnham, 1996).

The Focused Attention and Cognitive Flexibility performance scores are significantly correlated (r=.18, p<.01). This significant correlation may be explained by the fact that the Focused Attention and Cognitive Flexibility performance measures are both visual based reaction time tests. While these two measures are not related in past studies, there have been results from studies of event related potential (ERP) which demonstrate that the cognitive control associated with the Stroop led to increased focused attention (Hylton, et al., 2008), suggestive of shared cognitive processes between the abilities. Yet the relatively small correlation is still suggestive of two unique measurements. However the intercorrelations found within the self report and other rater reports are not as small.

The intercorrelations within the self and other reports are moderate to high. One explanation is that the significant correlations are suggestive of a potential common method bias (Cote and Buckley, 1987). For instance, the Cognitive Openness Self report
correlates with the Focused Attention Self Report (r=.236, p<.01), despite there not being any theoretical connection between the two measures. Yet the simple explanation of common method bias may not fit, as there is not a significant correlation between Focused Attention Self Report and Cognitive Flexibility Self Report (r=.087, p>.1). Cognitive Openness Self Report is highly correlated with the Cognitive Flexibility Self Report (r=.471, p<.001). This correlation can be explained in part to the similarity of items between the two measures (in regard to interest in ideas).

The Other Rater reports are all significantly intercorrelated (ranging from .346 to .546). The Cognitive Openness Other Report is correlated with the Focused Attention Other Report measure (r=.346, p<.001). This modest to strong correlation is somewhat similar to the correlation of the two measures in the self reports. The Focused Attention Other Report measure is strongly correlated with the Cognitive Flexibility Other Report measure (r=.449, p<.001). Lastly, the Cognitive Flexibility measure is highly correlated with Cognitive Openness scale (r=.536, p<.001). Again, there may be some degree of explanation attributed to common method variance and item overlap.

The exploratory factor analysis was consistent with the results explained above. The factor analysis shows three relatively solid factors that separate by method rather than trait. The factor analysis (Table 8) provides further evidence of methods that seem to be measuring different traits, in the case of comparing performance measures to questionnaires. While the self/other reports did correlate in correspondence with their respective traits, the relationship by method remains stronger. The factor analysis helps to confirm these findings in the context of all the measures.
Discussion of Results for Hypotheses 15-24

Hypotheses 15-24 measure the impact of each of the variables when regressed on the dependent variable beyond the intelligence. The outcomes of these tests produce mixed results. Each of the multicollinearity diagnostics is in proper range, suggesting that there is not a concern of multicollinearity amongst the independent variables in the regressions (i.e. all tolerance numbers are close to 1.00 and all VIF numbers are well under 4.0). In general the performance variables remain strong while the majority of the self and other rater measures lose significance in relation to the dependent variable.

Hypothesis 15 predicts that the intelligence factor explains unique variance in adaptive performance in the dynamic decision making environment. The results of this study with regard to the measurement of intelligence can be summarized in the following ways. While significant correlations have been found between intelligence measures and performance in past microworld studies (Ackerman, 1988); intelligence has not been able to consistently predict performance in dynamic decision making microworlds (Brehmer, 1992; Rigas and Brehmer, 1999). This inconsistency has been explained through the different demands hypothesis; that dynamic situations require specific cognitive abilities that are separate from general intelligence (Putz-Osterloh, 1993; Rigas and Brehmer, 1999). These inconsistent findings are also said to be a function of low reliability coefficients found within studies using dynamic decision making tasks (Rigas and Brehmer, 1999). The results of the current research
demonstrate a significant predictive impact of intelligence on the dynamic decision making performance (joining others e.g. Gonzalez et al., 2005; Rigas, Carling, and Brehmer, 2002). Furthermore the reliability coefficient for the Networked Fire Chief performance across the trials was .73, thus providing a fairly reliable testing scenario. Therefore, this study adequately refutes the different demands hypothesis in that it finds intelligence to be predictive of performance. Yet it also supports the different demands hypothesis by showing the impact of aspects of cognitive openness, focused attention and cognitive flexibility on the adaptive performance measure within the DDM.

In this study both forms of intelligence significantly correlate with adaptive performance on the dynamic decision making task. The intelligence factor score also significantly correlates with the total adaptive performance score on the dynamic decision making task (r=.448, p<.001). The results of the regression analysis demonstrate that the intelligence factor is a strong predictor of performance in the DDM microworld, explaining about 20% of the variance. While other measures of intelligence have been used in dynamic decision making microworlds (Gonzalez et al., 2005; LePine et al., 2000), the present measures have not before been used. Furthermore, no decision-making microworld has used a factor for verbal and spatial intelligence (Cattell, 1963; Horn, 1989). These results suggest a valid intelligence measure that is predictive of performance in this dynamic decision making microworld.

The hypotheses 16-24 predict, that beyond intelligence, each of the individual methods of measurement (e.g. Cognitive Openness Performance, Cognitive Flexibility Performance, and Focused Attention Performance) adds unique variance in explaining adaptive performance in the dynamic decision making microworld. To test these
hypotheses a series of linear regressions were performed entering the intelligence factor in block 1, and then the corresponding measure in block 2.

Each of the performance measures explains unique variance beyond intelligence. The performance measure of Cognitive Openness (i.e. the Alternate Uses Test) displays a small yet significant predictive capacity beyond intelligence ($\Delta R^2 = .03$). This suggests that the ability to include many ideas (Wallach & Kogan, 1965) and scan an environment more broadly (Runco, 1991) may be important in understanding performance in a real time dynamic context. The dynamic decision making microworld requires one to pay attention to multiple parts of the environment and actively search for new information, therefore it is theoretically consistent that one’s ability to create new cognitive associations is predictive of performance. The performance measure of Focused Attention (i.e. the Go/No Go Test) also demonstrates significant predictive capacity beyond intelligence ($\Delta R^2 = .02$). The dynamic decision making microworld provides the user with large amounts of data and a continual choice to react or ignore the new information as it is presented in the changing environment. One’s ability to focus attention; to block out information in order to attend to a particular part of the task (Lustig et al., 2001) is necessary in the ongoing adjustment to the dynamic context. Finally, the Cognitive Flexibility Performance measure also shows a significant predictive capacity beyond intelligence ($\Delta R^2 = .07$). The ability to flexibly control cognition (Rende, 2000) is vital in the dynamic context as one needs to often times overcome dominant response sets (Jost et al., 1998) in order to vary strategy successfully (Kiesler & Sproull, 1982). Each of these individual abilities is significant in the
prediction of performance across the dynamic decision making microworld (NFC) beyond the intelligence factor.

Most notable among these findings is the Cognitive Flexibility performance score, measured by the Stroop Task. The Stroop Task explains about 7% of the variance beyond intelligence. The Stroop Task has not been used in the testing with dynamic decision making microworlds prior to this study. The fast paced nature of change within the DDM microworld requires that subjects alter strategies to adjust with the changes. Therefore, the capacity to overcome a dominant or automatic response set (i.e. The Stroop) may be a very necessary component of success in such an environment. The other two performance measures are also significant in predicting success in the DDM microworld. As explained above, Focused Attention (as measured by the Go/No Go) accounts for 2% variance beyond intelligence and Cognitive Openness (measured by the Alternate Uses Test) accounts for 3% unique variance, respectively. While not hypothesized, it makes some theoretical sense that Cognitive Flexibility accounts for more explained variance than the Focused Attention and Cognitive Openness performance measures. Cognitive agility is conceptualized as the capacity to flexibly operate with both openness and focus. Therefore, it is flexibility that is perhaps most crucial in being able to balance both openness and focus. An individual who is extremely open may notice too much information and become overwhelmed (Brunstein & Olbrich, 1985; Kuhl & Kazen-Saad, 1988). Likewise, one who is extremely focused may become stuck on one part of the context and not notice necessary environmental signals (Anderson, 1983). Such a claim is never made on behalf of the flexibility measure; that too much flexibility could disrupt effort. Still, each of the three performance measures
demonstrates unique variance beyond intelligence, which is a contribution to the extent research performed within dynamic decision-making microworlds.

The impact of the individual self-report measures within the regression analyses show results that do not fully support the hypotheses. Only the Self Report for Cognitive Openness produces results that indicate it as having predictive capacity beyond intelligence – explaining approximately 3% unique variance on the dynamic decision making microworld. This measure, in general, asks participants the degree to which they seek novelty, are curious and investigate ideas. Therefore in what would be a likely novel scenario (the Networked Fire Chief dynamic decision making microworld); participants rating themselves higher on this measure of Cognitive Openness may be disposed to approach this context with greater interest (Bodner and Langer, 2001). The Focused Attention and Cognitive Flexibility self reports, no longer retain any predictive effect on the dependent variable beyond intelligence. This indicates that intelligence accounts for the variance in these relationships. Regardless of how one perceives their capacity to focus attention or regulate cognition, this effect is mitigated beyond the measure of intelligence. In the context of a real time dynamic decision making environment, only the Cognitive Openness self report remains a significant predictor of success beyond intelligence.

The impact of the individual Other Report measures within the regression analyses are also less valid in terms of findings. Only the Cognitive Flexibility Other Rater measure is significant beyond intelligence. Yet like the correlations reported above, the explained variance (at 4%) is inversely related to the dependent variable. This finding is intriguing as it suggests that beyond intelligence, an external perception of
another’s cognitive regulation has a substantial, albeit inverse relationship to adaptive performance in the dynamic decision making microworld. The metacognitive regulation measure used for Cognitive Flexibility includes items about monitoring and control of cognitive activity. A potential explanation may be that external raters view ratees who “obsess” about outcomes and processes as being more cognitively regulated. In fact metacognitive regulation has recently been associated with obsessive-compulsive behavior (Purdon and Clark, 2009). Given the inverse relationship, it may be that too much cognitive control, while a necessary component of being flexible, can have a negative impact in a fast paced real time dynamic context. Furthermore, according to these results, one’s self report is not as meaningful as an external rater’s perception.

Overall it would appear from these results that the individual performance tests are a more valid set of predictors toward success in the DV than the self or other reports. Again this makes theoretical sense based on the implicit nature of the performance tests and the fire chief exercises (Blair, 2001; Dovidio, Kawakami, & Beach, 2001). The self and other reports are missing this implicit nature, and may have a lower degree of consistent predictability with the DV. Furthermore each of the performance tests and the DV have a time intensive component to them; whether it be reaction time (Stroop and Go/No Go), product creation (in the case of the AUT) or decision speed (with the DV).

Discussion of Results for Hypotheses 25-27

Hypotheses 25-27 attempts to measure the Cognitive Agility formative construct grouped by method. The most significant finding within this set of regression analyses
was the *Cognitive Agility* performance composite score. In this case a composite score of the performance measures for Cognitive Openness (AUT), Cognitive Flexibility (Stroop Task) and Focused Attention (Go/No Go) was regressed on the adaptive performance score of the Networked Fire Chief. The results indicate that the addition of the *Cognitive Agility* composite performance score provides 11% unique significant variance beyond intelligence ($R^2 \Delta = .11$, $p < .001$). This finding suggests that in a real time dynamic exercise, that the formative performance construct of *Cognitive Agility* is important in predicting successful adaptation. This finding is especially interesting given that research in microworlds have not previously measured the impact of additional cognitive abilities beyond general intelligence. In other studies using microworld simulations both conscientiousness and openness to experience (as measured by the NEO) accounted for 2% unique variance beyond intelligence (LePine et al., 2000). This gives a frame of reference for the significance of this finding. It is also worth noting that the *Cognitive Agility* composite score provides a greater degree of unique variance than any of the individual variables that form it (i.e. Cognitive Openness, Focused Attention or Cognitive Flexibility), suggesting an important formative conceptual addition to such real time adaptive capacities. Lastly, the tests used in this study (the Stroop, Alternate Uses and the Go/NoGo) have never been tested as predictors in a microworld domain, thus providing a novel measurement approach to such contexts.

As noted in the results section it is not possible to create a formative construct for the self and other rater reports, as intended, due to the negative correlation that the Cognitive Flexibility self and other reports has with the Networked Fire Chief adaptive
performance score. Instead each of the respective methods (self and other) was entered listwise in a single regression block, preceded by the intelligence factor.

The self-reports (Cognitive Openness, Cognitive Flexibility and Focused Attention) were entered listwise in a regression to see the combined effect beyond intelligence. Entered together these variables account for 6% unique explained variance in the adaptive performance score on the dynamic decision making scenario ($R^2\Delta = .06$, $p=.006$). When looking at the individual variables in the model it shows a clearer picture. In this model Openness Self-Report is significant ($\beta=.24$, $p=.002$). This suggests that Cognitive Openness as a self-report has some significant capacity to predict success in the dynamic decision making microworld in this model, as it did as a separate variable. This provides further evidence that self-perceived cognitive openness is an important and significant component in such a real time dynamic environment. The Focused Attention self report within the model does not add any unique variance to the overall model ($\beta=.05$, $p=.49$) as was also demonstrated in the earlier regression with it as an individual variable. The Cognitive Flexibility Self report demonstrates near significance in this model ($\beta=-.19$, $p=.07$). Again the most interesting part of this model in regards to Cognitive Flexibility is the sign direction, which was not originally predicted to have an inverse relationship to the dependent variable. The Cognitive Flexibility score demonstrates that a high score on the scale predicts a lower performance on the Networked Fire Chief microworld. The Cognitive Flexibility Self Report does not demonstrate any significant variance when entered by itself beyond intelligence. Therefore, the full model, with the interaction of Cognitive Openness and Focused Attention, changes the impact that Cognitive Flexibility has on the dependent variable.
(i.e. in interaction with the other variables it gains predictive capacity). While the full model is significant, these results taken together suggest that the self report measures chosen to predict adaptive performance on the Networked Fire Chief microworld are not fully adequate.

The impact of the other rater reports also demonstrate results that do not fully support the hypothesis. As with the Self Reports it is not possible to create a formative construct given the negative correlation that the Cognitive Flexibility Other Rater measure has with the Networked Fire Chief. Therefore the three measures (Cognitive Openness Other Rater, Focused Attention Other Rater and Cognitive Flexibility Other Rater) were entered together into a model listwise, following the intelligence factor. In support of the hypothesis, the overall model is in fact significant, adding 6% of unique variance ($R^2\Delta=.06, p=.002$). While this is a supportive finding, the negative $\beta$ score for Cognitive Flexibility again suggests that this finding is not in line with the intent behind the conception of the hypothesis. The Cognitive Flexibility measure as reported by others demonstrates a significant inverse predictive capacity to adaptive performance on the Networked Fire Chief ($\beta=-.32, p=.000$). This score indicates the strongest relationship of any of the individual scales (either Self or Other) to the Networked Fire Chief (Dependent Variable). The Cognitive Flexibility Other Rater measure is a stronger inverse predictor in this model than it was as an individual variable entered beyond intelligence ($\beta=-.20$). Therefore in the current model, with Cognitive Openness and Focused Attention, the inverse impact of Cognitive Flexibility (as measured by a Metacognitive Regulation Subscale) is even more significant. In this regard it is an important finding, adding further evidence that an external perspective of how another
appears to regulate cognition, may be a powerful way of predicting performance in a real-time dynamic situation.

The Focused Attention Other Rater Report, in the context of full model, is more powerful in predicting success on the dynamic decision making microworld than it was as a single variable. In the case of the Focused Attention Other Report, informants’ views of how focused others are has a significant impact on the adaptive performance outcome ($\beta=0.14, p=0.05$). Most interesting here is the difference that the external rating of Focused Attention has within the full model compared to it as an individual variable beyond intelligence. As an individual variable beyond intelligence it had no significant impact in the prediction of adaptive performance in the microworld. Yet when included with Cognitive Openness and Cognitive Flexibility an external rater’s perception of the ratee’s focus does demonstrate unique importance relative to the given model.

The Cognitive Openness Other Rater measure is near significant in its impact in this current model ($\beta=0.13, p=0.10$). As a singular measure beyond intelligence the Cognitive Openness Other Report showed no significance but when added within the model, with the other measures, it reaches near significance. This demonstrates that in interaction with the other variables the external rater’s perception of a ratee’s cognitive openness is a potentially important predictor of real time adaptive performance.

Discussion of Post Hoc results

The post hoc analysis produces very significant findings. Most notable is the significant influence that the control variables have in explaining variance toward the
dependent variable ($R^2=.22$, $p<.001$). Furthermore, as individual variables both gender and video game experience demonstrate significant $\beta$ scores (Gender demonstrates $\beta=.24$, $p=.001$ and video game experience shows $\beta=.34$, $p<.001$). Past studies using microworlds either do not collect gender and gaming experience data or simply do not report the results. Only one study shows the results of video game experience and its relation to performance in a microworld; with a very significant correlation to the outcome variable ($r=.73$, $p<.01$ Valentine, 2005). Furthermore the sample size for this study is quite small ($n=15$). Yet this variable is not normally reported in microworld studies. The same seems to be true of results related to gender. Therefore the addition of these variables (in a sample of this size, $n=181$) in explaining performance is a potentially significant addition to the extant literature.

The intelligence factor still retains significance beyond gender and video game experience ($\beta=.40$, $p<.001$). The intelligence factor explains approximately 16% of the unique variance beyond the control variables. This is approximately 4% less variance than intelligence accounts for in the regression without the control variables. This suggests that intelligence is still an important predictor of adaptive performance and clearly demonstrates that the control variables are relatively unique from intelligence in relation to the dependent variable.

The performance measures all remain significant after accounting for the control variables and intelligence. The Focused Attention performance measure explains approximately 1% variance at near significant levels ($\Delta R^2=.01$, $\beta=.11$; $p=.07$) beyond the controls and intelligence factor. The measure of Cognitive Openness performance still remains significant beyond controls and intelligence, accounting for about 2% explained
variance ($\beta=.15; p=.016$). The measure of Cognitive Flexibility performance score also remains significant, accounting for 8% of explained variance ($\beta=.30, p<.001$). While the amount of explained variance decreases slightly with each of the measures, these results add further evidence to their unique impact in being able to predict adaptive performance in the real time dynamic decision making microworld.

The next set of analysis tests the two individual questionnaire measures that were significant in the earlier regressions beyond control variables and intelligence (Cognitive Openness Self report and Cognitive Flexibility Other Rater Report). In these results the Cognitive Openness Self Report no longer remains significant after accounting for the control variables and the intelligence factor ($\beta=.087, p=.15$). This suggests that the control variables likely account for the majority of the significance explained regarding the Cognitive Openness Self Report. The Cognitive Flexibility Other Rater Report remains significant accounting for 2% of unique variance beyond the controls and intelligence ($\beta=-.14, p=.017$). While the explained variance is cut in half, this finding further demonstrates the predictive capacity that an external rater’s perception of meta-cognitive regulation has on adaptive performance in a real time dynamic decision making microworld.

The composite performance factor for Cognitive Agility remains a significant predictor of adaptive performance beyond the control variables and intelligence, accounting for 9% unique variance ($B=.31, p<.001$). While this model explains approximately 2% less variance than the earlier model, it is strong evidence of Cognitive Agility as an important predictor variable of adaptive performance. Furthermore, it
suggests a unique composite construct which maintains a relatively large predictive ability in the dynamic decision making microworld.

The three self-reports no longer remain significant as an overall model beyond the control variables and intelligence. The results of the three self-report measures indicate an overall model that is no longer significant (ΔR²=.02, p=.148). This suggests that Gender and Video game experience account for the variance that was originally explained by the earlier Cognitive Agility Self Report model (prior to the inclusion of the control variables).

The other rater reports representing the variables of Cognitive Agility account for nearly 4% unique variance beyond the controls and intelligence (ΔR²=.037, p=.014). The total R² is approximately 2% less than in the earlier model without the control variables. This suggests that beyond the control variables and intelligence, the external rater perception is still significant in explaining variance in adaptive performance. The Cognitive Flexibility measure as reported by others demonstrates a significant inverse relationship to adaptive performance on the Networked Fire Chief (β=-.24, p=.002). This is slightly smaller than in the earlier regression but still demonstrates unique importance relative to the given model. In the case of the Focused Attention Other Report, informants’ views of how focused others are remains nearly significant in its relative explanatory importance (β=.11, p=.08).

Finally, a hierarchical regression was run including the controls, the intelligence factor, the composite performance measure, the three self reports and the three other rater reports. The results of this table are in Table 19. The total model has an R² of .499 and is
significant (p=.000). The composite measure, self reports and other reports (entered in a single step listwise) explain 12% unique variance beyond the controls and intelligence. In this full model the only measures that remain significant are Cognitive Flexibility Other Rater Report ($\beta = -.19$, p=.008) and the *Cognitive Agility* Composite Performance measure ($\beta = .275$, p=.000). The Cognitive Openness Self Report measure demonstrates results that suggest a near significant relationship in this model to the dependent variable ($\beta = .12$, p=.074). Therefore when investigating all the variables the $R^2$ becomes larger but the variables that remain significant are far fewer.

Lastly, the correlation tables (Tables 20 and 21) that break out the relationships based on gender reveal exciting data for future study. The significant relationships that exist between the predictor variables and the Networked Fire Chief is largely driven by gender (as evidenced by Table 21). This would suggest a potential moderating effect that gender has between *cognitive agility* and adaptive performance on the Networked Fire Chief. This relationship was tested and supported (Table 22) as unique variance is explained by the interaction term (Gender X Cognitive Agility beyond the previous regression steps ($\Delta R^2 = .05$, p<.001).

*Limitations*

This study has several major limitations that when addressed may provide future research opportunities. This research is an initial step in proposing a new construct, and therefore a great deal of future work toward validation is necessary, which is beyond the scope of this section. However, current study limitations are noted regarding
generalizability of results. Limitations to generalizability may be found within the study sample and task conditions of the dependent variable.

With regard to this study, the testing scenario of the microworld greatly limits direct generalizability of the results to decision making of individuals in organizations. Laboratory based decision making studies do not fully capture real life decision making (Dawes, 1988) Admittedly, the choice to use a microworld in no way is meant to simulate the context of organizational experiences. Instead it is used as a way to capture the elements found throughout the dynamic experiences individual encounter often within organizational life (Brehmer & Dorner, 1993; Funke, 1991; Omodei & Wearing, 1995). These elements include the interaction of dynamism, complexity, time-constraints and feedback delays (Brehmer 1992). The microworld provides a method for controlling the task conditions across time and participant while testing for relationships to the dynamic phenomena (Brehmer and Dorner, 1993). Microworlds are considered especially optimal for studies that investigate highly complex phenomena in a dynamic context (Brehmer & Dorner, 1993; Brehmer, Leplat & Rasmussen, 1991).

While few would argue that experiences in organizational life have become more dynamic and complex, the results produced by this microworld based laboratory study still need to be handled with caution. The results pertaining to cognitive agility and the individual variables which form it (Cognitive Openness, Focused Attention and Cognitive Flexibility), are promising in being able to predict adaptive performance, yet this outcome is within the context of a computer simulated game. Microworld simulation performance outcomes are seldom studied alongside actual organizational performance outcomes, making generalizability of results limited. The predicament between realism
and control is an old and ongoing debate in research setting selection (Berkowitz and Donnerstein, 1982; Dipboye and Flanagan, 1979; Runkel and McGrath, 1972). Microworlds have been lauded as a method to “bridge the gap” between laboratory and field studies (Brehmer & Dorner, 1993). Yet, the current results, while a promising contribution to dynamic decision making, are still limited due to the computer based format. Therefore, measurement of cognitive agility must be further tested in more real world organizational contexts to claim additional external validity.

The sample population presents another potential limitation of the present study. The sample in this study was drawn entirely from undergraduate students at a highly selective university. This sample creates two possible limitations. The first is that the relationship of the independent variables to the dependent variable is limited to individuals who have a mean age of 20 years. This becomes a potential issue since past research demonstrates that each of the independent variables could be impacted by age. This age restriction may especially impact the intelligence tests and the performance measures, as they are implicit measures prone to age related differences in neuroanatomy.

In general executive functions are impacted by age (West and Bell, 1997) as are adaptive problem solving abilities (Ridderinkhop, Span & van der Molen, 2002). In a recent study, Salthouse (2009) shows cognitive functions, like speed of thinking and spatial visualization, peak by age twenty-two and start to decline around age twenty-seven. Specifically the Stroop Task has shown performance decrements with increases in age (Delis et al 2001), based in part on processing speed (Salthouse and Meinz, 1995). Focused attention is also subject to age related decreases as inhibitory control (Kramer, Humphrey, Larish & Logan, 1994), response competition (Salthouse & Somberg, 1982),
and response suppression (Fluster, 1997) are also subject to age related decrements. Additionally, divergent thinking has been shown to decline sharply after the age of 30 (Lehman, 1953). Also, fluid intelligence is subject to age decrements (Shilling et al., 2002), which would impact the outcomes on the spatial intelligence measure. With the average age of the US labor force at 40.5 years, the current sample is not representative of those inhabiting today’s organizations from an age – and therefore neuroanatomical perspective.

Additionally, this current population is taken entirely from a highly selective university. The median SAT score of an entering freshman at the university in the current study is 1300 and the average SAT of undergraduate business majors is 1270, ranking it number thirty-two in the country (Business Week Online, 2009). This suggests that the population being studied may not be generalized to a wider population as both age and preselection (from the University) indicate potential comparison limits.

The focus of this study is the investigation of a particular set of cognitive capacities and therefore a population with a uniform age provides a built in control. It has been previously noted that “…the generalizability of the results of behavioral research is not a function of the population sampled, but rather….the external validity of the research depends on the interaction of subject characteristics and the particular behavioral phenomena with which one is concerned” (Christensen, 1997, p. 482). Therefore, this sample serves as a valid initial group to study with future work extending to both older age groups and those in organizational contexts.

A potential limitation of this study may come from some of the measures chosen. Admittedly there is mixed theoretical and quite limited *empirical* support linking each of
the independent variables across methods. For example, there is not a definitive way to measure Cognitive Flexibility. It is a complex construct which is measured by many different performance tasks. Furthermore there is not a questionnaire that aims to measure the construct as defined for the study. Adding to this difficulty there is virtually no empirical support to link Cognitive Flexibility performance tasks with Cognitive Flexibility questionnaires. As reported throughout this chapter, the results were consistent with this limitation, as performance tests did not relate to the corresponding questionnaires. Therefore this became a major limitation in the results and restricts validity interpreted for the construct.
CHAPTER V

CONCLUSION

The primary purpose of this work is to propose the construct of *cognitive agility*, and to test whether *agility* predicts adaptive performance in a real time dynamic decision-making environment. As a formative construct comprised from the composite of the three performance measures, *cognitive agility* predicts adaptive performance in the dynamic decision making scenario beyond measures of general intelligence. This finding suggests that the unique combination of Cognitive Openness, Focused Attention and Cognitive Flexibility (as they are measured here), may be an important cluster of abilities in managing real time dynamic contexts. While the performance measures were predictive of success in the dynamic decision making task, the results of the self-reports and other-rater reports were not as conclusive. Much of this is due to the inverse relationship of the Cognitive Flexibility questionnaire(s) to the dependent variable. This
finding does however raise important questions about the roles of cognitive regulation, cognitive control and cognitive flexibility in real time dynamic decision making contexts. Overall this study investigates specific capabilities targeted to a specific context. Studies of highly contextualized aspects of adaptive performance are vital to our development in meeting the demands for research and practice in dynamic times.

Research Implications

There are several future research studies suggested below to further develop this work beyond the current findings. Future research should test the cognitive agility construct in other microworlds, in relationship to other relevant variables and in more organizationally relevant contexts. Each of these will help support further internal and external construct validation.

This study demonstrates significant relationships between the independent variables and adaptive performance in the microworld simulation know as the Networked Fire Chief (Omodei and Wearing, 1998). Further construct validation may be assessed through future testing of the cognitive agility construct in alternative microworlds. In general, dynamic decision-making microworld programs contain some defining features that are common across platforms. These common characteristic elements include, “…temporal dependencies among system states, nonlinear relationships among system variables, and a lack of user access to complete information about the system state and system structure.” (Gonzalez, 2005, p. 278). These characteristics manifest in four criteria by which Gonzalez (2005) and others (Brehmer & Dorner, 1993) rate the microworlds:

1. Dynamism - rates of change and the feedback loops that impact it (Edwards,
1962),

2. Complexity - the degree of interconnection amongst parts of the system (Brehmer & Allard, 1991).

3. Opaqueness - ready accessibility of system state to the user (Brehmer, 1992), and

4. Dynamic complexity - combination of dynamism and complexity, which creates conditions that limit ability of user to gain control of system, (Sterman, 1989).

The Networked Fire Chief is a microworld that is rated as being “high” in dynamism and complexity and “moderate” in its opaqueness and dynamic complexity. This means that the Networked Fire Chief is considered to have many ongoing changes and a great deal of interconnectedness between parts of the system. Yet it is only moderately difficult in terms of assessing one’s current performance and ability achieve control of the system.

Future studies could include the use of alternative microworlds, which represent different ends of the spectrums with regard to degree of dynamics, complexity, opaqueness, and dynamic complexity. For instance The Water Plant Purification Task (Gonzalez, 2004) is rated as ‘high’ across all categories, allowing for the effects of testing Cognitive Agility in a more intensive system of operation. Given the increased dynamic complexity The Water Plant Purification Task has over the Networked Fire Chief, one has to wonder if Cognitive Agility would predict more or less in the adaptive performance score, as general intelligence may account for more variance (Ackerman, 1988; Gonzalez, et al., 2005; Kyllonen, 1985). Another well-researched microworld is the Beer Game (Sterman, 1989), which offers much lower dynamism and complexity than the Networked Fire Chief, while retaining greater levels of opaqueness and dynamic complexity (Gonzalez, 2005). The greatest differences between the Beer Game and the Networked Fire Chief is that in the Beer Game the system only changes when the
participant acts upon it and the individual has more time to make decisions. These differences allow testing of Cognitive Agility in a completely different kind of dynamic decision making scenario in which speed may be less of a factor. Given that each of the performance tasks used to measure Cognitive Agility contain a speed component, this may significantly alter the construct’s impact. Yet, the difference in speed may also alter the Cognitive Flexibility questionnaire’s (Meta Cognitive Awareness Inventory) impact in predicting success (as opposed to having an inverse relationship to adaptive performance on the Networked Fire Chief). Each microworld has unique characteristics and assessing outcomes related to Cognitive Agility would help in determining specific real-time elements that are associated.

This study demonstrates significant relationships between the intelligence measures and dynamic decision-making. This finding is important in light of the mixed results that various forms of intelligence have had in relation to dynamic decision making microworlds (Andresen & Schmidt, 1993; Brehmer & Rigas, 1997; Dorner, Kreuzig, Reither, & Staudel, 1983; Omoei, Anastasios, Waddell, & Wearing, 1995; Putz-Osterloh & Luer, 1981; Staudel, 1987; Strohschneider, 1986, 1991). Furthermore, this study reveals that Cognitive Agility predicts unique variation in performance above and beyond intelligence measures.

Another method to further validate the construct of Cognitive Agility is the testing of additional or alternative intelligence tests. The intelligence tests in this study were chosen to incorporate both a verbal and spatial feature (Cattell, 1963; Horn, 1989). While the spatial test certainly taps into the measure of fluid intelligence (Ekstrom, 1976), it may also be of benefit to use a direct measure of fluid intelligence in future
Fluid intelligence describes the innate capacity to adapt knowledge to deal with novel situations (Snow & Lohman, 1984; Carpenter, Just, & Shell, 1990), and has been shown significant in explaining professional success in complex environments (Gottfredson, 1997). It is therefore, an important aspect of intelligence to measure alongside Cognitive Agility when predicting adaptive performance. A common measure of fluid intelligence is the Ravens Progressive Matrices – RPM (Raven, 1962, 1977; Raven et al., 2003). The RPM has demonstrated very strong correlation to performance on the Networked Fire Chief in a past study ($r=.60$, $p<.05$) (Gonzalez et al., 2005); yet this was based on a very small sample ($n=15$). Future studies of Cognitive Agility should measure its effect on microworld programs beyond fluid intelligence. Cognitive Agility as a predictor of adaptive performance beyond fluid intelligence would support additional construct validation.

One underlying cognitive process that supports high fluid intelligence is the ability to utilize working memory (Carpenter et al., 1990; Gray et al., 2003). Working memory measures an individual’s ability to maintain information when facing interference (Baddeley & Hitch, 1974). It is a limited capacity, which allows one to keep information for a temporary period of time while being able to apply it for strategic use (Baddeley, 1992). Working memory ability has been correlated with strategy adaptivity in past studies (Schunn and Reder, 1998). Given the dynamic testing context and focused attention component of Cognitive Agility, this may be an appropriate measure necessary to further illustrate discriminant validity of Cognitive Agility. Working memory can be measured with the reading span task (Daneman & Carpenter, 1980), the Digit Span Test (Baddeley, 1986), or the Operation Span Task (Turner & Engle, 1989); each measuring a
slightly different aspect of working memory.

Next, the measurement of Situation Awareness is appropriate in further validation of Cognitive Agility. Situation Awareness measures one’s knowledge of the current state of a dynamic context (Endsley, 1995). It is “the ability to extract and integrate information in a continuously changing environment and to use such information to direct future actions” (Wickens, 2000). Situation Awareness has been tested in other microworlds as a way of predicting performance under specific conditions (Endsley, 1995). In a dynamic context, placing attention on one part of the environment has an effect on understanding other parts of the environment (Endsley, 1995). The capacities underlying Cognitive Agility may lead to greater situation awareness of the dynamic microworld context.

Situation Awareness can be measured using the Situation Awareness Global Assessment Technique (SAGAT) (Endsley, 1987, 1990, 1995). Another way to measure Situation Awareness is through participant query. In this method the microworld can be paused at random points and the participant is queried for their awareness of the current environment (Endsley, 1995). Situation Awareness is another variable that Cognitive Agility could be tested alongside to further internal construct validation.

Future studies should aim to further validate Cognitive Agility as a formative construct. The literature on formative constructs suggests applying a structural equation model, relating the formative construct with an existing reflexive construct that should relate to it (Diamantopoulos, 2006). This would support greater criterion and nomological evidence for the formative construct (Diamantopoulos and Winklhofer, 2001). One potential construct to link cognitive agility is action control (Kuhl, 1992, 1994). Action control is meant to measure one’s ability to maintain focus on a task without becoming overwhelmed by competing cognitive activity. Action Control can be measured using the
Action Control Scale (Kuhl & Beckmann, 1994), which is comprised of three subscales: (1) Preoccupation versus Disengagement (which measures concentration on intention without becoming distracted by outside cognition), 2) Hesitation versus Initiative (which measures intention to move toward behavioral action without hesitating and (3) Volatility versus Persistence (which measures vigilance in completing the task).

Future studies may also assess the predictive impact of Cognitive Agility on more widely used organizationally relevant outcomes. Potential testing could compare Cognitive Agility results, beyond intelligence, with objective measures of organizational performance (e.g. productivity, supervisor ratings etc.). It is well documented that general cognitive intelligence predicts job performance (House et al, 1992; Schmidt and Hunter, 1989). Hundreds of studies demonstrate that general cognitive ability predicts performance in just about every job, situation and career (Gottfredson, 1986; Hunter, 1986; Ree & Earles, 1993; Schmidt & Hunter, 1981). Others have suggested that g is the best predictor of job performance (Barrett & Depinet, 1991; Gottfredson, 1986; Herrnstein & Murray, 1994; Hunter & Hunter,1984; Jensen, 1993; Ree & Earles, 1993; Schmidt & Hunter, 1981, 1993). Furthermore, as jobs require more information processing, the predictive capacity of general cognitive ability increases toward performance (Wright and Mischel, 1987). Yet there is still heavy debate in this arena, as IQ scores, despite being the “best available predictor” of job performance, still account for only half the variance (Neisser et al., 1996 p.83). Therefore, any unique variance that could be demonstrated by cognitive agility, beyond general intelligence, would be a major step towards additional external criterion related construct validity.

Lastly the testing of cognitive agility in some particular decision-based organizational contexts would be important. One potential context, rich with real-time
adaptive performance challenges is the daily role held by portfolio asset managers. Managers make a series of critical dynamic decisions that have profound implications for their personal wealth, the success of their firm and the assets of individuals invested either directly or indirectly in the fund. Expert investment decision-making process is associated with both personality and cognitive factors (Rohrbaugh and Shanteau, 1999). Beyond these, asset managers likely must be open to new information, focused on particular elements of the financial landscape and flexibly operate to avoid functional fixedness. Therefore, the study of portfolio managers presents a real world context in which cognitive agility may have a profound impact. Such a study design would control for a manager’s intelligence, age, tenure and level of education (Hambrick and Mason, 1984; Shukla and Singh (1994). Furthermore, other individual differences need to be accounted for, to include confidence/overconfidence (Odean (1998) and established cognitive abilities like pattern recognition (Brown and Soloman, 1990). Additional unique variance explained from cognitive agility may predict individual financial performance for the funds managed over a set periods of time. The study could track results in a variety of time horizons, gaining additional insight as to cognitive agility’s predictive impact in both real time and longer time periods.

Practical Implications

This dissertation offers a construct, which helps in explaining individual differences in adaptive performance in a specific real time dynamic context. Adaptive
performance is often assessed across multiple tasks, contexts and longer periods of time (Pulakos et al., 2000). Therefore, current conceptualizations overlook aspects of individual cognitive capacity that may support real time adjustments within a singular task. While results of this study are not conclusive, the knowledge generated begins to offer support to organization members in developing specific skill capacities related to real time adaptive performance. This capacity can be applied to individual and organizational level development.

A primary question from a practice-oriented perspective is: can cognitive agility be nurtured as a cognitive capacity? In order to accomplish this, each of the three variables that form Cognitive Agility must be subject to developmental improvement. Cognitive Openness as a performance variable is measured within the current study through a divergent thinking test. Past research has shown that divergent thinking can be developed and increased with training (Torrance, 1972). This suggests that with practice individuals can begin to create more cognitive associations (Torrance, 1974), improve scanning ability (Runco, 1991), and begin to notice more novelty (Mendelson, 1976). The abilities of focused attention and cognitive flexibility are usually considered less apt as developmental capacities, as they are closely associated with hereditable traits (Gray & Thompson, 2004). Yet, a recent study from Jaeggi and colleagues (2008) in the Academy of Science proceedings, suggests that contrary to past research, developing such abilities might be possible. In this study subjects engaged in “n back” style tests over a period of time and results showed changes to subjects’ level of fluid intelligence, an ability not considered viable of improvement in adults. What is most compelling is the training that subjects participated in, consisted of exercises that challenge response
inhibition, the ability to ignore irrelevant information, and monitoring of ongoing task progress. Within this training, there exist obvious parallels to focused attention and cognitive flexibility as described within the *Cognitive Agility* construct. For instance, focused attention is the capacity to ignore irrelevant information and maintain a coherent cognitive thread (Lustig et al., 2001). If tests that challenge “ignoring irrelevant” information lead to increases in general fluid intelligence, it is likely that those tests also lead to increases in the act of ignoring irrelevant data. Cognitive flexibility is the ability to overcome an automatic response set, which is associated with response inhibition (Clark, 1996; Rende, 2000). The ability to regulate cognition through monitoring and control is an aspect of cognitive flexibility (Clark, 1996; Schraw and Dennison, 1994) and is associated with metacognition. There appear to be individual differences in metacognitive capacity (Allen & Armour-Thomas, 1999), and strong evidence to suggest that it can be developed through training (Delclos & Harrington, 1991; Hartman & Sternberg, 1993; Schmidt and Ford, 2003). Therefore, the ability to monitor and control cognition can be enhanced through specific practice. Together it is plausible to increase the elements of *Cognitive Agility* and likely the overall construct. Such training can be an important addition to the developmental programs organization members undertake, especially if their jobs consist of managing real time adaptive contexts.

Such training programs may begin with cognitive agility testing. Cognitive Agility is a cognitive ability which is difficult to enhance since it tends to be more stable (Kozlowski, 1998). Yet with specific learning agendas this ability and the variables that form it may become permeable (Ross and Lussier, 2000). A learning agenda will have multiple parts. To begin with Individuals will be assessed on overall agility and the
individual abilities that form it. Individualized plans will be crafted to support gaps in ability. Once aspect that could be helpful is, Discovery learning, employed through real-time dynamic decision making microworld simulations (Kozlowski, 1998). In discovery learning, individuals participate in the simulations in order to hypothesize and self discover what the principles are that lead to success in that context (London & Bassman, 1989,). Discovery learning allows individuals to transfer new knowledge to novel settings Atlas, Cornett, Lane, & Napier, 1997; Smith et al., 1997

Another aspect of a learning agenda is to engage in deliberate practice to enhance weaknesses (Ross and Lussier (2000). For example, an individual lower in cognitive openness may engage in structured exercises to expand awareness of novel aspects of one’s lived contexts. Interactions with novelty may take the form of practicing new routines (e.g. taking a new driving route home from work), looking for new distinctions (e.g. recognizing characteristics you have never noticed in your environment), and using additional information (e.g. prior to making a decision think of additional perspectives or materials that can widen scope).

Cognitive Agility training should also extend to individuals working in teams or work groups. Team functioning may be enhanced by bringing awareness to each member’s cognitive agility based strengths (i.e. focus, openness or flexibility) and areas for improvement. Teams can structure opportunities for individuals who need development in an area to take a lead in a particular corresponding process. For instance, an individual that has targeted focused attention as a developmental opportunity may be given the chance to be more proactive in keeping a “brain storming” session very focused.
Furthermore, individual strengths can be harnessed when necessary. For example, an individual strong in cognitive flexibility may be in charge of preventing team functional fixedness.

Another result of this study that may have promise in organizational effectiveness practices is the impact that video game experience has on adaptive performance. In this study participants who play more video games perform better on adaptive performance in the Networked Fire Chief. Therefore, introducing video games as part of a “play/training” opportunity for organizational members may have some benefits to adaptive decision making in a real time context. This has been partially supported by past studies that show training using video games impacts differences in spatial cognition (Feng, Spence Pratt, 2007) and spatial selective attention (Green & Bavelier, 2003). This was potentially supported in this study as experience playing video games is associated with spatial cognition ($r=174, p<.05$). Additionally, video game experience is also related to self report measures of Cognitive Openness ($r=.125, p<.05$) and Focused Attention ($r=.14, p<.05$). Video game experience had a negative correlation with the Other Rater Report of Cognitive Flexibility ($r=-.137, p<.1$), suggesting an inverse relationship between how others view one’s cognitive regulation with the amount of video games one plays. Therefore, some exposure to video games may be a helpful training tool for organizations to introduce as it relates to variables that predict success in real time adaptive performance.

Furthermore, in the current study men also perform better than women on the measure of adaptive performance. This may be explained as men generally score higher in tests of spatial cognitive ability (Kimura, 1999; Terlecki & Newcombe, 2005; Voyer,
Voyer, & Bryden, 1995), which is supported by the results of this study \((r=.139, p<.05)\). Its been demonstrated that training through use of video games (e.g. Medal of Honor: Pacific Assault) erases the gender variance on tests of spatial cognition (Feng, Spence Pratt, 2007). Therefore, the use of video games may have multiple positive effects with regard to adaptive performance in real time dynamic contexts.

Cognitive agility as a construct describes the flexibility between what some consider conceptually opposing phenomena (cognitive openness and focused attention). Rather than separating them, in some particular contexts, combinatorial skills may form unique higher-order operations. A formative construct in this case may be an adequate way to consider these phenomena. The notion of managing opposites has been written about in organization science at multiple levels of system. In particular striking the optimal balance between the paradox of being open and flexible along with being focused has been a central concern in organization and leadership development for decades (Argyris, 1970; Bennis, 1966). At the organizational level March’s work on exploration versus exploitation describes the tendency for firms to either explore (search, innovate, experiment) or exploit (refine and become more efficient) (March, 1991). This work has led to the idea of “ambidexterity” which is the balance between exploration and exploitation that organizations must employ in order to reach superior performance (Tushman and O’Reilly, 1996). For firms to achieve ambidexterity it may be argued that they require a body of individuals who possess aspects of abilities linked to both; with a construct such as cognitive agility providing this support. At the individual level, leadership has been said to require the ability to employ the simultaneous use of
opposites (Kotter, 1990; Quinn, Spreitzer, & Hart, 1992; Zaccaro et al., 1991), and managerial flexibility has been described as the ability to strike ongoing balances between method and style (Quinn, Spreitzer, & Hart, 1992; Sloan, 1984). Rather than consider them in pure opposition the goal is to enhance the “the ability to act out a cognitively complex strategy by playing multiple, even competing roles, in a highly integrated and complementary way” Hooijberg & Quinn, 1992, p. 164) (2001: 131). Therefore, a formative construct at the individual cognitive level may provide additional understanding of particular skills in combination. In particular dynamic contexts, the construct of cognitive agility may support individual and organizational practices.

**Contributions**

This work makes several core contributions to the fields of psychology and organizational behavior. First of all organizational behavior, and specifically individual adaptability have not assessed cognitive performance measures beyond intelligence that predict adaptive performance. Next, much of the writing on both adaptability and flexibility has been far too general in its definition and description. The work in adaptive performance is focused on longer time horizons and across multiple tasks (Pulakos et al., 2000). This study contributes to the above literatures through:

1. The investigation of adaptive performance in very specific contexts – in real time within a singular task
2. Demonstration that a factor score of crystallized/fluid intelligence predicts performance in a microworld program.

3. Demonstration that beyond intelligence the individual variables as well as the formative construct of *Cognitive Agility* predict adaptive performance.

4. Demonstration that video game experience has a predictive association to adaptive performance, and

5. Demonstration that cognitive regulation has a significant inverse relationship to performance in a real time dynamic context.

The constant turmoil associated with working as a member of the modern organization creates conditions that have lead to an increase in the demands of individual dynamic decision making (Farhoomand and Drury, 2002). These demands are associated with big changes (like a merger with another organization) and with more micro-momentary contextual management (Porac, Thomas, & Baden-Fuller, 1989). In essence, individuals at work have to manage the big changes along with the continual ones (Kegan, 1994).

Adaptability is often referred to as the individual level ability best suited to properly manage oneself in relation to these changes (Edwards and Morrison, 1994; Hesketh, 1997; Ilgen & Pulakos, 1999; O’Connel et al., 2008; Pulakos et al., 2000). As such adaptability, the ability to perform well in dynamic contexts, has been cited as an important and missing component to include within the larger discussion of job and task performance (Campbell, 1999; Hesketh & Neal, 1999; London & Mone, 1999; P. R. Murphy & Jackson, 1999). However, scholars who explicitly contribute to the study of
adaptability do not often address the complexity inherent in the cognitive aspects of adaptive performance, as it pertains to real-time dynamic tasks. Understanding an individual’s ability to be adaptive at the cognitive level may be a vital starting point to successfully navigating dynamic environments (Glynn, 1996). In a real time dynamic task context the variables that form cognitive agility and the construct itself may support such necessary development.

In conclusion the purpose of this study is to investigate a potential individual capacity to adapt within a real time adaptive performance task. Specifically, the research sought to demonstrate whether the formative construct of cognitive agility predicts adaptive performance in a dynamic decision making microworld. Results show that beyond measures of intelligence, the *Cognitive Agility* construct was able to predict performance across three trials of increasing difficulty on the Networked Fire Chief microworld. While these findings need to be further tested in more natural organizational settings, the initial results are suggestive of a combination of skills that may support performance in real-time dynamic contexts.
APPENDIX

A. Informed Consent Document

INFORMED CONSENT DOCUMENT

Exploring the Concept of Cognitive Agility

You are being asked to participate in a research study about *individual cognitive agility*. You were selected as a possible participant because *you submitted your name and contact information to a University Research Participant List*. Please read this form and ask any questions that you may have before agreeing to be in the research.

Researchers at Case Western Reserve University are conducting this study.

**Background Information**

The purpose of this research is to explore the idea that individuals can be cognitively agile.

**Procedures**

If you agree to be a participant in this research, we would ask you complete the following things, which should require approximately *One Hour* of your time:

1. A questionnaire asking you about how you learn and pay attention
2. Three short tests measuring how you use your attention and think
3. A short questionnaire assessing your subjective well being
(4) A vocabulary test

(5) A test of visual spatial ability

(6) A simulation game in which you are asked to prevent the spread of brush fires

(7) Finally, you will be requested to provide the researcher of this study with a name and email address of someone who you consider to be “close to you” (i.e. a friend, significant other, roommate). This person will be contacted to fill out a brief email questionnaire regarding what they perceive to be your tendencies to learn and pay attention. This will require no more than 10-15 minutes of their time and will require no additional time of yours. Once it is returned, their name and email address will be removed from all files. The results of their questionnaire will not be known to you.

**Risks and Benefits to Being in the Study**

This research study has no known or foreseeable risks and should be completed within a year.

There are no direct or secondary benefits associated with your participation in this research study.

**Compensation**

You will receive $20 in total for your participation in this study. You will receive $10 in cash following your participation in the test taking portion of this study. A check for $10
will be sent to you once the person you have asked to fill out the questionnaire on your behalf has done so

**Confidentiality**

The records of this research will be kept private at Case Western Reserve University. In any sort of report we might publish, we will not include any information that will make it possible to identify a participant. Research records will be kept in a locked file, and access will be limited to the researchers, the University review board responsible for protecting human participants, and regulatory agencies.

**Voluntary Nature of the Study**

Your participation is voluntary. If you choose not to participate, it will not affect your current or future relations with the University or with your standing at the Weatherhead School of Management. There is no penalty or loss of benefits for not participating or for discontinuing your participation. If you do withdraw from the study while taking the tests you will not receive the $20 compensation. If however, you complete the tests but the individual you have assigned to fill out the questionnaire on your behalf does not do so, then you will still receive half the compensation in the form of $10 cash.

**Contacts and Questions**

The researchers conducting this study are *Darren Good and Professor Richard Boyatzis*. You may ask any questions you have now. If you have any additional questions, concerns or complaints about the study, you may contact them at:
Darren Good: (216) 368-2189 or by email to darren.good@case.edu

Richard Boyatzis: (216) 368-2053 or by email to Richard.boyatzis@case.edu.

If the researchers cannot be reached, or if you would like to talk to someone other than the researcher(s) about; (1) questions, concerns or complaints regarding this study, (2) research participant rights, (3) research-related injuries, or (4) other human subjects issues, please contact Case Western Reserve University's Institutional Review Board at (216) 368-6925 or write: Case Western Reserve University; Institutional Review Board; 10900 Euclid Ave.; Cleveland, OH 44106-7230.

You will be given a copy of this form for your records.

**Statement of Consent**

I have read the above information. I have received answers to the questions I have asked.

I consent to participate in this research. I am at least 18 years of age.

Print Name of Participant: __________________________________________

Signature of Participant: __________________________________________ Date: _

___________
B. INVITATION LETTER to PARTICIPANTS -- SENT VIA EMAIL

Subject: Invitation to Participate in a Paid Research Study

Dear Student,

You are invited to participate in a research study conducted on the campus of Case Western Reserve University at the Weatherhead School of Management. This study is investigating an individual’s cognitive agility. If you choose to join this study you will be compensated with $20 in cash upon its completion. Participation in this study would require approximately one hour of your time.

If you are interested please send a reply email stating your interest. You will be contacted by the researcher with a list of potential times the study is running and the location.

***You have been contacted as an undergraduate student who has volunteered to be on an e-mail list for research participation. You have the right to withdraw your name from this list without any consequence or loss of standing with the University. Your
participation in this study is also completely voluntary. If you choose not to participate, it will not affect your current or future relations with the University or your standing at the Weatherhead School of Management. There is no penalty or loss of benefits for not participating or for discontinuing your participation.***

Thank you for taking the time to read this message.

Darren Good
Principal Researcher
216 368-2189
darren.good@case.edu

C. Invitation Sent to External Raters

SUBJECT: A Survey on Behalf of XXXXXX (Participant’s name)

To: XXXX

XXXX (Participant’s Name) is participating in a research study through Case Western Reserve University to measure Cognitive Agility. He/She has submitted your name and email address to assist him/her in the completion of this study. You are being requested to
respond to a series of questions about XXXX’s (Participant’s Name) behavior. If you would like to participate in this survey on behalf of XXXX (Participant’s Name), please click on the link below which will take you to a web site with instructions on how to answer the questionnaire. Once at the website you will be prompted to fill in the user code listed below. The questionnaire would require no more than 15 minutes of your time. Your participation in this study would be greatly appreciated.

[Website URL]

Code Number: 1234

***This invitation to participate in this study is completely voluntary. You are in no way obligated to participate in this study on behalf of XXXX. You will not be receiving any monetary compensation for your participation. Your participation and responses would remain completely anonymous and confidential. XXXX will have no knowledge regarding your decision to participate. You can end your participation in this questionnaire at any point after you begin without any consequence. If you decline to participate it will have no effect on your standing or that of XXXX with Case Western Reserve University.

If you should have any questions or concerns with this process please feel free to contact the researchers on this study or the Case Western Institutional Review Board - Office of Research Compliance.
Researchers

Darren Good

Darren.good@case.edu
216.368.2189

Richard Boyatzis

Richard.Boyatzis@case.edu
216.368.2053

Case Western Institutional Review Board

Office of Research Compliance
216.368.6925
Dear Research Participant,

Thank you for taking part in this research study on Cognitive Agility. At least one of the people you selected to fill out a questionnaire on your behalf has done so. Therefore, enclosed you will find $10 Cash to pay you for the second part of the study. At this point you are completed with the study and will not be contacted further.

If you should have any questions or concerns please do not hesitate to contact me.

Thank you,

Darren Good

Researcher

Case Western Reserve University
Dept of Organizational Behavior

darren.good@case.edu
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